TECHNICAL UNIVERSITY OF LIBEREC

New Opportunities for the Development of Education at the Technical University of Liberec

Specific objective A2: Development in the field of distance learning, online learning and blended learning

NPO_TUL_MSMT-16598/2022

Construction and Properties of Yarns

Ing. Gabriela Krupincová, Ph.D.

Funded by
the European Union
NextGenerationEU

CZECH
RECOVERY
PLAN

MINISTRY OF EDUCATION,
YOUTH AND SPORTS

Course objectives:

Within the course the students will be introduced to experimental analysis of textile structures. The aim of the subject is to connect the theoretical base with the practical use to allow a better understanding of the influence of yarn character given by the spinning technology described by evaluated parameters on the quality of the final product. The students will be familiarized with basic procedures for testing of selected yarn and fabrics qualitative indicators and processing acquired data using image analysis.

The course follows the knowledge of the subjects Textile Technology I, Structure, and Properties of Textiles, and Experimental Analysis of Structures from the Bachelor's Study Program. The course builds on the context of the subject Structure of Fibrous Structures from the master study program.

Project outputs:

The published outputs include only selected materials used for teaching the subject “construction and properties of yarns”, the reason being that the subject is taught by two teachers and the project allowed to support only one of them.

The teaching concept aims at linking the theoretical context acquired in selected courses of the bachelor's program and the subsequent master's program and its application to the practical analysis and quality assessment of mainly linear textiles in the laboratory. For the analysis, the available equipment and internal procedures are used to enable the quantification and qualification of selected quality indicators and the assessment of the impact of the chosen production technology or its adjustment on the properties of staple yarns or the quality of yarns for areal textiles.

In the course of the guarantor's involvement in the project, the syllabus and conditions for the course were revised, with a specific definition of the activities and results that have to be developed in order to obtain credit and examination.

Study materials were developed in the form of teaching presentations, which included additional recommended sources of information (thematic books, scientific articles, videos of technological units) in the form of standard pdf and interactive flipbooks. Newly developed tutorials in the form of short inspirational videos with worksheets are used for practicums. All topics include a set of questions for revision and knowledge testing. With the support of the project, the study guides were developed in English and revised in Czech versions. Student activation is achieved through the interactive application of various laboratory techniques and image analysis of NIS Elements. Through exercises centered around specific themes, students are able to familiarize themselves with this tool and utilize it for assessing key properties of textile structures. The acquired knowledge and skills are designed to equip students for independent work towards the end of the semester, with the expectation that they will further apply these capabilities when working on their bachelor's thesis.

Topics/ Témata:

1. PŘÍSTUPY K HODNOCENÍ TEXTILNÍCH STRUKTUR/ VARIOUS APPROACHES TO EVALUATION OF TEXTILE STRUCTURES

3. and 4. SOUVISLOST MEZI T, D, Z A TECHNOLOGIÍ VÝROBY PŘÍZE I A II/ CONTEXT AMONG T, D, Z AND TECHNOLOGY OF YARN PRODUCTION I & II

7. CHLUPATOST PŘÍZE/ HAIRINESS OF YARN

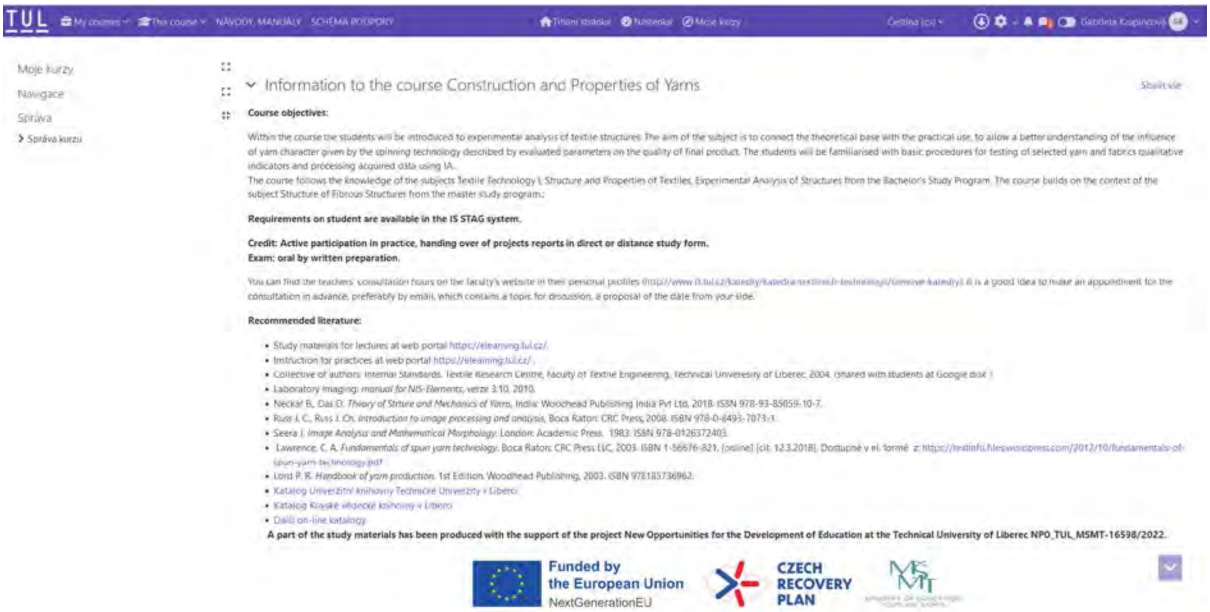
8. CHARAKTER A POVRCHOVÁ STRUKTURA ROTOROVÝCH PŘÍZÍ/ CHARACTER AND SURFACE STRUCTURE OF OE YARNS

9. and 10. CHARAKTER EFEKTNÍCH A KOMPOZITNÍCH PŘÍZÍ I a II/ CHARACTER OF FANCY AND COMPOSED YARNS I & II

11. TŘENÍ A ODĚR DÉLKOVÝCH TEXTILIÍ / YARN FRICTION AND ABRASION RESISTANCE

The only English versions of the teachers' presentations used for lectures and worksheets for practicum are attached to this document as a summary. All outputs generated by the project support are included and are available to students in the Czech and English courses on the e-learning platform. The availability of some interactive materials (interactive video tutorials for workshops and practicum, videos, additional study materials in the form of books or other interesting documents for study) is due to their size and rights available through links. The data collected for each topic in the form of images, data sheets, and reports for various textile structures are available on the shared Google Drive of that topic, and the access to the data is for enrolled students or based on the relevant request. The manner in which the information and available materials on the e-learning are organized is outlined in the form of a print screen in the following text for selected topics as an example. The logic for the rest of the topics remains the same.

A preview of the course in e-learning:



Information to the course Construction and Properties of Yarns

Course objectives:

Within the course the students will be introduced to experimental analysis of textile structures. The aim of the subject is to connect the theoretical base with the practical use, to allow a better understanding of the influence of yarn character given by the spinning technology described by evaluated parameters on the quality of final product. The students will be familiarised with basic procedures for testing of selected yarn and fabrics qualitative indicators and processing acquired data using IA.
The course follows the knowledge of the subjects Textile Technology I, Structure and Properties of Textiles, Experimental Analysis of Structures from the Bachelor's Study Program. The course builds on the context of the subject Structure of Fibrous Structures from the master study program.;

Requirements on student are available in the IS STAG system.

Credit: Active participation in practice, handing over of projects reports in direct or distance study form.
Exam: oral by written preparation.

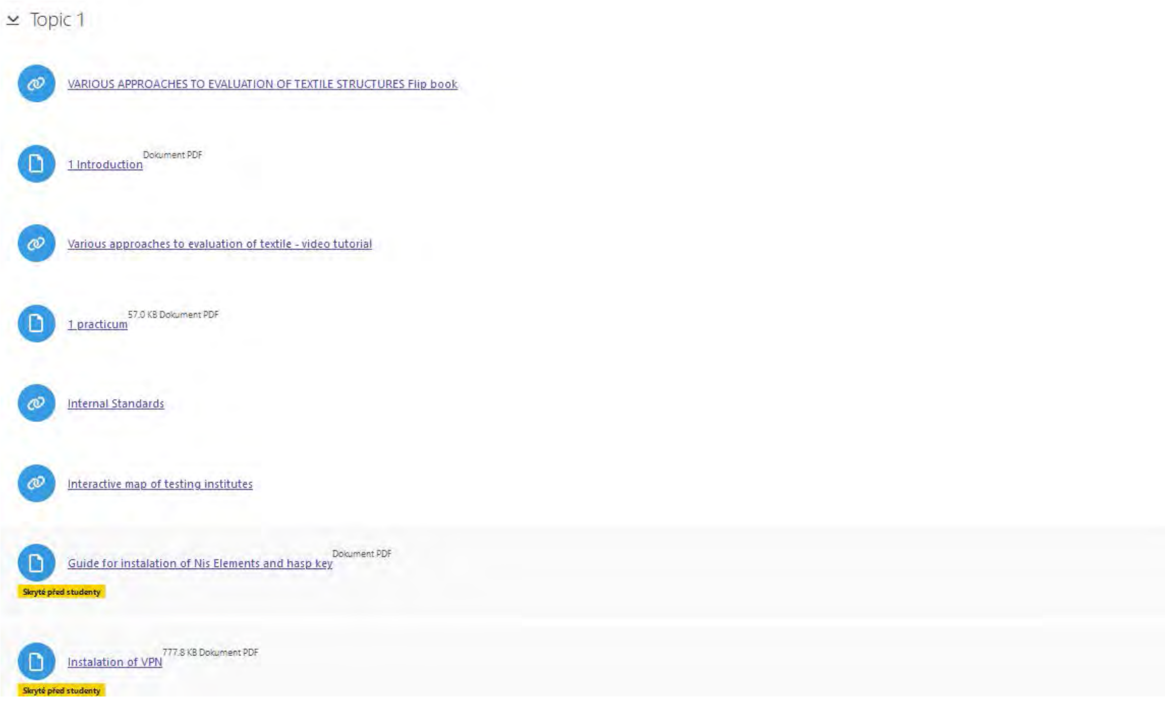
You can find the teachers' consultation hours on the faculty's website in their personal profiles (http://www.ft.tul.cz/katedry/katedra-textilnich-technologii/clenove-katedry). It is a good idea to make an appointment for the consultation in advance, preferably by email, which contains a topic for discussion, a proposal of the date from your side.

Recommended literature:

- Study materials for lectures at web portal https://elearning.tul.cz/.
- Instruction for practices at web portal https://elearning.tul.cz/ .
- Collective of authors: Internal Standards. Textile Research Centre, Faculty of Textile Engineering, Technical Univeresity of Liberec. 2004. (shared with students at Google disk)
- Laboratory Imaging: *manual for NIS-Elements*, verze 3.10, 2010.
- Neckář B., Das D. *Theory of Strture and Mechanics of Yarns*, India: Woodhead Publishing India Pvt Ltd, 2018. ISBN 978-93-85059-10-7.
- Russ J. C., Russ J. Ch. *Introduction to image processing and analysis*, Boca Raton: CRC Press, 2008. ISBN 978-0-8493-7073-1.
- Seera J. *Image Analysis and Mathematical Morphology*. London: Academic Press. 1983. ISBN 978-0126372403.
- Lawrence, C. A. *Fundamentals of spun yarn technology*. Boca Raton: CRC Press LLC, 2003. ISBN 1-56676-821. [online] [cit. 12.3.2018]. Dostupné v el. formě z: https://textinfo.files.wordpress.com/2012/10/fundamentals-of-spun-yarn-technology.pdf
- Lord P. R. *Handbook of yarn production*. 1st Edition. Woodhead Publishing, 2003. ISBN 9781855736962.
- Katalog Univerzitní knihovny Technické Univerzity v Liberci
- Katalog Krajské vědecké knihovny v Liberci
- Další on-line katalogy

A part of the study materials has been produced with the support of the project New Opportunities for the Development of Education at the Technical University of Liberec NPO_TUL_MSMT-16598/2022.

A preview of the examples for the topics of the first, third and fourth topic of a course on e-learning.



Topic 1

- VARIOUS APPROACHES TO EVALUATION OF TEXTILE STRUCTURES Flip book
- 1 Introduction Dokument PDF
- Various approaches to evaluation of textile - video tutorial
- 1 practicum 57.0 KB Dokument PDF
- Internal Standards
- Interactive map of testing institutes
- Guide for instalation of Nis Elements and hasp key Dokument PDF
  Skryté před studenty
- Instalation of VPN 777.8 KB Dokument PDF
  Skryté před studenty

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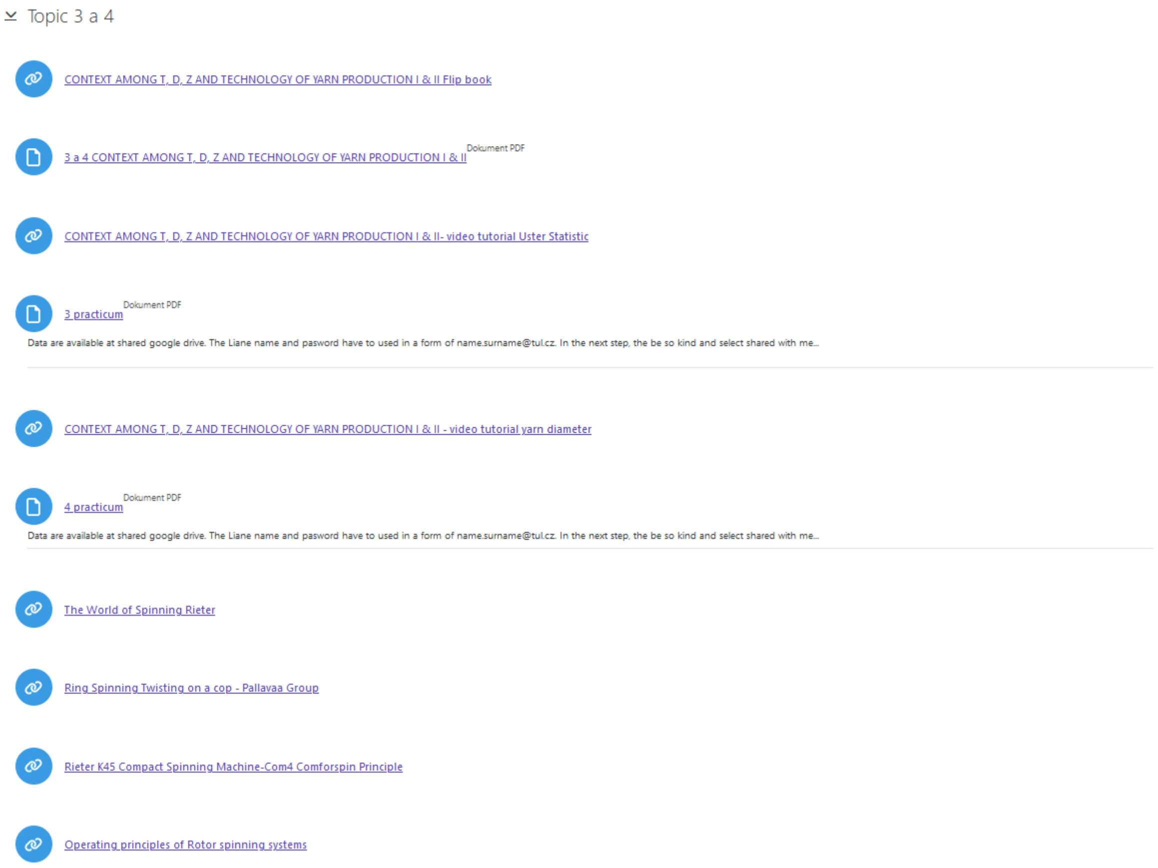
MINISTRY OF EDUCATION, YOUTH AND SPORTS



Topic 3 a 4

CONTEXT AMONG T, D, Z AND TECHNOLOGY OF YARN PRODUCTION I & II Flip book

3 a 4 CONTEXT AMONG T, D, Z AND TECHNOLOGY OF YARN PRODUCTION I & II Dokument PDF

CONTEXT AMONG T, D, Z AND TECHNOLOGY OF YARN PRODUCTION I & II- video tutorial Uster Statistic

3 practicum Dokument PDF

Data are available at shared google drive. The Liane name and pasword have to used in a form of name.surname@tul.cz. In the next step, the be so kind and select shared with me...

CONTEXT AMONG T, D, Z AND TECHNOLOGY OF YARN PRODUCTION I & II - video tutorial yarn diameter

4 practicum Dokument PDF

Data are available at shared google drive. The Liane name and pasword have to used in a form of name.surname@tul.cz. In the next step, the be so kind and select shared with me...

The World of Spinning Rieter

Ring Spinning Twisting on a cop - Pallavaa Group

Rieter K45 Compact Spinning Machine-Com4 Comforspin Principle

Operating principles of Rotor spinning systems

A preview of the examples for flipbook – teachers materials used during lectures available on e-learning as URL link.

PŘÍSTUPY K HODNOCENÍ TEXTILNÍCH STRUKTUR/ VARIOUS APPROACHES TO EVALUATION OF TEXTILE STRUCTURES

Ing. Gabriela Krupincová, Ph.D. / Department of technologies and struct

Funded by the European Union NextGenerationEU

CZECH RECOVERY PLAN

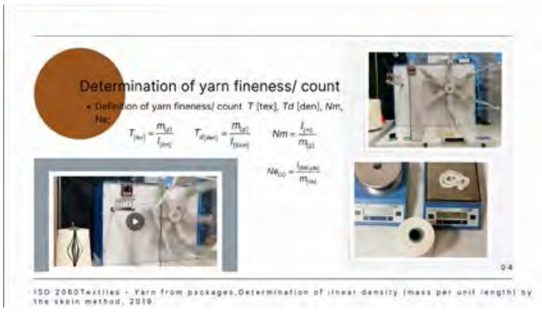
MINISTRY OF EDUCATION, YOUTH AND SPORTS

A preview of the examples for video tutorial for practicum available on e-learning as URL link.

VARIOUS APPROACHES TO EVALUATION OF TEXTILE

EXERCISE INSTRUCTIONS AND NOTES

[illegible] PH.D. / DEPARTMENT OF TECHNOLOGIES AND STRUCTURES



Determination of yarn fineness/ count

- Definition of yarn fineness/ count *T* [tex], *Td* [den], *Nm*, *Ne*;

$T_{[tex]} = \frac{m_{[g]}}{l_{[km]}}$ $T_{d[den]} = \frac{m_{[g]}}{l_{[9km]}}$ $Nm = \frac{l_{[m]}}{m_{[g]}}$

$Ne_{CO} = \frac{l_{[840yds]}}{m_{[lbs]}}$

04

ISO 2060Textiles - Yarn from packages,Determination of linear density (mass per unit length) by the skein method, 2019.

PŘÍSTUPY K HODNOCENÍ TEXTILNÍCH STRUKTUR/ VARIOUS APPROACHES TO EVALUATION OF TEXTILE STRUCTURES

Ing. Gabriela Krupincová, Ph.D. / Department of technologies and structures

Aims and motivation

Motivation:

- ✓ there are theoretical bases describing the character of the behaviour of longitudinal structures in the geometric and mechanical levels, procedures how to describe, model and capture the behaviour of longitudinal textiles in hierarchical fibrous structure (fibre - length fabrics – 2D and 3D fabrics) are known;
- ✓ previous studies of the current state of knowledge are available, as well as information from practice;
- ✓ technical means and technological equipments are available, thanks to which it is possible to determine the basic and additional properties of fibres, yarns, fabrics and 3D textiles and describe their quality, verify and confirm the possibilities of their subsequent processing in industrial practice;
- ✓ thanks to continues innovations in science and industry, it is always possible to further develop the acquired knowledge and find topics that are not yet fully explored in professional publications and their potential increases with the interest of industrial practice, or to use textile techniques used in other fields (inspiration).

Aims and motivation

Aims of the subject:

- ✓ introduction to experimental analysis of textile structures;
- ✓ linking theoretical contexts with practical use;
- ✓ a deeper understanding of the relationship between the characteristics of yarns given by the technologies of their production, the determination of qualitative indicators and their influence on the final product;
- ✓ acquaintance with the basic procedures of testing selected qualitative indicators preparation of data processing using OA;
- ✓ providing information on the possibilities that selected testing and semi-production laboratories of FT TUL offer.

Overview of the current state

- ✓ Introduction to the subject, rules of cooperation.
- ✓ Approaches to the evaluation of textile structures.
- ✓ System of standards and internal standards.
- ✓ Special methodologies using image analysis.

Introduction to the subject, rules of cooperation

Knowledge, experience, inspiration, cooperation, sharing and openness, the desire and decision to seek and develop (behind a comfortable personal and team zone) leads to new knowledge ...

Rules of cooperation on my site:

- ✓ study materials available on e-learning together with a list of related literature; refreshment of related knowledge or self-study is necessary (BSP: Textile Technology I, Structure and properties of textiles, Experimental analysis of structures. NMSP: Structure of fibrous structures and other specialized subjects);
- ✓ discussions and consultations is possible and the date is arranged by email;
- ✓ submission of all protocols from laboratory exercises in respect to deadlines;
- ✓ oral exam with written preparation;

Rules of cooperation on your site:

- ✓ have to be specified and sett during the first lecture.

Approaches to the evaluation of textile structures

Team of the Department of technologies and structures
(http://www.ft.tul.cz/en/departments/department-of-technologies-and-structures/members-of-the-department)

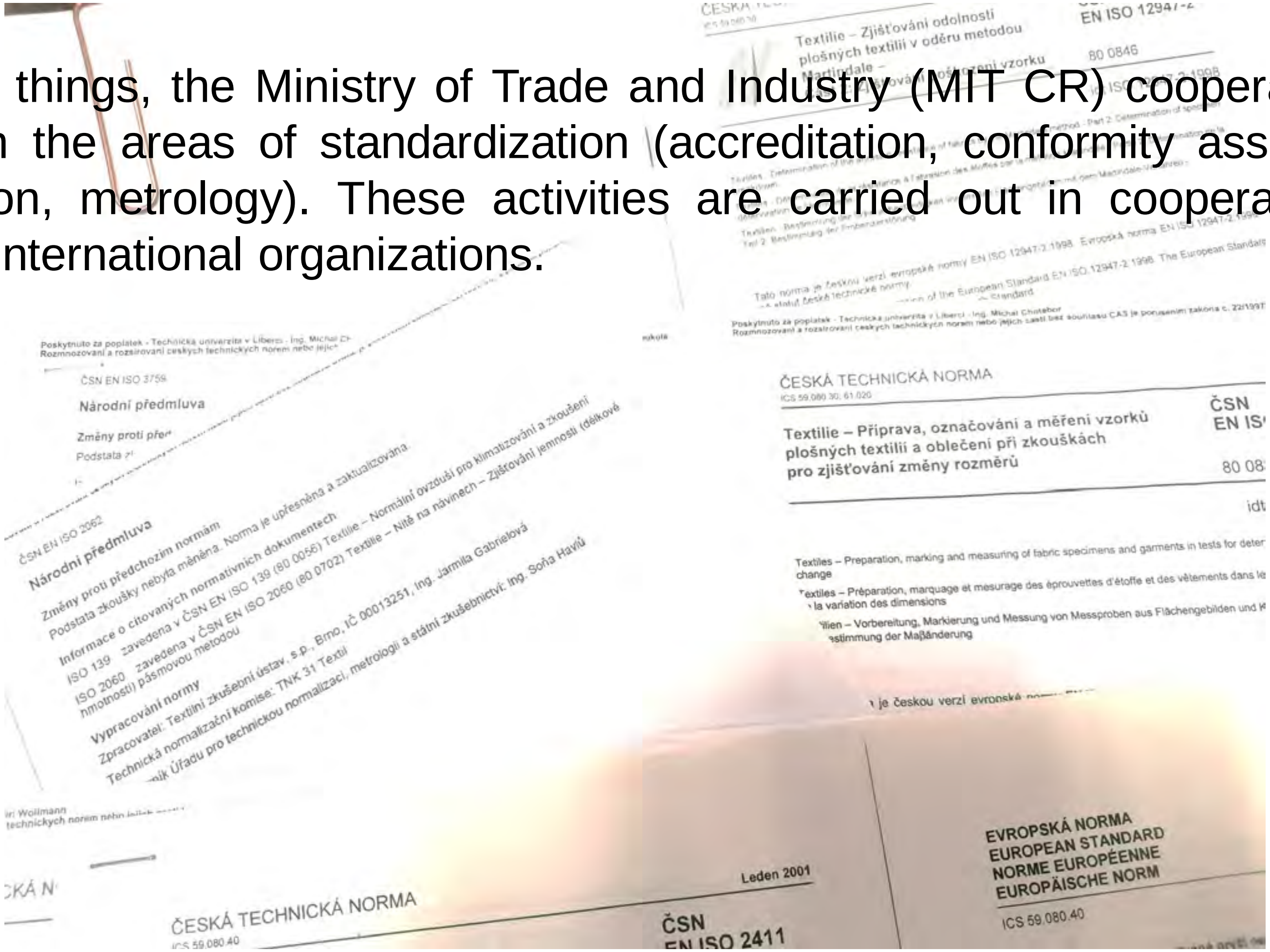
Laboratory background of FT TUL
(http://www.ft.tul.cz/en/labs)

Laboratories and semi-production laboratories of the Department of Technologies and Structures
(http://www.ft.tul.cz/en/departments/department-of-technologies-and-structures/laboratory)

Virtual tour of the FT TUL
(https://www.ft.tul.cz/fakulta/o-fakulte/virtualni-prohlidka)

System of standards and internal standards

Among other things, the Ministry of Trade and Industry (MIT CR) cooperates with key actors in the areas of standardization (accreditation, conformity assessment, standardization, metrology). These activities are carried out in cooperation with national and international organizations.



Textilie – Zjišťování odolnosti plošných textilií v oděru metodou Martindale –

EN ISO 12947-2

80 0846

ČSN EN ISO 2062

Národní předmluva

Změny proti předchozím normám

Podstata zkoušky nebyla měněna. Norma je upřesněna a zaktualizována.

Informace o citovaných normativních dokumentech

ISO 139 zavedena v ČSN EN ISO 139 (80 0056) Textilie – Normální ovzduší pro klimatizování a zkoušení

ISO 2060 zavedena v ČSN EN ISO 2060 (80 0702) Textilie – Nitě na návinech – Zjišťování jemnosti (délkové hmotnosti) pásmovou metodou

Vypracování normy

Zpracovatel: Textilní zkušební ústav, s.p., Brno, IČ 00013251, Ing. Jarmila Gabrielová

Technická normalizační komise: TNK 31 Textil

Úřadu pro technickou normalizaci, metrologii a státní zkušebnictví: Ing. Soňa Havlů

ČESKÁ TECHNICKÁ NORMA

ICS 59.080.30; 61.020

Textilie – Příprava, označování a měření vzorků plošných textilií a oblečení při zkouškách pro zjišťování změny rozměrů

Textiles – Preparation, marking and measuring of fabric specimens and garments in tests for deter change

ČESKÁ TECHNICKÁ NORMA

ICS 59.080.40

Leden 2001

ČSN

EVROPSKÁ NORMA
EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

ICS 59.080.40

System of standards and internal standards

The ÚNMZ Office carries out the competence of the state in the following areas:

- technical standardization,
- metrology,
- testing,
- harmonization of technical regulations.

Responsibilities of the Office are stipulated by the Act No. 20/1993 Coll. on Safeguarding the Organization of the State Administration in the Field of Technical Standardization, Metrology and Testing, the Act No. 22/1997 Coll. on Technical Requirements for Products, the Act No. 505/1990 Coll. on Metrology. The competences also result from relevant governmental resolutions and international treaties to which the Czech Republic is bound.

System of standards and internal standards

Czech metrology institute provides uniformity and precision of measuring instruments and measurement in all the fields of research, technical and economic activities in the range of Law about metrology Nr. 505/90 Sb. in valid issue.

The Institute provides services in all basic fields of metrology:

- ✓ fundamental metrology, maintenance and development of national standards, research and development in metrology,
- ✓ transfer of units, calibration of standards and measuring instruments,
- ✓ legal metrology, type approvals of legal metrology instruments, initial and subsequent verification of measuring instruments, metrological supervision, conformity assessment in metrology.

Institute provides certification of reference materials, provides state metrology assessment of measuring instruments and other services too. CMI cooperates in many national bodies.

CZECH
METROLOGY
INSTITUTE

System of standards and internal standards

ČESKÝ INSTITUT
PRO AKREDITACI, O.P.S.

Apart from provision of public beneficial services Czech Accreditation Institute CAI is entitled to conduct additional activities, such as out-of-school education and workshops, organization of courses and trainings, including lecturing and also publishing and editorial activities.

In the Czech Republic, CAI has developed an accreditation system, in compliance with international requirements and rules (established by EC and EA), which seeks an achievement of a system comparable with the systems used in EU and EFTA countries. The activity was therefore, from the outset, focused on international co-operation with an objective to become member in the reputable international organizations dealing with accreditation and a signatory of multilateral agreements.

CAI is currently a full member of:

European cooperation for Accreditation (EA), International Laboratory Accreditation Co-operation (ILAC), International Accreditation Forum (IAF), Forum of the Accreditation and Licensing Bodies (FALB) and a signatory of all existing multilateral agreements (EA MLA, ILAC MRA and IAF MLA).

Technical standards

- ✓ are documents that set out requirements for specific objects, materials, components, systems or services, or describe in detail specific methods and procedures;
- ✓ they are drawn up by consensus and approved by recognized standardization bodies, and there are several types of technical standards (some of the most commonly used standards set out the requirements for a particular type of product, service or process must meet in order to demonstrate that it is "fit for purpose";
- ✓ relate to test methods, terminology and definitions, information requirements or interconnection compatibility);
- ✓ provide a common basis for mutual understanding between individuals, businesses and different organizations;
- ✓ they are especially useful for communication, measurement, trade and production;
- ✓ technical standards are not generally binding, which means that companies and other organizations are not required by law to use them. However, in some cases, standards may facilitate compliance with legislation, such as those contained in European directives and regulations, (harmonized standards allow companies to ensure that their products / services comply with the essential requirements set out in European legislation (directives));

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www.unmz.cz Regulation of the European Parliament and of the Council on European standardization (1025/2012)
www.mpo.cz Act No. 22/1997 Coll., „About technical requirements for products " and other related Government Regulation .

Technical standards

- ✓ the binding nature of technical standards results from another legal act (another legal regulation, contract, instruction of a superior or decision of an administrative body). The legal order of the Czech Republic contains a number of regulations which directly or indirectly stipulate the obligation to comply with technical standards.
- ✓ Thanks to EU membership and related legislation, the Czech Republic have to adopt all EN standards within 6 months at the latest. However, the Czech Republic is not obliged to adopt international standards unless it decides to do so.
- ✓ Types of standards: international standards, national standards, branch standards, standards of associations, associations, corporate standards - internal.
- ✓ If an international or European standard is taken over into the system of Czech standards with the designation ČSN xx xxxx, then the marking is modified - ČSN ISO, ČSN EN ISO, ČSN EN… Other types of national standards STN (Slovak Technical Standard, Slovak Republic), DIN (Deutshe Industriere Norm, Federal Republic of Germany), BS (British Standard, Great Britain), ÖNORM (Östereich Norm, Austria),…

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www.unmz.cz Regulation of the European Parliament and of the Council on European standardization (1025/2012) www.mpo.cz Act No. 22/1997 Coll., „About technical requirements for products “ and other related Government Regulation .

Technical standards

Basic terms arising from the legislation:

- ✓ technical regulation - legal regulation containing technical requirements for the product,
- ✓ (Czech) technical standard - a standard adopted in accordance with Act No. 22/1997 Coll. and published in the Gazette of the Office for Technical Standardization, Metrology and State Testing (for textiles, the main class is technical standards - 80 Textile raw materials and products, but important standards related to textiles are also found in other classes, e.g. 83 protective equipment,
- ✓ another technical standard - the term is notprecisely defined, it means in particular technical standards adopted in a similar way in other states or supranational institutions,
- ✓ technical document - another document containing technical requirements for a product, which is not a technical regulation or technical standard.

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www.unmz.cz Regulation of the European Parliament and of the Council on European standardization (1025/2012)
www.mpo.cz Act No. 22/1997 Coll., „About technical requirements for products " and other related Government Regulation .

Technical standards

Why define, implement and use them?

Ensure the quality and safety of products and / or services; achieve compatibility between products and / or their components; make new markets and customers available abroad; satisfy customer requirements and expectations; reduce costs, reduce waste and increase efficiency; comply with relevant legislation, including EU regulations; gain knowledge about new technologies and innovations.

Who defines, creates and implements them?

National standardization bodies (e.g. CEN - or CENLEK or ETSI members) can develop their own national standards and also contribute to the development and adoption of standards at European and international level; provide information on all types of technical standards; brings together business and industry representatives as well as other stakeholders, such as consumer organizations, environmental groups and safety and health organizations.

The actual work on defining and developing standards is carried out by experts in the Technical Commissions, who are appointed by the various stakeholders.

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www.unmz.cz Regulation of the European Parliament and of the Council on European standardization (1025/2012)
www.mpo.cz Act No. 22/1997 Coll., „About technical requirements for products “ and other related Government Regulation .

Technical standards

Technical commissions:

- ✓ Technical commissions and sub-commissions are working bodies of the standardization system at the national level, as well as in international, European and foreign standardization organizations.
- ✓ assess, discuss and process draft national, European and international standards, or proposals for the development of other standardization tasks and projects; monitor and continuously analyze the course and results of European and international standardization.
- ✓ Access to them is open. All interest groups are represented in them: producers, consumers, trade organizations, schools, public administration, research. Participation in them is voluntary and at your own expense.
- ✓ ÚNMZ provides documents and information for their activities and mediates contact with international and European standardization organizations. Active participation in Technical Standards Committees brings members up-to-date information on what is happening in their field of interest, through draft standards it is possible to effectively monitor and influence technical developments, an overview of the latest trends and news on the market; participation in the development of international and European standards and thus create quality, transparent and effective economic cooperation in Europe and worldwide.

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www.unmz.cz Regulation of the European Parliament and of the Council on European standardization (1025/2012)
www.mpo.cz Act No. 22/1997 Coll., „About technical requirements for products " and other related Government Regulation .

Technical standards

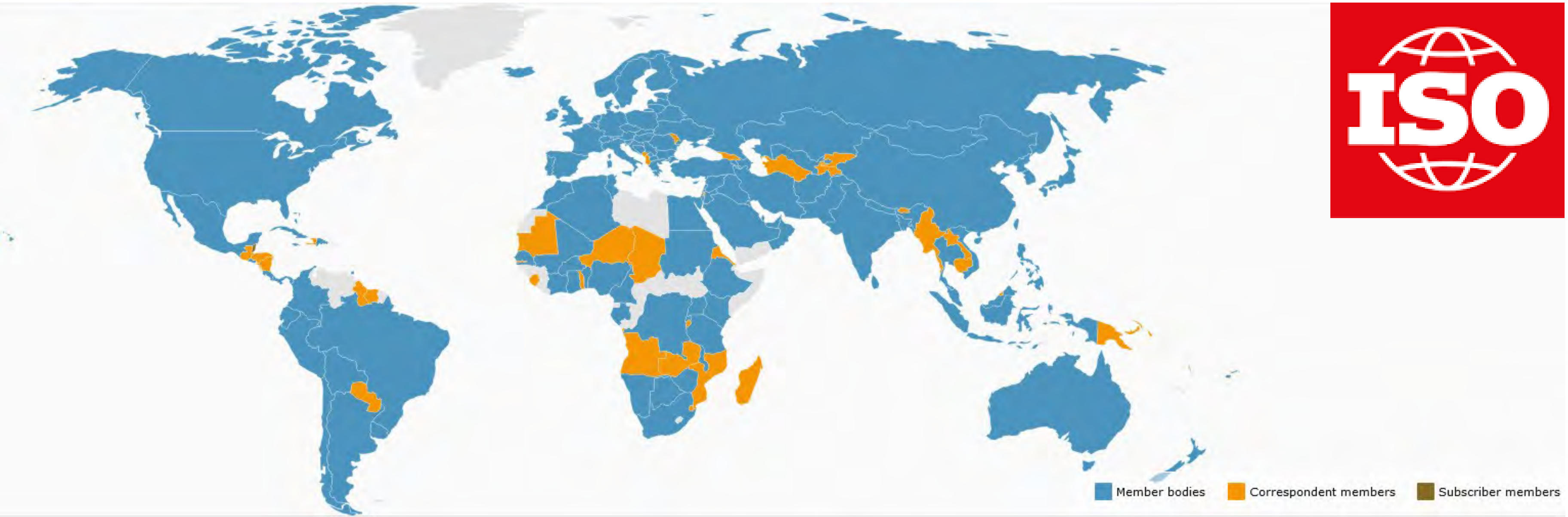
- **European standards** are developed and published by European standardization organizations: the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI).
- **International Standards** are developed and published by international standardization organizations: the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC) and the International Telecommunication Union (ITU). International standards are particularly important as a means of facilitating trade between different countries.
- Most technical standards (including European standards implemented in national systems and international standards) can be purchased from the national standardization body in the country. Revenues from the sale of standards contribute to the financial sustainability of the entire technical standardization system.
- It is possible to participate in the preparation, comments are possible through the national standardization body, professional associations, associations or chambers of commerce.

www.unmz.cz Regulation of the European Parliament and of the Council on European standardization (1025/2012)
www.mpo.cz Act No. 22/1997 Coll., „About technical requirements for products “ and other related Government Regulation .

Technical standards

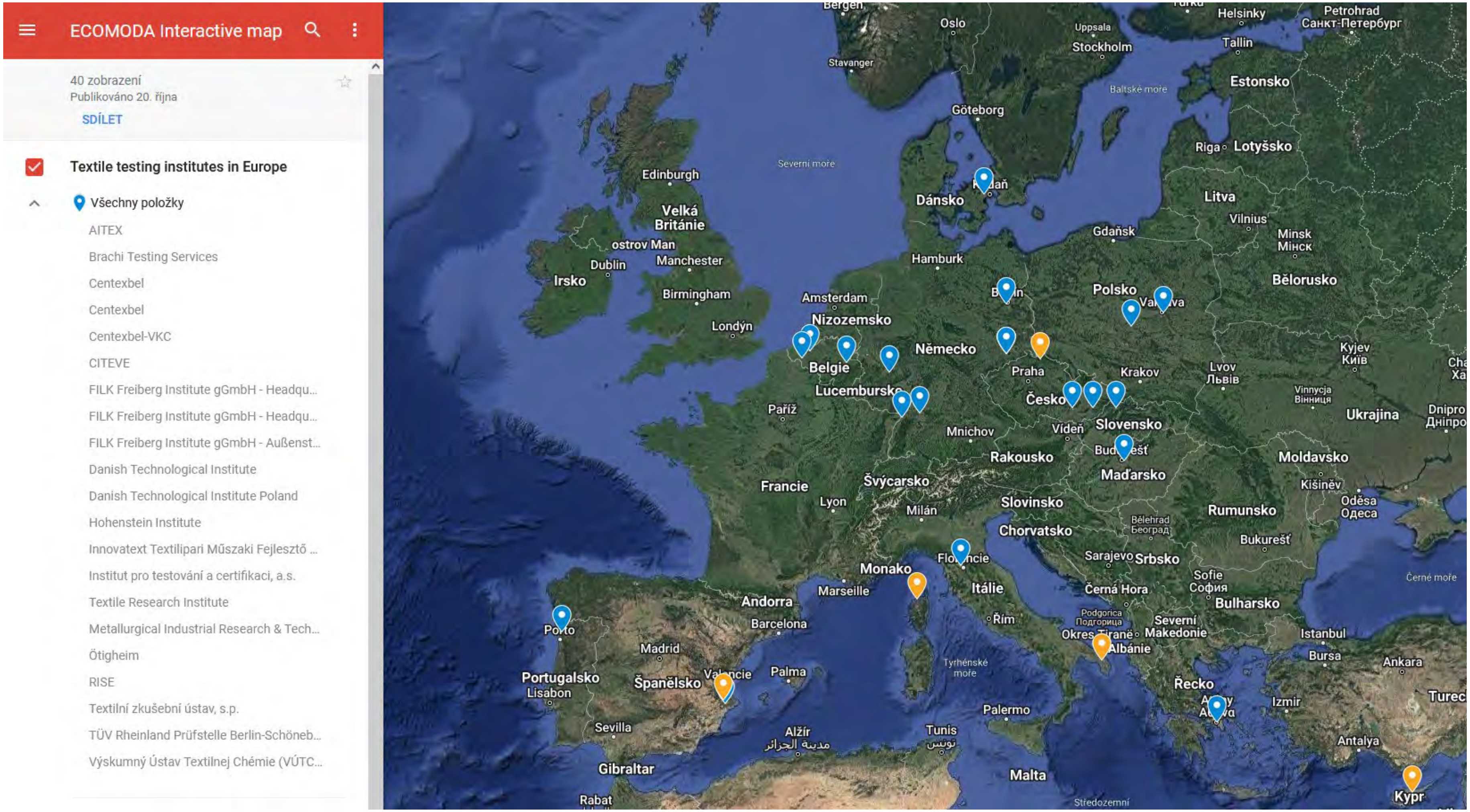
International Organization for Standardization (ISO)

- ✓ ISO is a world federation of national standards organizations based in Geneva, founded on February 23, 1947, and now has 165 members from various countries (full membership, associate membership, and candidates for membership).
- ✓ The International Organization for Standardization deals with the creation of international ISO standards and other types of documents in selected areas of standardization (TS - technical specifications, TR - technical reports, PAS - publicly available specifications, TTA - agreements on technical trends, IWA - agreements from industry workshops, ISO guidelines).



https://www.iso.org

Testing institutes also for textiles in Czech Republic and cross the borders



ECOMODA Interactive map

40 zobrazení
Publikováno 20. října
SDÍLET

☑ Textile testing institutes in Europe

Všechny položky

- AITEX
- Brachi Testing Services
- Centexbel
- Centexbel
- Centexbel-VKC
- CITEVE
- FILK Freiberg Institute gGmbH - Headqu...
- FILK Freiberg Institute gGmbH - Headqu...
- FILK Freiberg Institute gGmbH - Außenst...
- Danish Technological Institute
- Danish Technological Institute Poland
- Hohenstein Institute
- Innovatext Textilipari Műszaki Fejlesztő ...
- Institut pro testování a certifikaci, a.s.
- Textile Research Institute
- Metallurgical Industrial Research & Tech...
- Ötigheim
- RISE
- Textilní zkušební ústav, s.p.
- TÜV Rheinland Prüfstelle Berlin-Schöneb...
- Výskumný Ústav Textilnej Chémie (VÚTC...

Interactive map of ECOMODA training course, A new approach to the perception of textile quality and its evaluation via testing Module 4, Pop Up Workspace. https://ecomoda-programme.eu/

Testing institutes also for textiles in Czech Republic and cross the borders

Textile Testing Institute s.p. (Brno, Czech Republic)

- ✓ Scope: testing, product certification, system certification, technical standardization, calibration, industry specifications and other services (provision of consultations, education, professional R&D activities;
- ✓ Testing the quality of textile products, including hygiene and maintenance in laundries, toys and the quality of upholstered furniture,…

Institute for Testing and Certification a.s. (Zlín, Czech Republic)

- ✓ Scope: an independent testing, certification, calibration and inspection company with international scope providing professional services in the field of product quality and safety assessment, certification of products and management systems and services in the field of technical standardization, education and more.
- ✓ Quality testing of textile products, maintenance, plastic products, composite materials, footwear,…

Hohenstain (Hohenstain, Germany)

- ✓ Scope: testing and certification of products, processes, other professional R&D activities and education.
- ✓ Quality testing, especially in terms of protective clothing and clothing maintenance for healthcare.

www.tzu.cz, http://www.itczlin.cz , ww.hohenstein.com

Special methodologies usingimage analysis

Internal standards are a comprehensive set of original methodologies that:

- ✓ define qualitative and quantitative parameters of fibrous structures (fibers, length fabrics, fabrics and 3D shapes);
- ✓ introduces procedures for determining these parameters as well as how to evaluate them;
- ✓ enable the establishment of known qualitative criteria in a new way using, inter alia, image processing procedures,
- ✓ extend the standard methodologies described in existing technical standards (e.g. ISO, ASTM,…),
- ✓ introduce new qualitative or quantitative criteria and procedures for their determination with regard to newly emerging needs (R&D activities, industrial practice, innovation;);
- ✓ were mostly processed by a team of experts collaborating on the solution of the TEXTIL I and II Research Center project, where they were also reviewed;
- ✓ are available in Czech and English;
- ✓ their adaptation and extension is still possible and desirable.

Research Centre Textile LN 00B090, MSMT ČR, 2002 - 2004. Research Centre Textile II M 0553, MSMT ČR, 2005 - 2011. ModSimTex, 7th Frame Program CP-FP 214181-2, 2008 - 2012.

Special methodologies using image analysis

Reasons for their processing and use

- ✓ limiting routine testing by standard procedures;
- ✓ high purchase price of specialized laboratory instruments, effort to extend testing into practice without the need for large investments;
- ✓ efforts to unify new procedures and the possibility of repeating and reproducing the results achieved;
- ✓ an effort to translate the results of R&D activities into practice.

Benefits

- ✓ simplicity and in some cases non-destructiveness of the tested fiber assembly;
- ✓ provide standard and extended information on the behavior or quality of textiles, which will make it easier to understand the context, for example, in resolving complaints, acceptances, …

Special methodologies using image analysis

Numbering of internal standards

The numbering system and the structure of the standards correspond to the established procedures of the technical standards.

The number of each internal standard is nine digits, e.g. AB-CDE-FG / HI. The first two digits indicate the type of standard (A) and the type of textile structure (B), the second three digits indicate the type of test, e.g. the type of properties (C) and the serial number of the selected property (DE), the third two digits the serial number of the standard (FG/), (HI).

A definition standard 1B-…., New method 2B-…., Extension of existing method 3B-…., Auxiliary techniques 4B-…., Fibres A1-…., Staple yarns and silk A2-…., Fabrics A3-….

B knitted fabrics A4-…., Non-woven fabrics A5-…., General (for different types of structures) A6-….

C properties geometric ..- 1…, mechanical ..- 2…, physiological ..- 3…, electrical ..- 4…

Special methodologies using image analysis

Cottonization degree of flax fibers

This standard defines measurement and evaluation of elementarization degree (cottonization degree) of flax technical fibers. Cottonization is biological, mechanical or chemical process or their combination leading to separation of element (ultimate) fiber from technical flax fibers. Cottonization degree is evaluated from bunch of technical flax fibers cross sections as relative frequency of fibrous bundles containing 1, 2, … ultimate fibers. It is possible to evaluate mean fineness of ultimate and technical fibers and some other characteristics of segregation or aggregation.

$$N_s = \sum_{j=1}^{n} x_j \qquad N = \sum_{j=1}^{n} j x_j \qquad f_j = \frac{x_j}{N_s} \qquad F_j = \sum_{k=1}^{j} f_k$$

Fibrous bundle created by $j=1,2,3, \ldots n$, N_s [-] total number of all bundles, N [-] total number of all ultimate fibers, f_j [-] relative frequency of fibrous bundles created by j fibers, F_j [-] cumulative frequency of all kind of fibrous bundles till j fibers.

Internal standard 21-104-01/01 Cottonization degree of flax fibres. FT TUL Research Centre Textile, 2004.

Special methodologies using image analysis

Segregation characteristics f_1 is relative frequency of ultimate fibers in cross section i.e. relative frequency of fibrous bundles created by one ultimate fibers $j=1$. For $2 \leq j \leq 10$ it is possible to assume that relative frequency of fibrous bundles is decreasing function of number of ultimate fibers. Corresponding probability function can be described by geometric distribution:

$$f_j = p(1-p)^j,$$

Parameter p of this distribution is another indicator of segregation because for higher p is higher relative frequency of bundles created from few fibers. Parameter p can be estimated by the least squares method.

Aggregation characteristic R_{10} is chosen as probability of fibrous bundles appearance created by $j \geq 10$ ultimate fibers.

$$R_{10} = 100(1-F_{10})$$

f_j [-] relative frequency of ultimate fibers in cross section of j fibers, f_1 [-] segregation characteristics, p segregation characteristic – relative frequency of fibrous bundles created by low number of fibers, R_{10} aggregation characteristic , F_{10} cumulative frequency of all kind of fibrous bundles till $j=10$ ultimate fibers

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Internal standard 21-104-01/01 Cottonization degree of flax fibres. FT TUL Research Centre Textile, 2004.

Special methodologies using image analysis

Test principle:

Principle of test is treatment of technical flax fibers and creation of their cross-sections microscopic images. The contours of all kind of fibrous bundles are manually identified. The cross-section areas and number of ultimate fibers are computed by the image analysis software. From these raw data the relative frequencies of various bundles and characteristics of aggregation or segregation are computed.

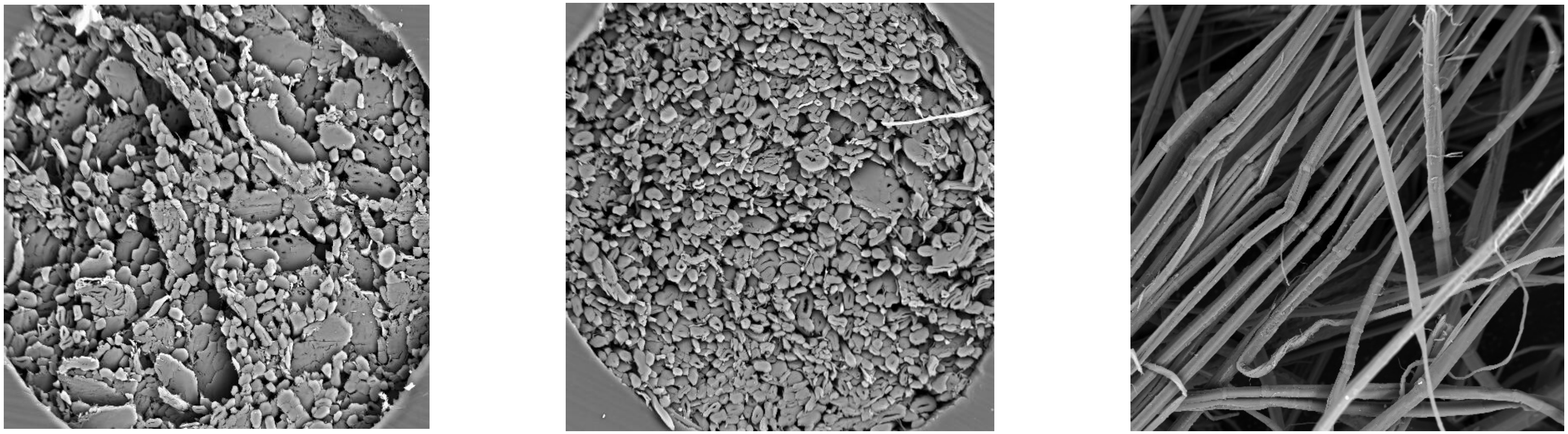
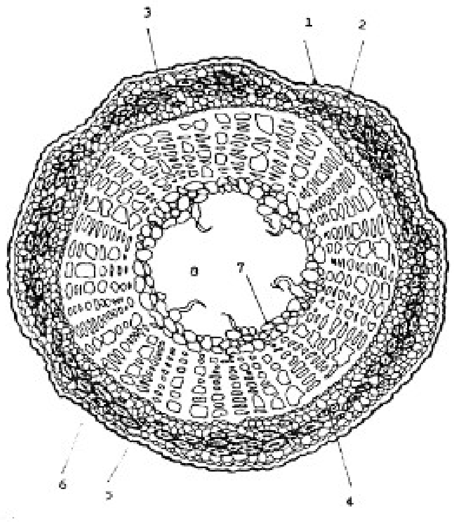


Fig. 1 Flax fibers AquaSEM a) cross section before cotonization, b) cross section after cotonization c) longitudinal view

Internal standard 21-104-01/01 Cottonization degree of flax fibres. FT TUL Research Centre Textile, 2004.

Special methodologies using image analysis



1kutikula
2 epidermis
3 parenchym
4bundles of flax fibers
5 kambium
6 wood cells
7 pulp plants
8 lumen

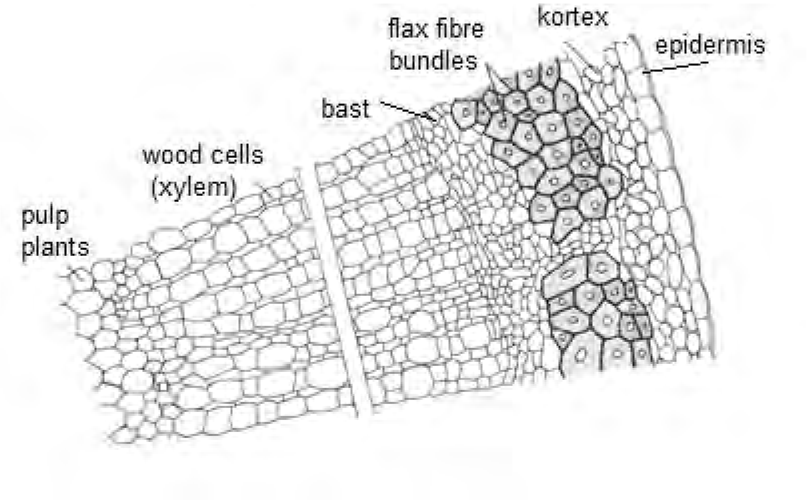


Fig. 2 Structure of flax steam – cross section

Šamonilová V. Vlastnosti lněných směsových přízí vypředených z vláken připravených na zařízení REA 120. DP FT TUL 2006.

Special methodologies using image analysis

Fig. 3 Demonstration of semi-products in the processing of hemp fibers

Examples of results

Experimental material:

Flax fibers was processed by various methods to separate elemental fibers. In the first phase only mechanical or enzymatic treatment were realized. However, the fiber refinement achieved in this way was not fully sufficient and therefore the combined enzyme-chemical processing technologies (demineralization, alkaline boiling, reducing boiling and peroxide bleaching) were tested.

The result was, on the one hand, a greater reduction in the content of inter-fiber binders and a higher refinement of the fibers, but on the other hand also a higher weight loss of the material, a shortening of the fibers and a reduction in strength appears.

The most suitable combination with regard to the cost, availability and achieved quality of cotonized flax fibers and subsequently produced yarns was found. This procedure was verified on cotton blended yarns 50/50 CO / linen produced (ring, open end, novaspin technology), which were subsequently processed into fabrics.

It has been proven that the mechanical opening device REA 120 Rieter can be used not only for the first mechanical opening but also for already coronized flax fibers, where it achieves better results in terms of unification and does not cause damage and significant shortening of fiber lengths as comparable competitive technologies that can be preferably used only for coarse loosening.

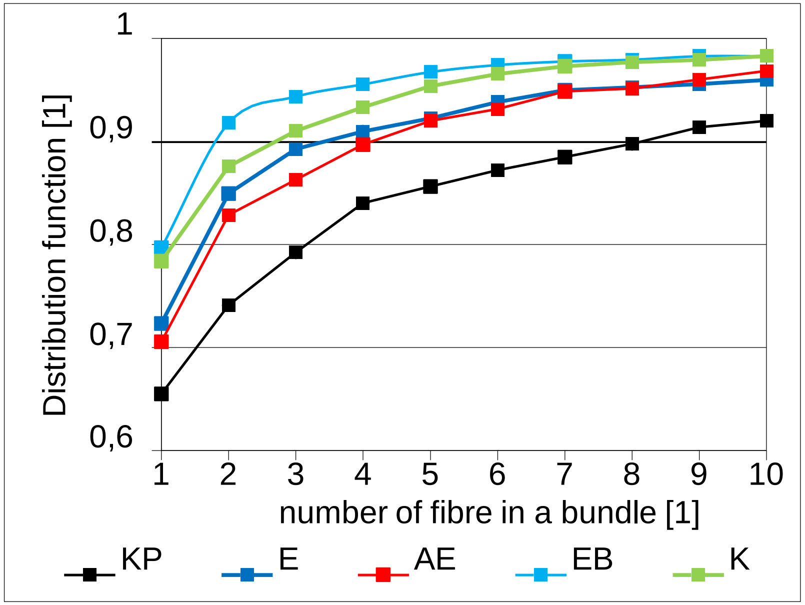
Antonov V., Křemenáková D., Wiener J. Partial project: Textile for special application 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

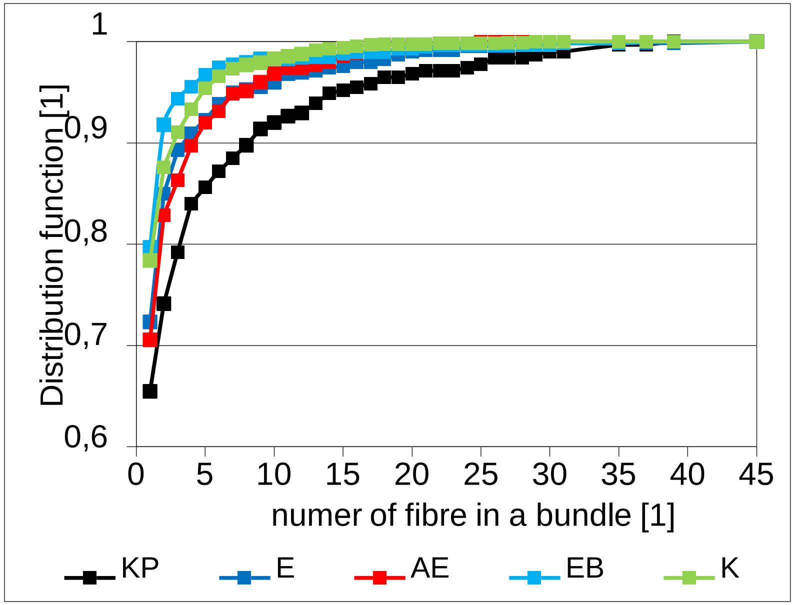
Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Examples of results

Tab. 1 Selected characteristics for evaluation of level of linen fibre aggregation

sample (flax tow)	***p*** **[-]**	***F*$_1$ [-]**	***R*$_{10}$ [%]**
KP original sliver	0,56	0,655	7,987
E enzymatic processing	0,53	0,724	4,011
AE alkali treatment and enzymatic processing	0,53	0,706	3,143
EB enzymatic processing and peroxide bleaching	0,57	0,797	1,706
K alkali treatment and enzymatic processing in combination with peroxide bleaching	0,6	0,784	1,686





Antonov V., Křemenáková D., Wiener J. Partial project: Textile for special application 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Examples of results

Experimental material:

Geranium, colonized flax fiber, micronaire 6,97, L_1 = 23.03 mm, L_2 = 30,8 mm, short fiber content 14,58%,

Indicative values obtained by using Vibroscope and Vibrodyn: fiber fineness 0,376 tex (0,338 tex; 0,414 tex); fiber strength 0,495 Ntex^{-1} (0,412 Ntex^{-1}; 0,577 Ntex^{-1}), elongation 4,25% (2,90%; 5,59%), this method is limited and not entirely suitable for fibers with lumen in a structure, the data was used for regression analysis between the fineness of the bundle and the fibers. ...

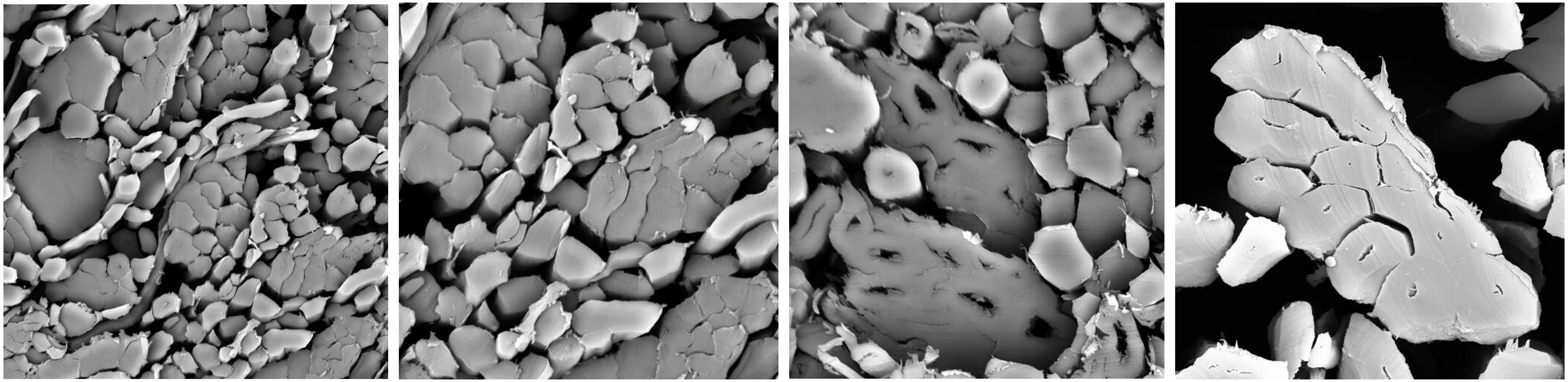
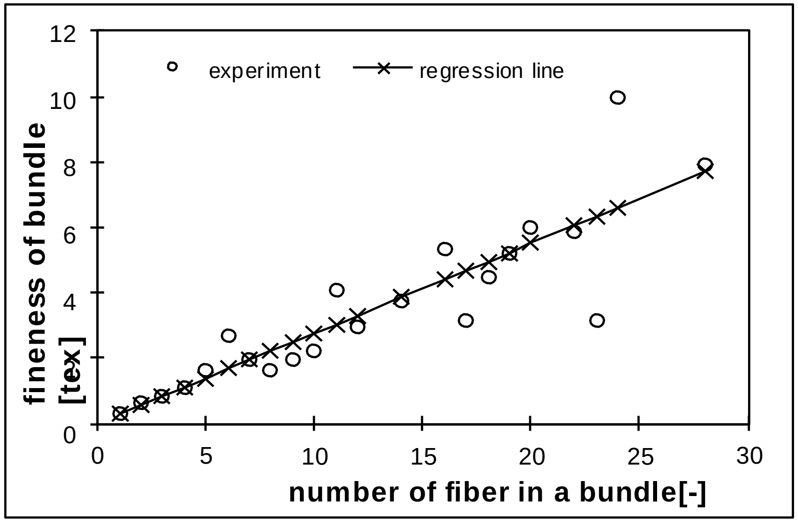


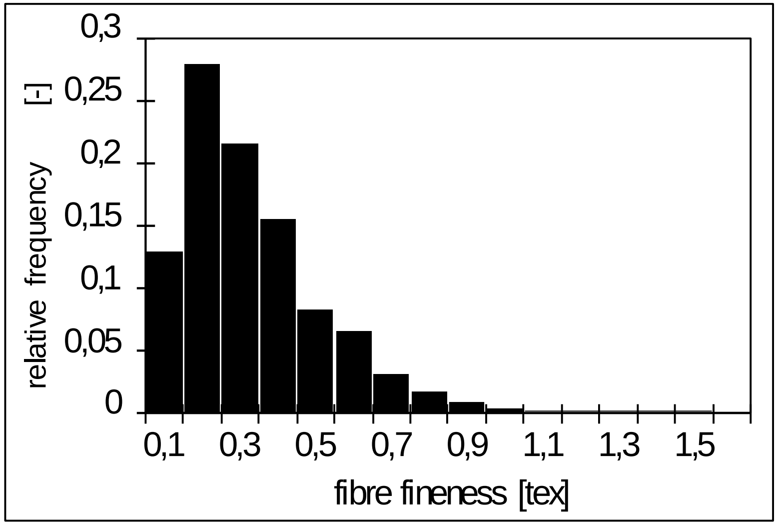
Fig. 5 Cross section of linen fibers AquaSEM

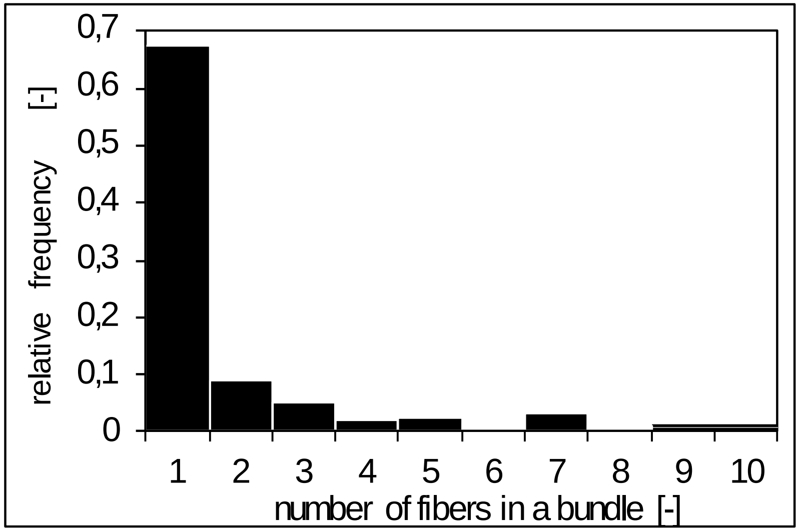
Antonov V., Křemenáková D., Wiener J. Partial project: Textile for special application 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Examples of results







Antonov V., Křemenáková D., Wiener J. Partial project: Textile for special application 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3.rd stage of project. Research report, Research Centre Textile, FT TUL 2003.

Questions for knowledge verification and repetition

- What are technical standards, what are they for, how are they created and are they binding?
- What types of technical standards do you know and how do they differ?
- What is "ISO", what activities does it implement and how is the Czech Republic involved in them?
- Do you know any accredited laboratories that perform certified analyzes of textile products? Which are they and what does it offer in general?
- What does it mean internal standards and how do they differ from other types of standards?

Thank you for your attention…

SOUVISLOST MEZI T, D, Z A TECHNOLOGIÍ VÝROBY PŘÍZE I A II/ CONTEXT AMONG T, D, Z AND TECHNOLOGY OF YARN PRODUCTION I & II

Ing. Gabriela Krupincová, Ph.D. / **Department of technologies and structures**

Aims and motivation

Motivation:

- ✓ Understanding the relationship between T, D, Z and yarn production technology is key to determining the appropriate design and technology parameters for a given application.
- ✓ The aim is to understand the production process, name the factors that affect the quality of yarns, describe the way in which the quality of yarn occurs and, thanks to this knowledge, enable further development (technology innovation, yarn quality, application possibilities,…).

Aims and motivation

Study of the connection between *T*, *D*, *Z* and yarn production technology:

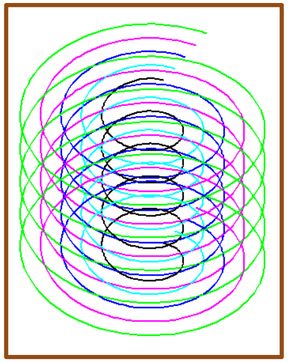
- ✓ It will make it easier to describe the qualitative indicators of yarns and find their limits.
- ✓ It allows to compile recommendations related to machine setup and the use of different types of machine parts.
- ✓ The research process will provide feedback and verify the quality of the yarn and the production equipment itself.

Overview of the current state

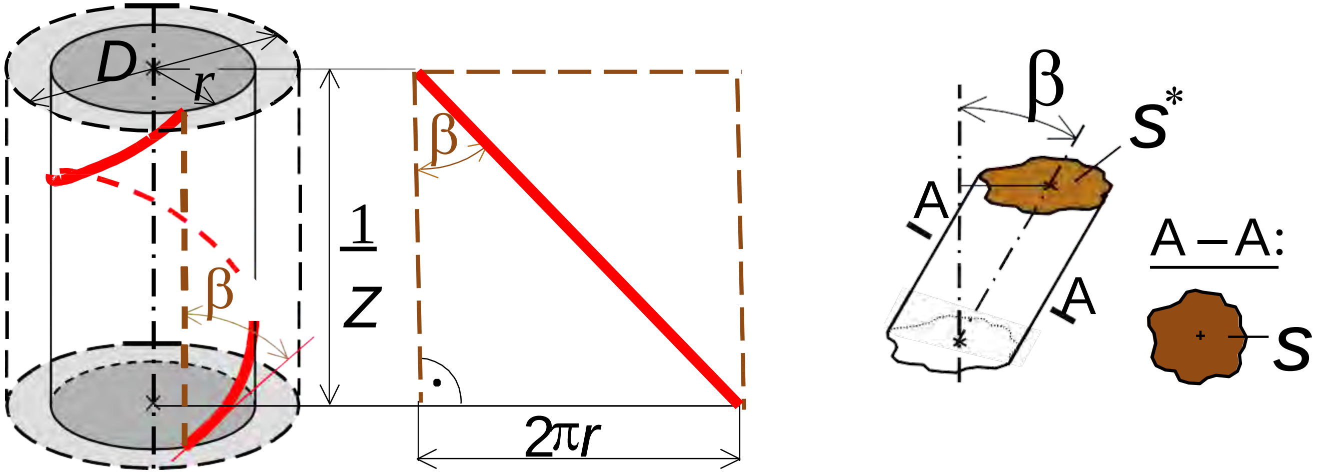
- ✓ Theoretical connections between *T*, *D*, *Z* and selected procedures for their determination,
- ✓ Basic technological procedures of yarn production – repetition,
- ✓ Selected qualitative indicators of yarns - Uster®Statistic, practical examples.

Theoretical connections between *T*, *D*, *Z*

Helix model of yarn (only idea, not description of a real state)



- ✓ Helical paths of fibers (same sense of rotation).
- ✓ Common axis of all helixes is yarn axis.
- ✓ Same coil height for all fibers.



$$tg\beta = 2\pi r Z$$

$$s^{*} = \frac{s}{\cos\beta}$$

Fig. 1 Schema of yarn helix model, detail fiber cross section perpendicularly to yarn axis and to fiber axis

$$k_n = \frac{2}{(\pi D Z)^2}\left[\sqrt{1+(\pi D Z)^2}-1\right] \qquad n = \frac{2\tau}{(\pi D Z)^2}\left[\sqrt{1+(\pi D Z)^2}-1\right] = \tau k_n$$

β [°] slope angle of fiber , β_D [°] slope angle of fiber on a surface, Z [m^{-1}] yarn twist, r [m] yarn radius, s^* [m^2] area of oblique section of one fiber, s [m^2] cross section of one fiber, k_n [-] coefficient, n [-] number of fibers.

Theoretical connections between *T*, *D*, *Z*

Köchlin's hypothesis (1828)

- ✓ **Assumption 1:** The yarn packing density μ is only a function of the (monotonically increasing) twist intensity κ.
- ✓ **Consequence:** the coefficient of the diameter K, K_S, Köchlin's twist coefficient α, α_S is only a function of the twist intensity κ.

- ✓ **Assumption 2:** Yarns of the same material spun by the same technology for the same purpose have analogous properties just if they have the same twist intensity κ is constant (idea of geometric similarity).
- ✓ **Consequence:** packing density μ , the diameter K, K_S, Köchlin's twist coefficient α, α_S.

Next generation were more accurate, measuring the coefficients of diameter, diameters and twist intensity of yarns. They found that this simple geometric model was only suitable for medium count, but finer yarns had smaller diameters and higher packing density and corrected of Köchlin's theory.

Theoretical connections between *T*, *D*, *Z*

Phrix's correction of Köchlin's hypothesis (1940s)

- ✓ **Assumptions:** Phrix's twist coefficient *a* is recommended to be constant.
- ✓ **Consequence:** The Köchlin's twist coefficient α (α_S) changes, similarly the yarn packing density μ, the yarn diameter *D* and the coefficient of the diameter *K*, K_S, changes too. The finer yarns have a smaller diameter and a higher yarn packing density. The intensity of the twist κ remains constant.

Empirical experience shows that the intensity of the twist is not constant, it does not correspond to relation πDZ, nor to the slope angle of the surface fiber helices. The model is suitable only for medium count. (In practice, the Köchlin's hypothesis is suitable for coarser longitudinal textile - roving and Phrix's for finer longitudinal textile - yarns). The geometric model is no longer enough, a new model based on the internal mechanics of the yarn is needed.

Theoretical connections between *T*, *D*, *Z*

$$T_{[tex]}=\frac{m_{[g]}}{l_{[km]}}=\frac{V_{\left[m^{3}\right]}\,\rho_{\left[kgm^{-3}\right]}}{l_{[km]}}=\frac{S_{\left[m^{2}\right]}\,l_{[km]}\,\rho_{\left[kgm^{-3}\right]}}{l_{[km]}}=\frac{\pi d_{[mm]}^{2}\mu_{[1]}\rho_{\left[kgm^{-3}\right]}}{4}$$

$$D_{[\mathrm{mm}]}=\sqrt{\frac{4T_{[\mathrm{tex}]}}{\pi\mu_{[1]}\rho_{\left[\mathrm{kgm}^{-3}\right]}}}\qquad D_{[\mathrm{mm}]}=\kappa_{[1]}\cdot 10^{3}\Big/\left(\pi Z_{\left[\mathrm{m}^{-1}\right]}\right)\qquad D[\mathrm{mm}]=K\left[\mathrm{mmtex}^{-1/2}\right]\sqrt{T[\mathrm{tex}]}$$

$$Z_{\left[\mathrm{m}^{-1}\right]}=\frac{31{,}6\;\alpha_{\left[\mathrm{m}^{-1}\mathrm{ktex}^{1/2}\right]}}{T_{[tex]}^{1/2}}=\frac{100\;a_{\left[\mathrm{m}^{-1}\mathrm{ktex}^{2/3}\right]}}{T_{[tex]}^{2/3}}=\frac{\kappa_{[1]}}{\pi D_{[m]}}=\frac{n_{\left[\mathrm{min}^{-1}\right]}}{v_{\left[m\,\mathrm{min}^{-1}\right]}}$$

$$\alpha_{\left[\mathrm{m}^{-1}\mathrm{ktex}^{1/2}\right]}=Z_{\left[\mathrm{m}^{-1}\right]}\,T_{[ktex]}^{1/2}\qquad\qquad \kappa_{[-]}=tg\beta_{D}=\pi D_{[\mathrm{m}]}\,Z_{\left[\mathrm{m}^{-1}\right]}$$

$$a_{\left[\mathrm{m}^{-1}\mathrm{ktex}^{2/3}\right]}=Z_{\left[\mathrm{m}^{-1}\right]}\,T_{[ktex]}^{2/3}$$

D [mm] yarn diameter, *T* [tex] yarn count, μ [-] yarn packing density, ρ [kgm^{-3}] fiber specific mass, *K* [mmtex$^{-1/2}$] coefficient of yarn diameter, *Z* [m^{-1}] yarn twist, α [m^{-1}ktex$^{1/2}$] Köchlin's twist coefficient, *a* [m^{-1}ktex$^{1/2}$] Phrixův's twist coefficient, κ [-] twist intensity, β_D [°] slope angle of fibers on a surface, *n* [min^{-1}] number of rotation, *v* [mmin^{-1}] delivery speed.

Theoretical connections between *T*, *D*, *Z*

Modified relations, compression theory Neckar's (2nd half of the 20th century)

- ✓ **Assumptions:** the fibers are compressed in the yarn as a result of twisting, the compression is induced by the outer layers of the fibers, the thickness of the compression layer is constant, the arrangement of fibers can be described by a helical model, dependence of pressure and yarn packing density can be described by generalized van Wyk's theory.
- ✓ **Consequence:** correction of 1. Köchlin's assumption, yarn packing density is a function not only of the intensity of the twist, but also of the yarn count.

$$\frac{\mu^{1,5}}{\left[1-\left(\mu/0,8\right)^{3}\right]^{3}}=\frac{R_{[\mathrm{tex}^{1/2}]}}{\sqrt{T_{[\mathrm{tex}]}}\left(1-\sqrt{t_{[\mathrm{tex}]}/T_{[\mathrm{tex}]}}\right)^{2}}$$

ŠNR I

μ_m

$$\frac{\mu^{2,5}}{\left[1-\left(\mu/0,8\right)^{3}\right]^{3}}=Q_{[\mathrm{m}^{2}\,\mathrm{tex}^{-1/2}]}\left(Z_{[\mathrm{m}^{-1}]}T_{[\mathrm{tex}]}^{1/4}\right)^{2}$$

ŠNR II

$$Z=\sqrt{\frac{\mu^{2,5}}{\left[1-\left(\mu/0,8\right)^{3}\right]^{3}Q_{[\mathrm{m}^{2}\,\mathrm{tex}^{-1/2}]}\left(T_{[\mathrm{tex}]}^{1/4}\right)^{2}}}$$

a [$\mathrm{m}^{-1}\mathrm{ktex}^{1/2}$] Phrix's twist coefficient, α [$\mathrm{m}^{-1}\mathrm{ktex}^{1/2}$] Köchlin's twist coefficient, *T* [tex] yarn count, *Z* [m^{-1}] yarn twist, *D* [mm] yarn diameter, μ [-] packing density, μ_m [-] maximal yarn packing density, ρ [kgm^{-3}] fiber specific mass, *Q* [$\mathrm{m}^{2}\mathrm{tex}^{-1/2}$] a *R* [$\mathrm{tex}^{-1/2}$] empirical parameters related to the technology of yarn production.

Neckář B. Study material, FT TUL

Selected methods of their determination *T*, *D*, *Z*

Determination of fineness *T*: by the weighting of given length or by calculation using knowledge of yarn diameter *D* and material composition, whereby yarn diameter *D* can be determined using image analysis (evaluation of longitudinal views or cross-sections).

The yarn diameter *D* is evaluated during yarn production using control sensors, which usually work as line cameras. Some laboratory measuring devices also use a line camera system to determine the yarn diameter, but with regard to the measuring speed and the measuring speed, they average or assign values from such short sections to longer sections (3 mm Uster Tester, 25 mm for 50 mmin^{-1}/0, 5 mm for a speed of 100 mmin^{-1}, 1 mm = 308 pxl, max. 6 mm Lawson Hemphill CTT) as well as experimental methodologies that use image processing of partial sections of yarn).

All methodologies use a specific convention for definition the region, where the diameter is found.

ČSN EN ISO 2060 Yarn from packages - Determination of linear density (mass per unit length) by the skein method. ČNI, 1/1997.

IS 12-108-01/01 Definitions. Geometrical properties of staple yarns. Textile Research Centre, FT TUL 2002.

IS 22-102-01/01 Yarn diameter and hairiness. Textile Research Centre, FT TUL 2004.

IS 22-102-02/01 Transverse dimensions of two-ply yarn and single yarn diameter. Textile Research Centre, FT TUL 2009.

IS 22-103-01/01 Yarn packing density. Textile Research Centre, FT TUL 2004.

IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.

IS 22-103 -03/01 Yarn packing density Iso-quantities. Textile Research Centre, FT TUL 2009.

IS 32-102-01/01 Transverse dimensions of two-ply yarn and single yarn diameter Longitudinal viewsTextile Research Centre FT TUL 2009.

Selected methods of their determination *T*, *D*, *Z*

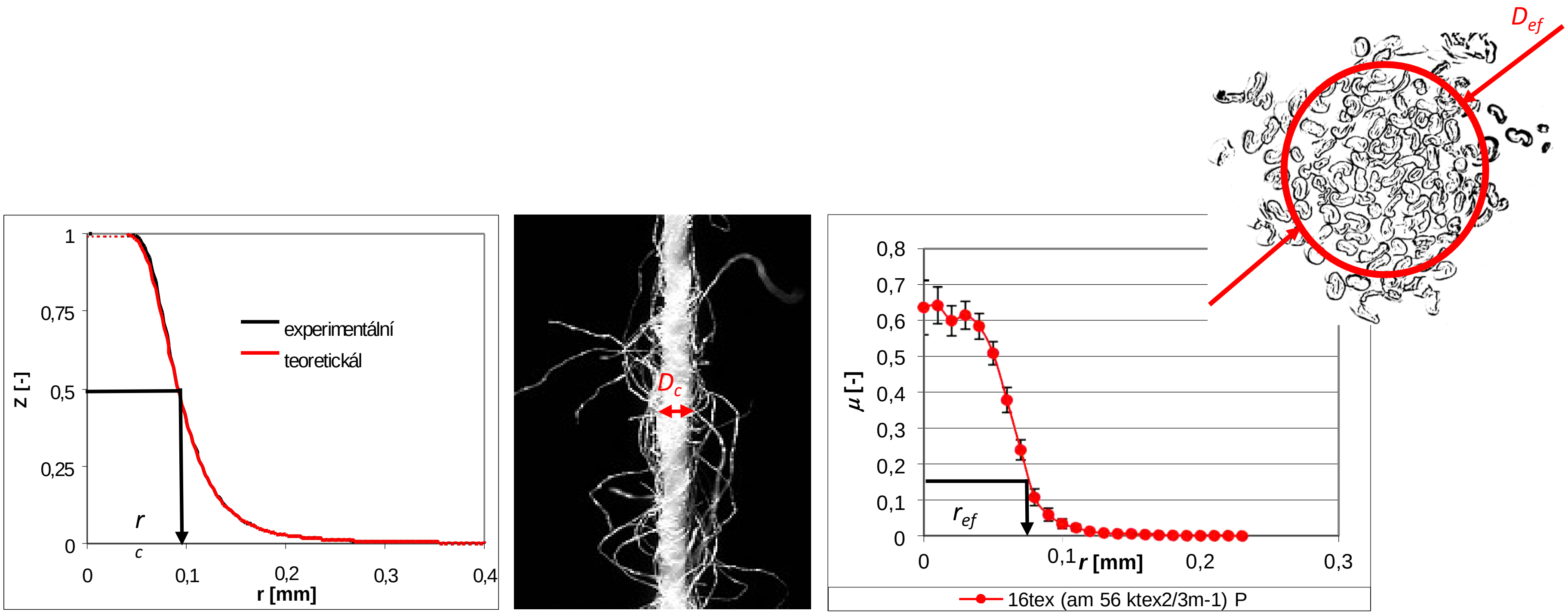


Fig. 2 An example of used convection for finding yarn diameter D by using of Internal standards

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IS 12-108-01/01 Definitions. Geometrical properties of staple yarns. Textile Research Centre, FT TUL 2002.
IS 22-102-01/01 Yarn diameter and hairiness. Textile Research Centre, FT TUL 2004.
IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.
IS 22-103-03/01 Yarn packing density Iso- quantities. Textile Research Centre, FT TUL 2009.

Selected methods of their determination *T*, *D*, *Z*

Iso-quantities - lines connecting the points (places) with the same amount of the given phenomenon. Output is then information about the distribution of the number of fibers in the „average“ section (cut) through the yarn.

- ✓ The principle of the test is processing (cross) section (cut) images through a simple, doubletwist (double- ply), one-component free, woven and knitted yarn in the system of image analysis and subsequent evaluation of the gained data by the program in the MatLab environment with the aim of acquiring information on the density of fiber distribution in the observed formation through iso-quantities.
- ✓ The loaded cut section is orientated with its longer half axis into the direction of x - axis of the coordinate system, the center of gravity of the cut section is always in [0,0]. The coordinates of the center of gravity of the cut section are calculated. The furthest point of the cut section – x_{max} is found out. The difference *delta* = x_T - x_{max} is calculated.
- ✓ All the coordinates are divided by the number of *delta*, then the distance of the center of gravity from the furthest point is exactly 1, i.e., all the others are smaller than 1.

IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.

IS 22-103-03/01 Yarn packing density Iso-quantities. Textile Research Centre, FT TUL 2009.

IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Selected methods of their determination *T*, *D*, *Z*

- ✓ The cut section is placed in the network (grid) of optional „resolution“ - default 16x16. In each field of the network (grid), the number of fibers (fiber centers) is calculated. For each field, the mean number of fibers with regard to the number of processed cut sections is calculated.
- ✓ Distances of the horizontal and vertical lines of the network (grid) are converted to real (actual) distances – they are multiplied by the average delta (it is the average of all the deltas of all the cut sections).

Outputs: Output data of the matrix distribution of the number of fibers in the network in the "average" cut section + real (actual) distances of the horizontal and vertical lines of the grid and the graphical outputs.

IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.
IS 22-103-03/01 Yarn packing density Iso-quantities. Textile Research Centre, FT TUL 2009.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Selected methods of their determination *T*, *D*, *Z*

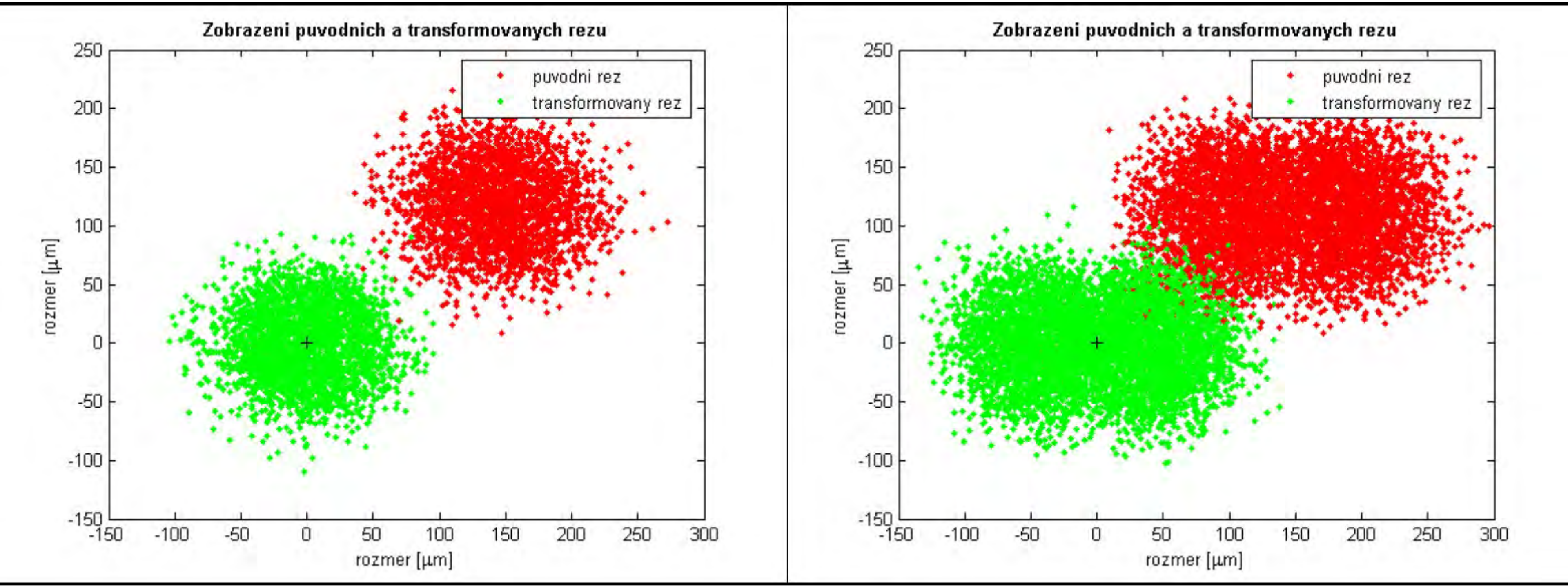


Fig. 3 An example of cut transformation through the single yarn (100 % CO combed yarn 10 tex) and two ply yarn (100 % CO 2 x 10 tex 601 m^{-1})

IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.
IS 22-103-03/01 Yarn packing density Iso-quantities. Textile Research Centre, FT TUL 2009.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Selected methods of their determination *T*, *D*, *Z*

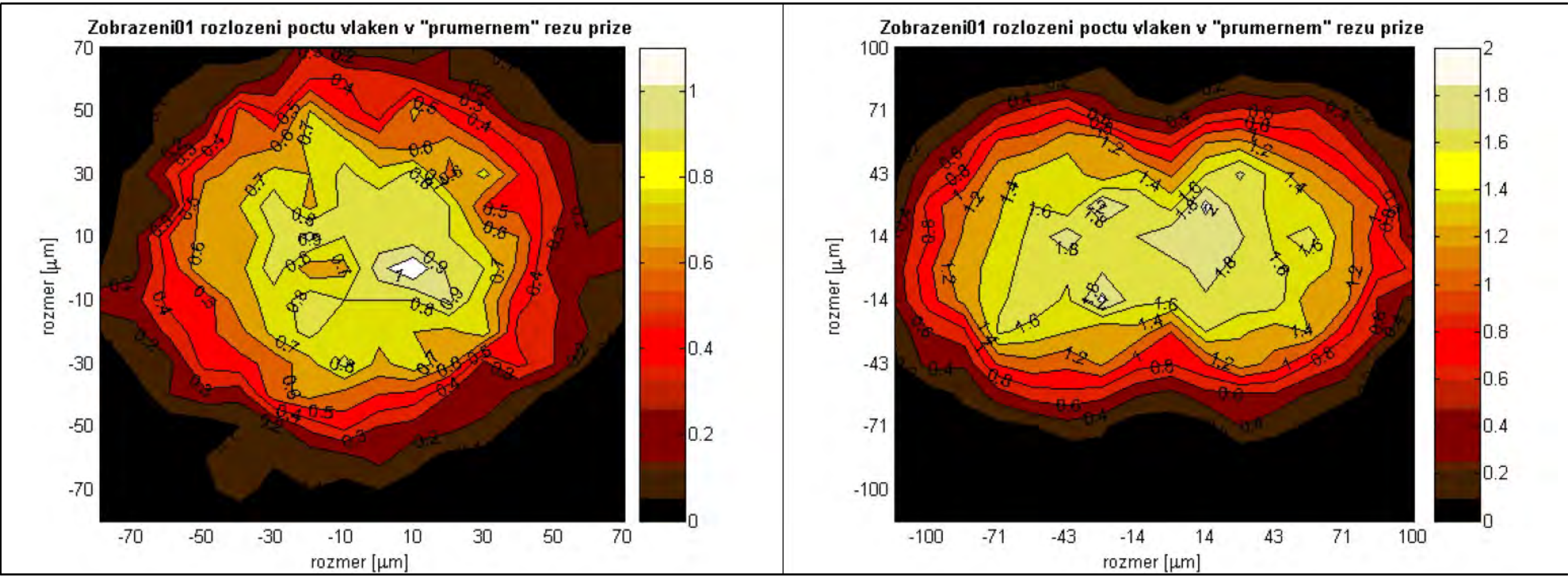


Fig. 4 *An example of contour graph – distribution of the average number of fibers in the „average“ cut section for single yarn* (100 % CO combed yarn 10 tex) and two ply yarn (100 % CO 2 x 10 tex 601 m^{-1})

IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.
IS 22-103-03/01 Yarn packing density Iso-quantities. Textile Research Centre, FT TUL 2009.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Selected methods of their determination T, D, Z

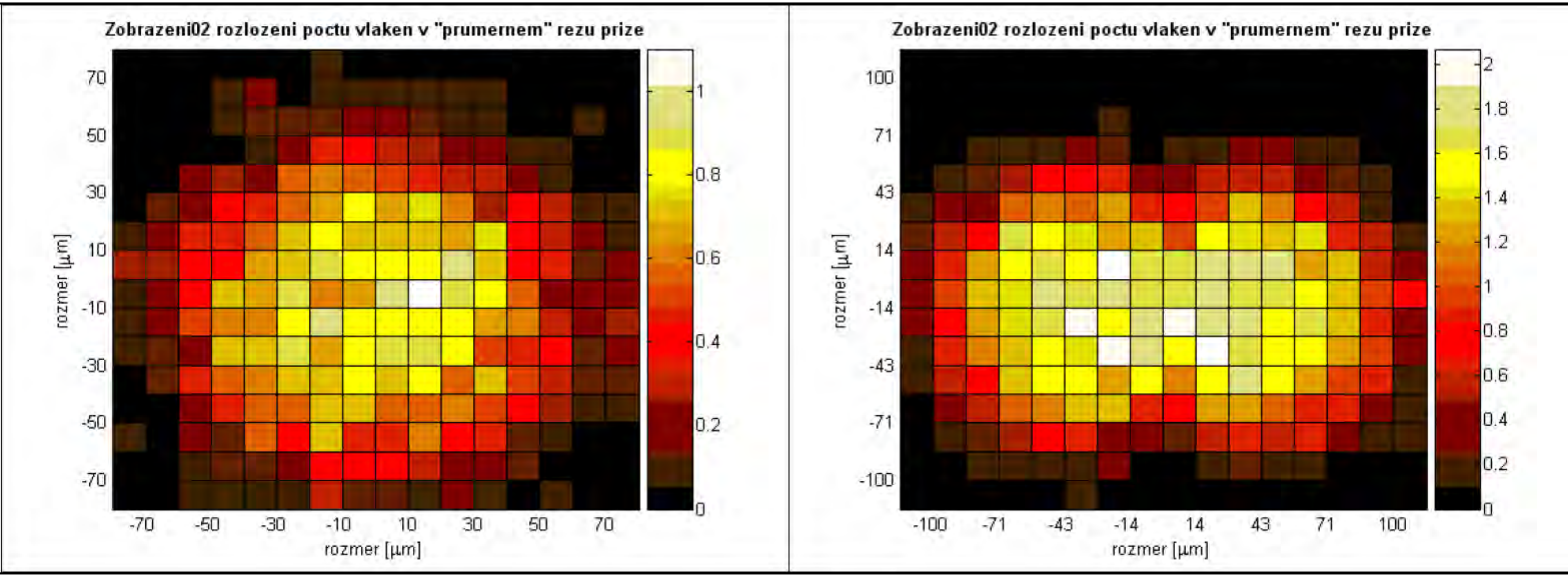


Fig. 5 An example of surf graph – distribution of the average number of fibers in the „average“ cut section for single yarn (100 % CO combed yarn 10 tex) and two ply yarn (100 % CO 2 x 10 tex 601 m^{-1})

IS 22-103-02/01 Yarn packing density Direct method. Textile Research Centre, FT TUL 2009.
IS 22-103-03/01 Yarn packing density Iso-quantities. Textile Research Centre, FT TUL 2009.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Selected methods of their determination *T*, *D*, *Z*

Procedure (Ozkaya):

- ✓ capturing longitudinal views of yarns (suitable way of focusing, exposure and image resolution);
- ✓ processing of longitudinal views (image filtering, transformation into grayscale and binary form by using morphological operations, scanning of two perpendicular views in order to refine the results);
- ✓ evaluation of the obtained data and their presentation including statistical indicators.

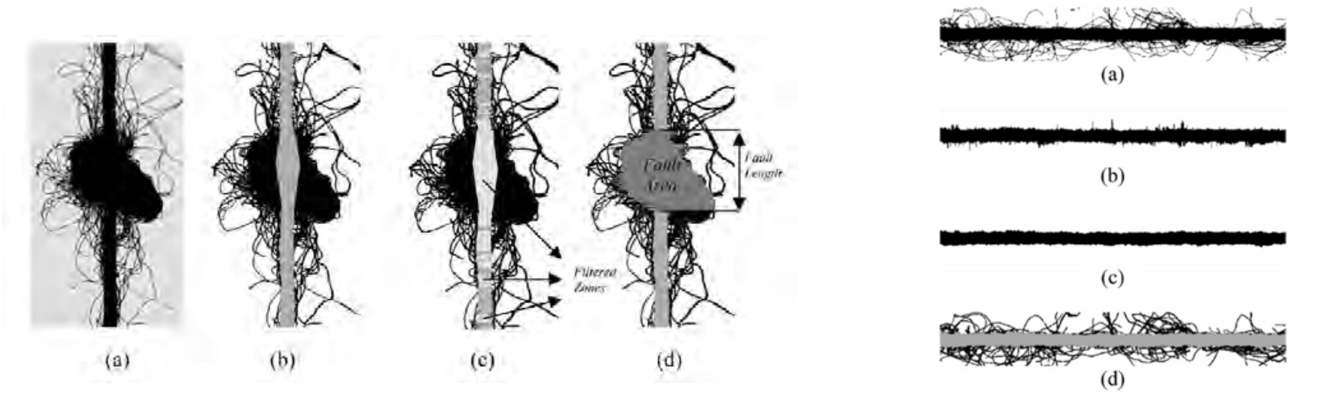


Fig. 6 An example of longitudinal views of yarn and the of image processing (Ozkaya)

Ozkaya Y., Acar M., Jackson M. R. Digital image processing and illumination techniques for yarn characterization. *Journal of Electronic Imaging* 14(2), 2005.

Carvalho V., Soares F., Vasconcelos R., Belsley M., Goncalves N. *Yarn hairienss determination using image procesing techniques*. IEEE EFTA 2011, Toulouse, 2011.

Carvalho V., Belsslay M., Vasconcelos R. M., Soares F. Yarn hariness and diameter characterization using a CMOS line array. *Measurement* 41, 2008.

Yildiz K., Ildiz Z., Demir Ö., Buldu A. Determination of yarn twist using mage processing techniques. *International Conferece on Image Processing, Pruduction and Computer Science 2015*. Istambul Turkey, June 3-4.

Hladnik A., pavko-Cuden A., Farajikhah S. Image segmentation based determination of elastane core yarn diameter. *Fibers and Textile in Eastern Europe* 24, 2(116), 2016.

Selected methods of their determination *T*, *D*, *Z*

Determination of twists Z: by the standard procedure where the twists are counted (two ply yarns) or by the indirect twist method in accordance with an international standard (single yarns). Another possibility is the processing of longitudinal views using image analysis by subjective determination of the angle of surface fibers or automatic detection. A procedure using a median filter and determination of the angle of inclination of surface fibers thanks to the analysis of the immediate surroundings or a methodology using the Hough transformation is also published.

Procedure (Ozkaya):

capturing longitudinal views of yarns (suitable way of focusing, exposure, resolution);

processing of longitudinal views (image filtering, transformation into grayscale and binary shape);

determination of the slope angle based on spatial analysis using filtration thanks to the Sobel filter to detect edges or subsequent frequency analysis using Furier transformation, or a combination of both methods.

ČSN EN ISO 2061 Textiles. Determination of twist in yarns. Direct counting method., ČNI 2/2016.

Czaplicki Z. A new method of measuring twist of yarn. *Fibers and Textile in Eastern Europe* 14, 1(55), 2006.

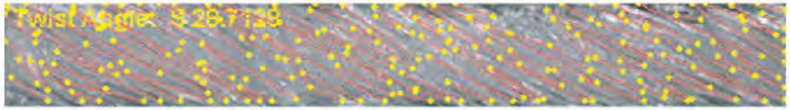
Ozkaya Y. A., Acar M., Jackson M. R., Yarn twist measurement using digital imaging. *The Journal of the Textile Institute*, 101(2), 2010.

Selected methods of their determination *T*, *D*, *Z*

(a) Core image segmented into 64 × 64 portions

(b) Filtered spectrums of each individual portion

(c) After taking the inverse FFT, thresholding and merging the portions



(d) The output of spatial analysis algorithm applied to the image in (c)

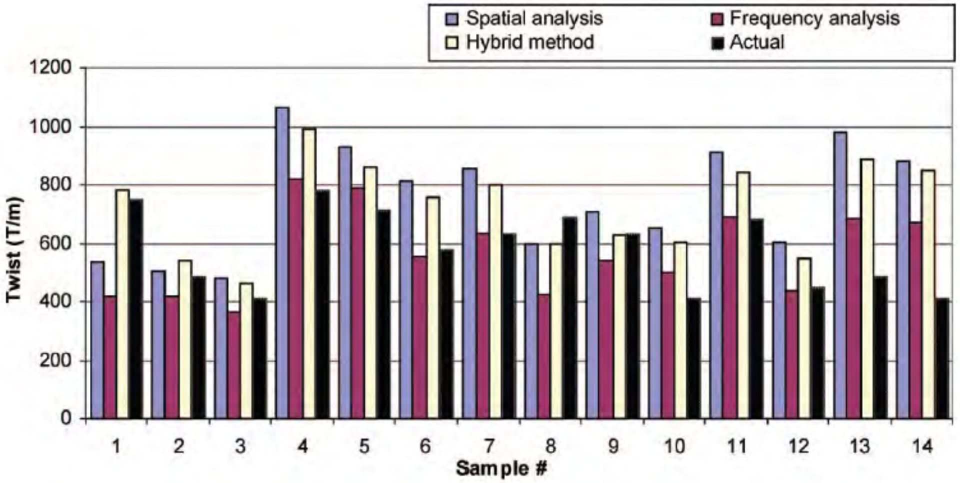


Fig. 7 An example of result – combine method

Cybulska M. Assessing Yarn structure with image analysis methods. *Textile Research Journal* 69(5), 1999.

Ozkaya Y. A., Acar M., Jackson M. R., Yarn twist measurment using digital imaging. *The Journal of the Textile Institute*, 101(2), 2010.

Basu A., Doraiswamy I., Gotipamul R. L. Measurement of yarn diameter and twit by image Analysis, *The Journal of the Textile Institute* 94(1-2), 2003.

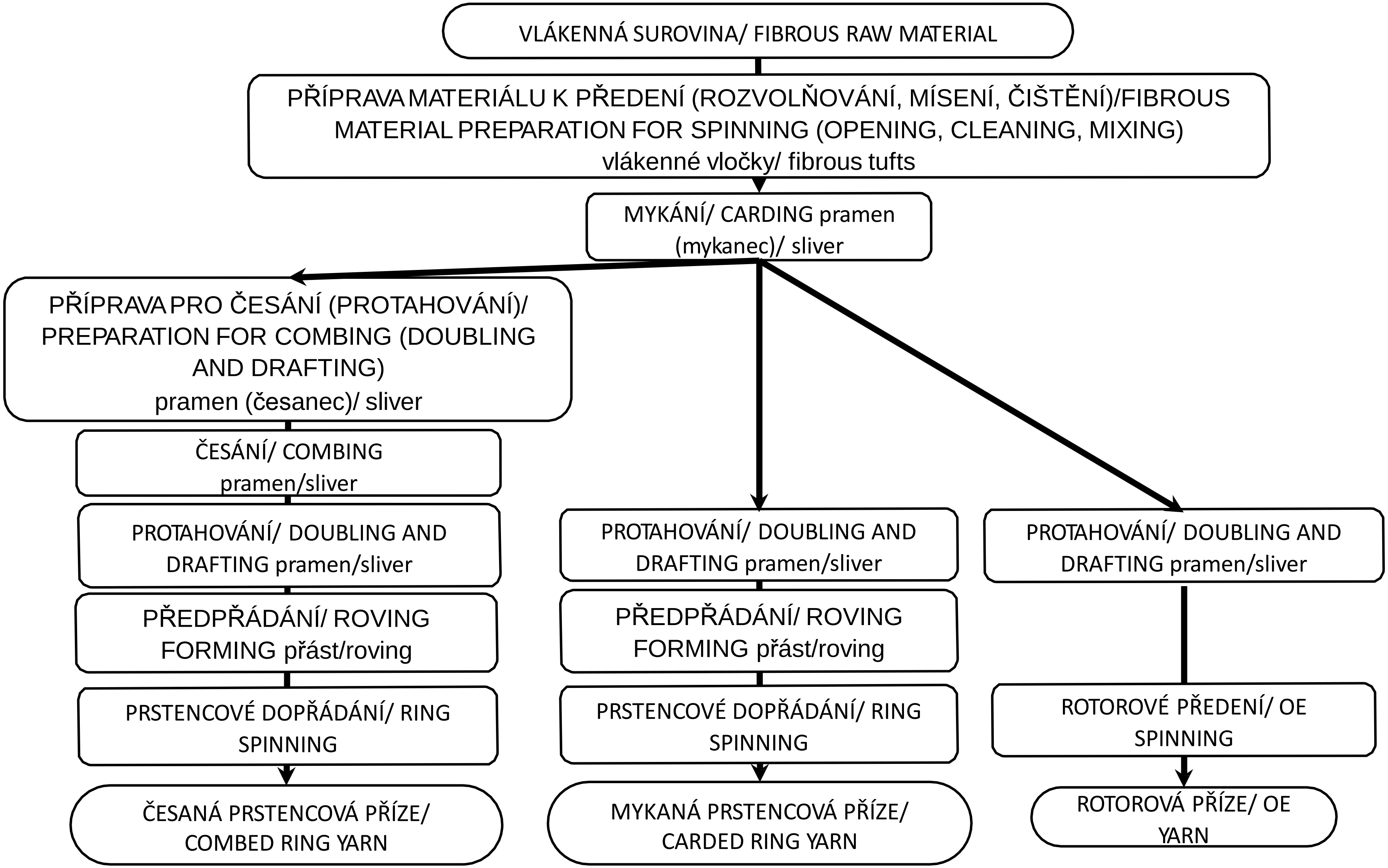
Yildiz K., Ildiz Z., Demir Ö., Buldu A. Determination of yarn twist using mage processing techniques. *International Conferece on Image Processing, Pruduction and Computer Science 2015*. Istambul Turkey, June 3-4.

Carvalho V. H., Belsley M. S., Vasconcelos R. M., Soares F. O. Determination of yarn production characeristics using image processing. Wilay Online Library 20(4), 2010.

Perechesova A. D., Soloveva G. A., Kalapyshina I. I. Hough transrom for the calculation of twist angle of aramid torsion. Conference on Computer Graphics, Visualizatio an Computer Vision, 2015.

Martínek O. Vliv zákrutu na geometrické a mechanicko-fyzikální vlastnosti multifilu. DP FT TUL 2018.

Technology of yarn production - schema



VLÁKENNÁ SUROVINA/ FIBROUS RAW MATERIAL

PŘÍPRAVA MATERIÁLU K PŘEDENÍ (ROZVOLŇOVÁNÍ, MÍSENÍ, ČIŠTĚNÍ)/FIBROUS MATERIAL PREPARATION FOR SPINNING (OPENING, CLEANING, MIXING)
vlákenné vločky/ fibrous tufts

MYKÁNÍ/ CARDING pramen (mykanec)/ sliver

PŘÍPRAVA PRO ČESÁNÍ (PROTAHOVÁNÍ)/ PREPARATION FOR COMBING (DOUBLING AND DRAFTING)
pramen (česanec)/ sliver

ČESÁNÍ/ COMBING pramen/sliver

PROTAHOVÁNÍ/ DOUBLING AND DRAFTING pramen/sliver

PŘEDPŘÁDÁNÍ/ ROVING FORMING přást/roving

PRSTENCOVÉ DOPŘÁDÁNÍ/ RING SPINNING

ČESANÁ PRSTENCOVÁ PŘÍZE/ COMBED RING YARN

PROTAHOVÁNÍ/ DOUBLING AND DRAFTING pramen/sliver

PŘEDPŘÁDÁNÍ/ ROVING FORMING přást/roving

PRSTENCOVÉ DOPŘÁDÁNÍ/ RING SPINNING

MYKANÁ PRSTENCOVÁ PŘÍZE/ CARDED RING YARN

PROTAHOVÁNÍ/ DOUBLING AND DRAFTING pramen/sliver

ROTOROVÉ PŘEDENÍ/ OE SPINNING

ROTOROVÁ PŘÍZE/ OE YARN

Technology of yarn production - videos

P, C, OE technologie Rieter

Ring Spinning Twisting on a cop - Pallava Group

Rieter K45 Compact Spinning Machine-Com4 Comforspin Principle

Operating principles of Rotor spinning systems

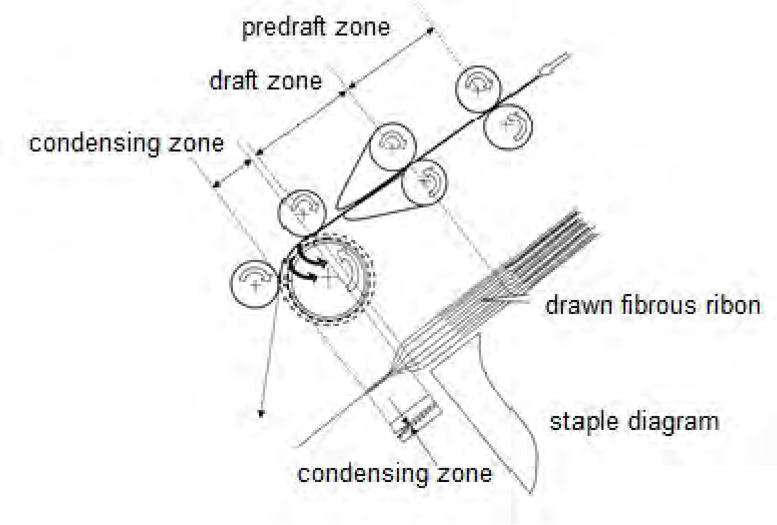
Air jet Murata

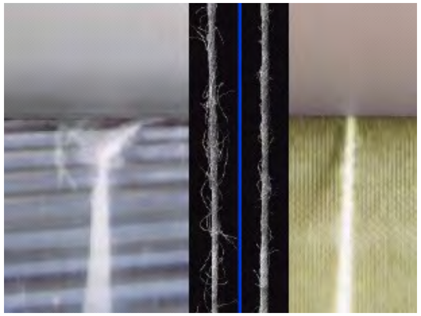
Technology of yarn production – ring spinning

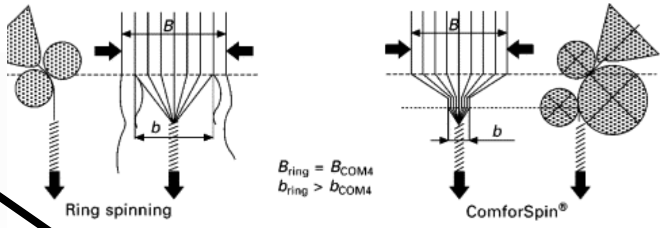
Fig. 8 Principal of ring spinning, detail of spinning machine unit Rieter G32

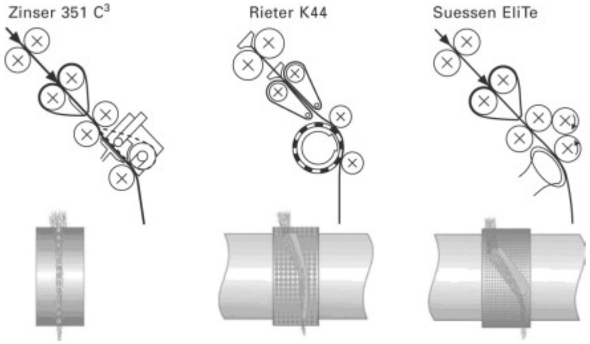
Blažek, Z. Ways of staple fibers spinning by the draw - spindle system in the third millennium. Textiles on the beginning of new millennium. FT TUL and Research Centre Textile, TUL 2002.
Ring Spinning Machine Rieter G32. www.rieter.com
Lawrence C. A. *Advances in yarn spinning technology*. The Textile Institute, 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Technology of yarn production – compact spinning









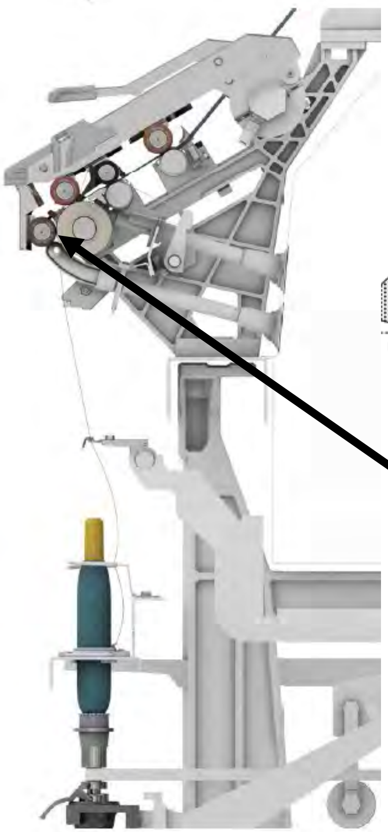


Fig. 9 Principal of compact spinning – various producers. Rieter K46, detail of spinning triangle

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Blažek, Z. Ways of staple fibers spinning by the draw - spindle system in the third millennium. Textiles on the beginning of new millennium. FT TUL and Research Centre Textile, TUL 2002.

Compact Spinning Machine Rieter K46. www.rieter.com

Lawrence, C. A. Advances in yarn spinning technology, The Textile Institute, 2010.

Khan K. R., Hosne A. B., Sheikh R. An overview on the spinning triangle based modification of ting frame to reduce the staple yarn hairiness. *Journal of Textile Science and technology* 6 2020.

Technology of yarn production – compact spinning

- ✓ The twisted input staple semi- product has a form of ribbon fibrous assembly. There are two forms of twisting. One of it is coaxial twisting, which is relevant to the twisting of cylinder (high spinning tension). The second form of twisting is coiling, which is realized off the yarn axis under low spinning tension. The flat fibrous assembly is curl up, the structure of flat ribbon with cavity is formed and then twisted. The cavity gradually collapses and yarn structure is formed.

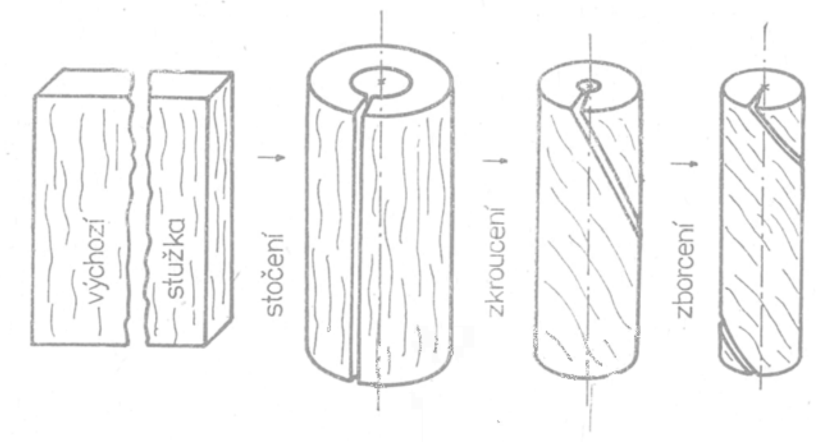

Fig. 10 Stages of ribbon making

initial ribbon →curl up → twisted → collapse of cavity

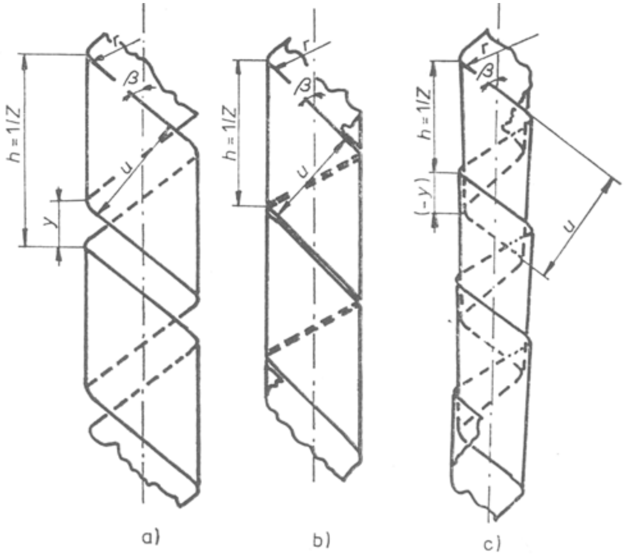

Fig. 11 ribbons form a) tight, b) free, c) overlapped.

Rohlena V. et all. Open end spinning. SNTL 1974 (In Czech language).
Neckář B. Yarn, formation, structure, characteristics. SNTL 1990 (In Czech language).

Technology of yarn production – open end spinning

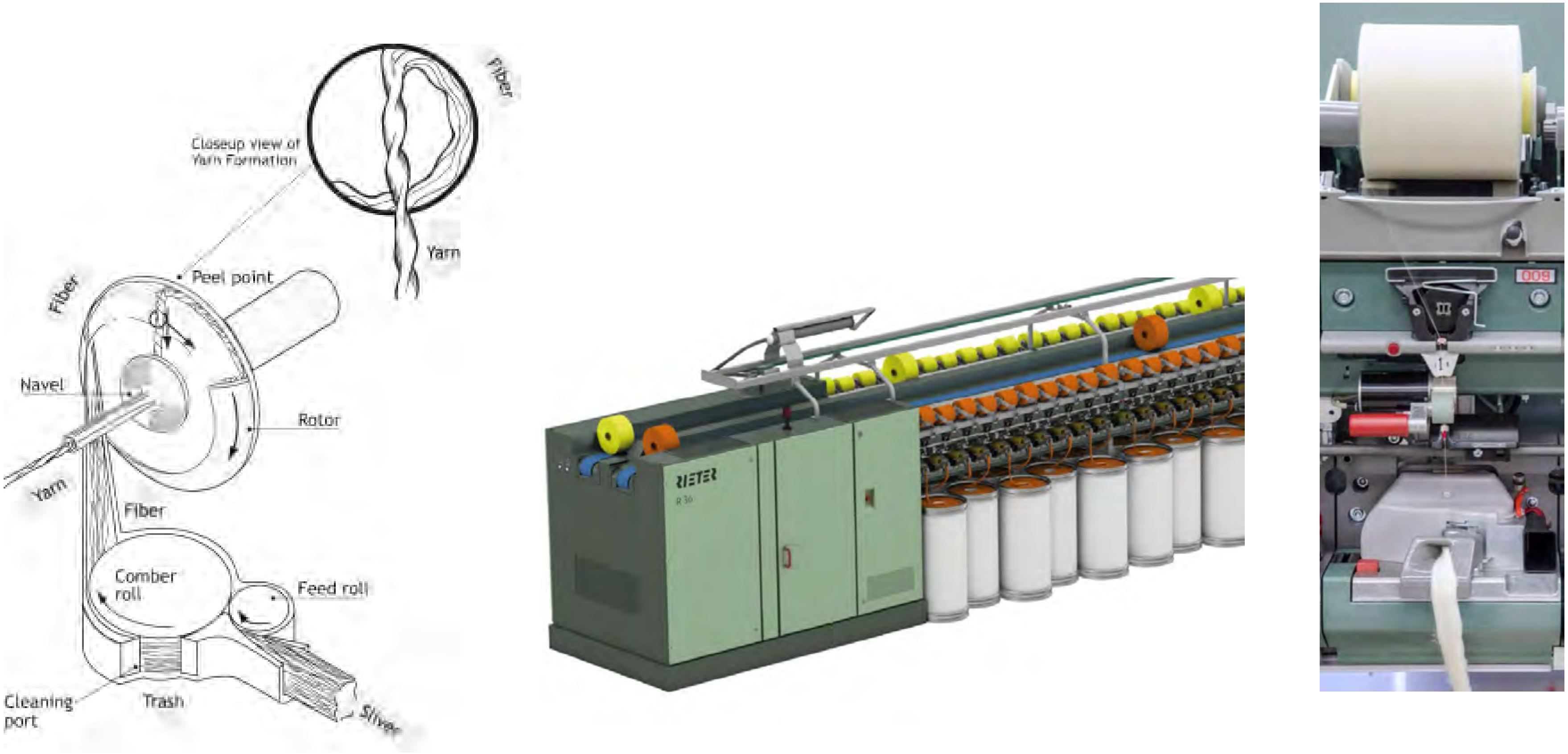

Fig. 13 Principle of open end spinning, detail - Rieter R36 spinning unit

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Rotor Spinning Machine Rieter R36. www.rieter.com
Lawrence, C. A. Advances in yarn spinning technology, The Textile Institute, 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Technology of yarn production – Air jet

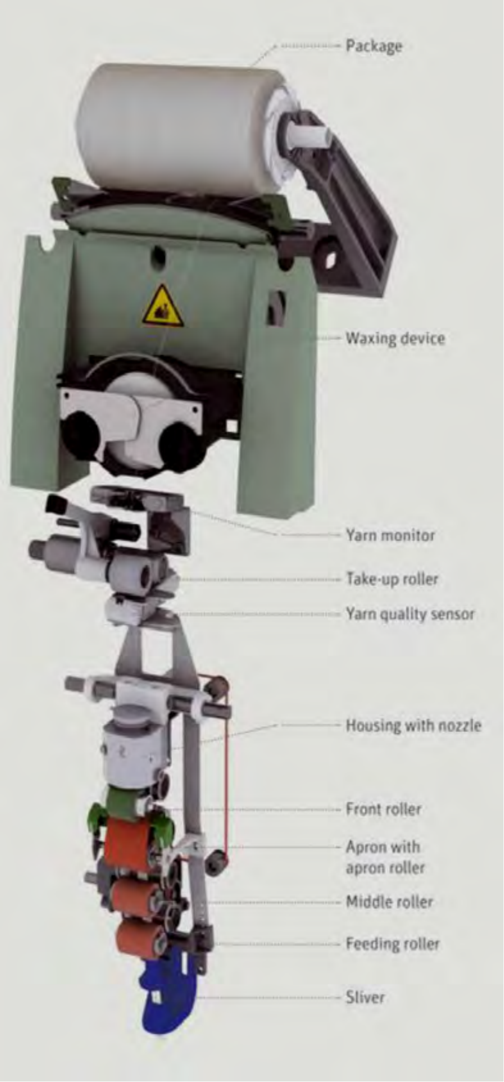


Fig. 14 Principle of Air Jet spinning, J26 Rieter
Note: Air Jet – general name of a technology, Com4 ™, Vortex ™ – trade marks

Rieter Air Jet Spinning Machine J26. www.rieter.com
Lawrence, C. A. *Advances in yarn spinning technology*, The Textile Institute, 2010.

Technology of yarn production – Novaspin and JetRing spinning

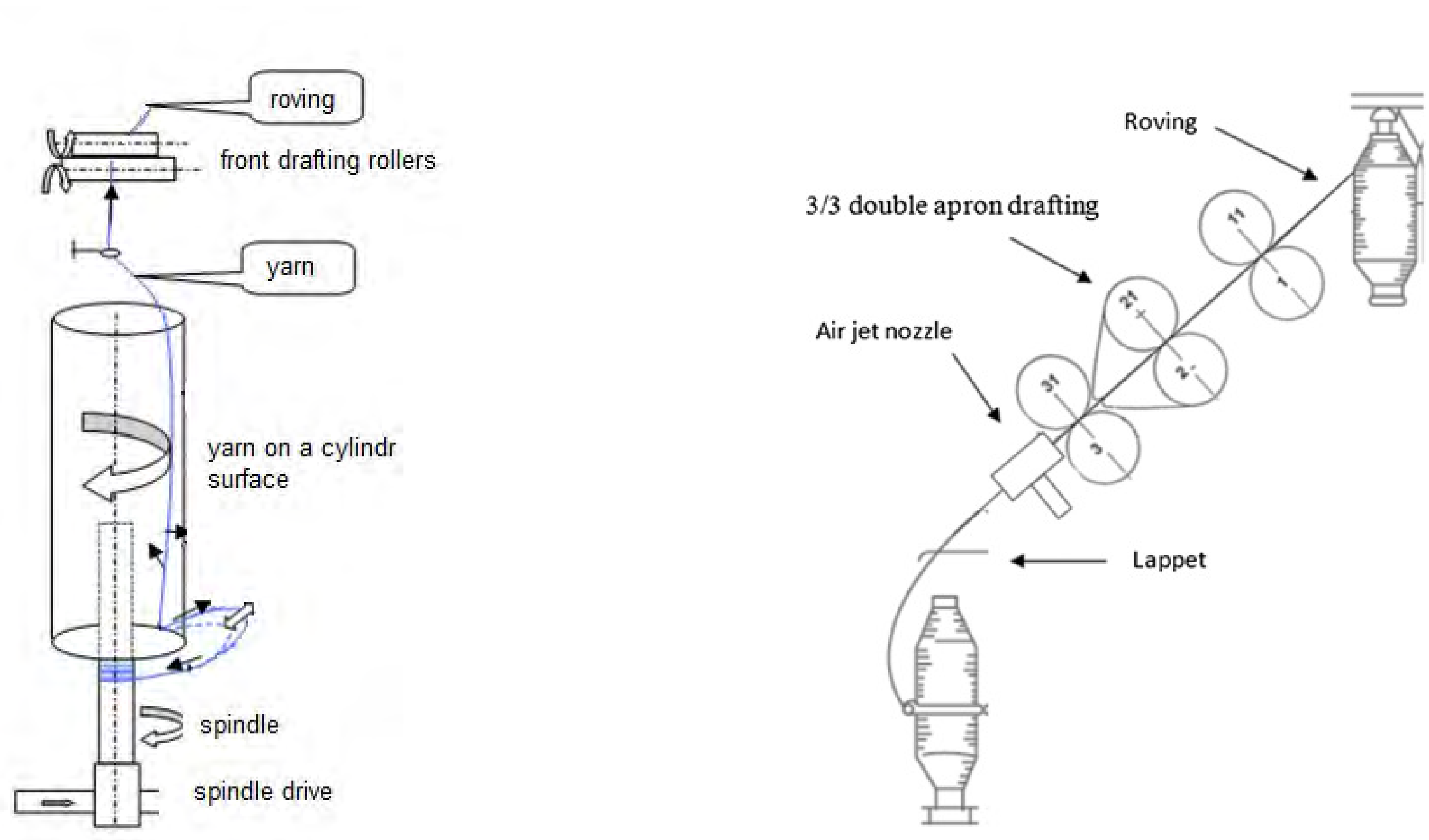


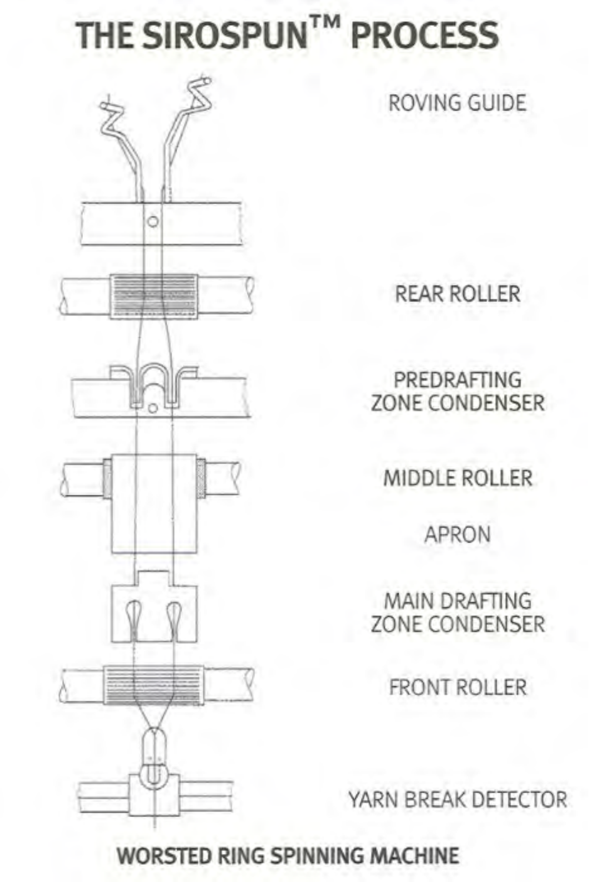
Fig. 15 Principle of Novaspin spinning, principle of JetRing spinning

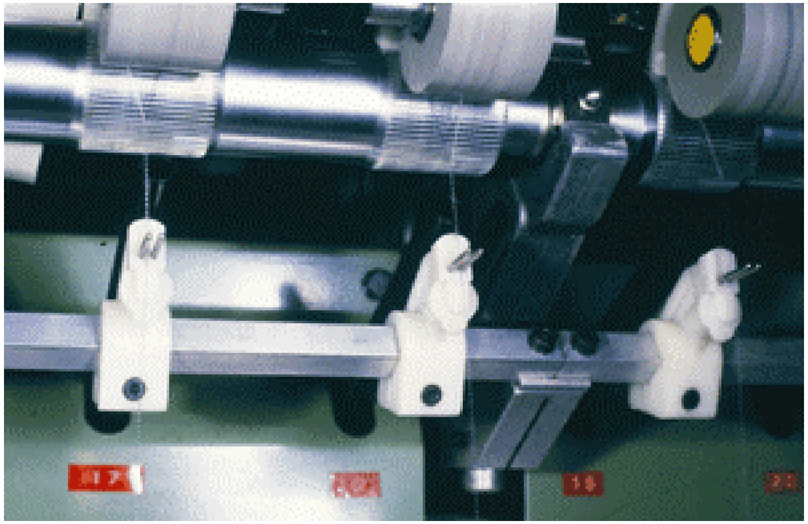
Blažek, Z. Ways of staple fibers spinning by the draw - spindle system in the third millennium. Textiles on the beginning of new millennium. FT TUL and Research Centre Textile, TUL 2002.

Ahmed H. A. Afify R. S., Hassanin A., H., El-Hawary I. A., Mashaly R., I.,Numerical and experimental study of the influence of nozzle flow parameters on yarn production by jet-ring spinning, *Alexandria Engineering Journal*, 57(4),2018.

EP 0 883 703 B1 Spindle spinning or spindle twisting method and operationg unit for carrying out this method.

Technology of yarn production – Twin spun (Sirospun™)





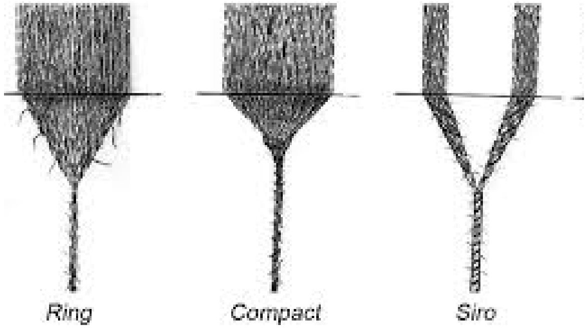
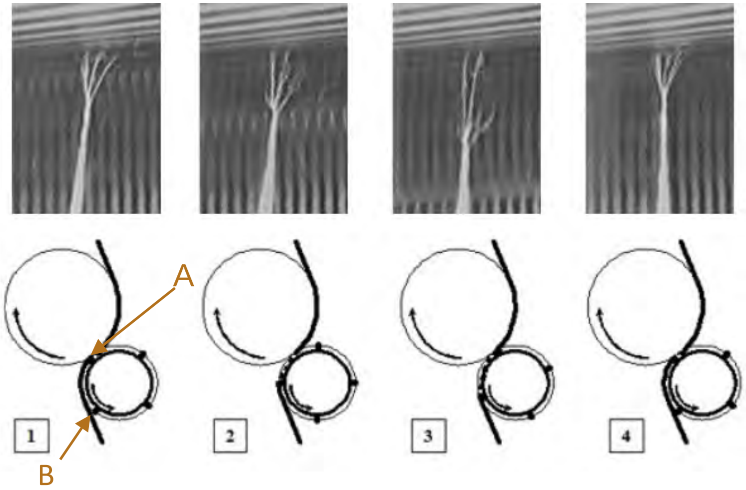


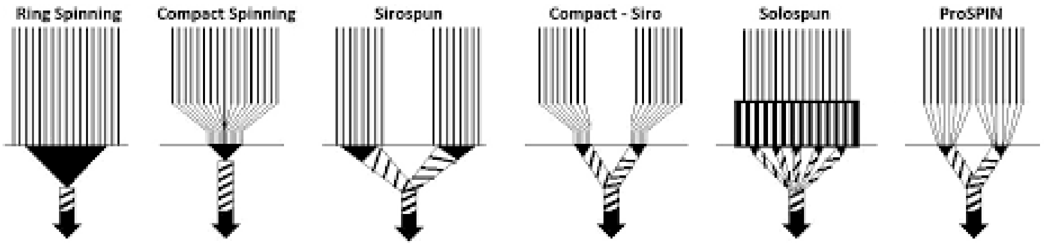
Fig. 16 Principle of Sirospun™ spinning (for long staple materials – worsted wool), detail of spinning triangle

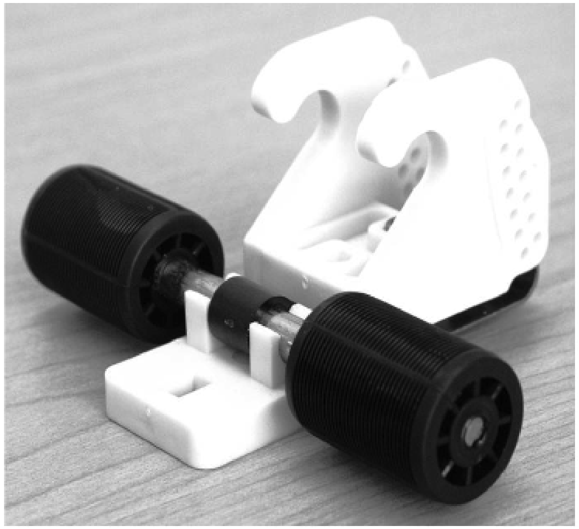
Commonwealth Scientific and Industrial Research Organisation CSIRO materials. www.csiro.au
Lawrence, C. A. Advances in yarn spinning technology, The Textile Institute, 2010.

Technology of yarn production – Solo spun



1) A set of sub-strands form as a Solospun™ roller land passes (A) the bottom draft roller nip point (B).
2 & 3) The sub-strands move down into the slots and lengthen, varying angles between each sub-strand.
4) A new set of sub-strands form as the next Solospun™ roller land passes the bottom roller nip point.





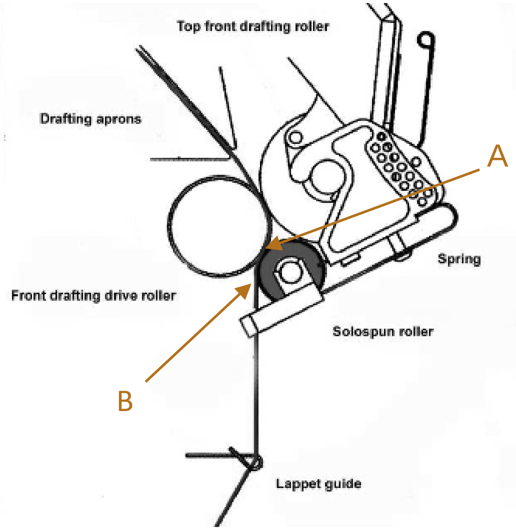


Fig. 17 Principle of Solospun spinning, detail of spinning triangle, Solospun ™ roller

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Commonwealth Scientific and Industrial Research Organisation CSIRO materials. www.csiro.au

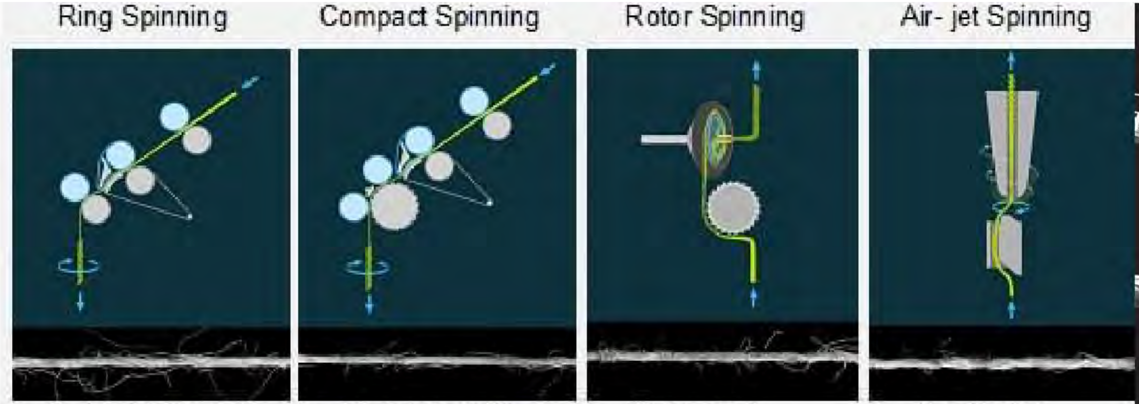
Khan R., K., Begum H. A., Sheik R. An Overview on the Spinning Triangle Based Modifications of Ring Frame to Reduce the Staple Yarn Hairiness. *Journal of Textile Science and Technology*, 6 , 2020.

Khan K. R., Hosne A. B., Sheikh R. An overview on the spinning triangle based modification of ting frame to reduce the staple yarn hairiness. *Journal of Textile Science and technology* 6 2020.

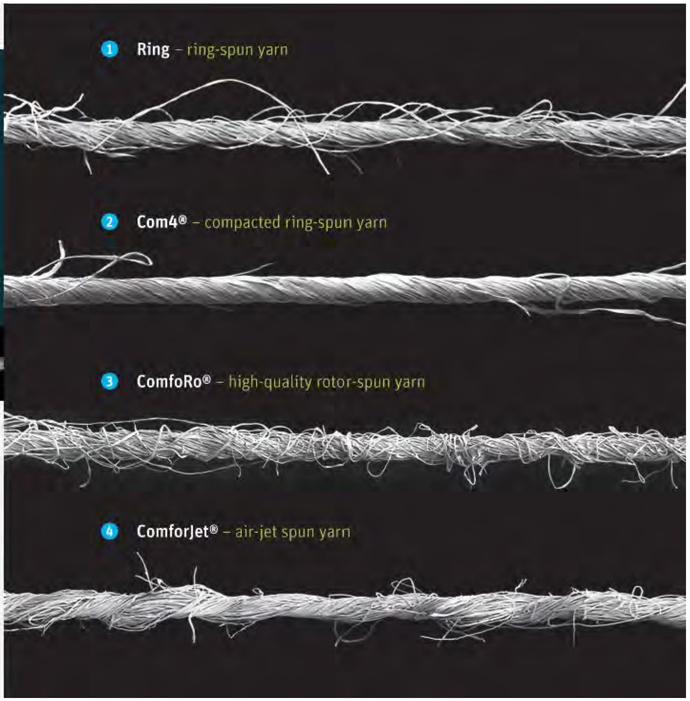
Lawrence, C. A. *Advances in yarn spinning technology*, The Textile Institute, 2010.

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Discussion and conclusions



Ring Spinning	Compact Spinning	Rotor Spinning	Air- jet Spinning
• Most flexible in raw material, count, characteristics • High tenacity • High hairiness	• Highest tenacity • Even yarn structure • Low hairiness • High yarn density	• High optical evenness • Low variation in tenacity • Designable hairiness • High abrasion resistance • High volume	• Unique low hairiness • High volume • Low tendency for staff • High abrasion resistance



Rieter Com4 Yarns. www.rieter.com

Selected qualitative characteristics - Uster ® Statistic

The Uster® Statistics are the global benchmarking tool based on the global collection and testing of fibre, sliver, roving, and yarn samples that have been produced in every part of the world. The statistics were first introduced in 1957 and are periodically updated.

The Uster® Statistics are recognized throughout the global textile industry as an essential tool for comparing key characteristics along the entire yarn production chain, from raw fiber, sliver, roving, and yarn.

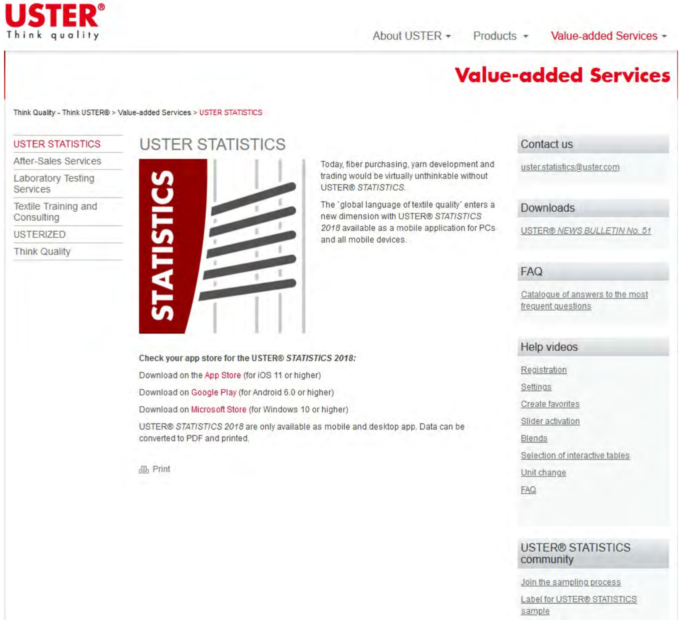
The Uster® Statistics haves three main user groups:

- ✓ Yarn producers – To set internal quality goals, identify performance gaps, communicate quality in an objective manner, and guarantee the quality of the yarn being produced and sold.
- ✓ Yarn users – To provide a basis for determining yarn quality specifications (yarn profiles) in contracts, selecting yarns of appropriate quality, optimize the portfolio of suppliers, pay the right price for the right quality.
- ✓ Machine manufactures – To evaluate new machines developments, linking productivity with quality and guaranteeing specific quality levels. The Uster® Statistics are also used as a basis of quality contracts between machine manufacturers and new spinning mills.

www.uster.com

Selected qualitative characteristics - Uster ® Statistic

- ✓ Comparative tables and interactive quantile-quantile graphs are divided according to the raw material, yarn production technology and use of yarn in a final product. The result of the evaluation of selected qualitative indicators is a percentage that indicates how many world producers produce yarns with a comparable qualitative indicator (e.g. 5 % means that only 5 % of the world's producers produce yarns of a given quality level).
- ✓ Different approaches can be used to determine the overall quality. Usually, a strict approach related to quality assessment is used and the owerall quality is described as a percentage of the "worst" sub-quality indicator. Or the another approach can be used and the final quality can be determined as a predominant percentage of partial quality characteristics.



USTER STATISTICS

Today, fiber purchasing, yarn development and trading would be virtually unthinkable without USTER® *STATISTICS*.

The `global language of textile quality´ enters a new dimension with USTER® *STATISTICS 2018* available as a mobile application for PCs and all mobile devices.

Check your app store for the USTER® *STATISTICS 2018:*

Download on the App Store (for iOS 11 or higher)

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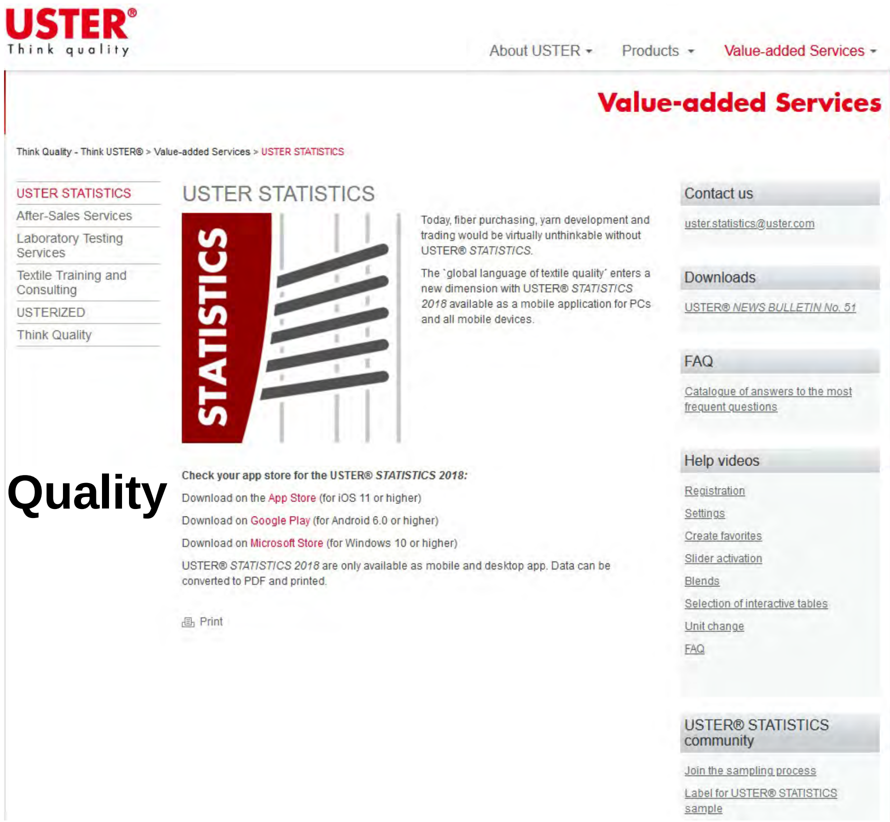
Selected qualitative characteristics - Uster ® Statistic

5 elements of ‘Think Quality’

- ✓ clear specification,
- ✓ reliable quality measuring,
- ✓ fast production control,
- ✓ application understanding,
- ✓ business sustainability.

The benefits of adopting the Think Quality concept

- ✓ consistent, repeatable quality,
- ✓ improved quality know-how,
- ✓ higher profit margins,
- ✓ sustainable management.



Value-added Services

Think Quality - Think USTER® > Value-added Services > USTER STATISTICS

USTER STATISTICS

Today, fiber purchasing, yarn development and trading would be virtually unthinkable without USTER® *STATISTICS*.

The `global language of textile quality´ enters a new dimension with USTER® *STATISTICS 2018* available as a mobile application for PCs and all mobile devices.

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Download on Google Play (for Android 6.0 or higher)

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FAQ

Catalogue of answers to the most frequent questions

Help videos

Registration

Settings

Create favorites

Slider activation

Blends

Selection of interactive tables

Unit change

FAQ

USTER® STATISTICS community

Join the sampling process

Label for USTER® STATISTICS sample

Selected qualitative characteristics - Uster ® Statistic

Uster ® AFIS PRO 2 (cotton fibres):

- ✓ Length characteristics of fibres, fibre fineness and maturity, trash and dust particles, neps, foreign particles.

Uster ® HVI 1000 (cotton fibres):

- ✓ Length characteristics of fibres, fibre fineness and maturity, moisture content, strength and elongation, trash and dust particles, reflectance and colour, *SCI* index.

Uster ® TESTER 6C (multifilament):

- ✓Uniformity in terms of number of intermingling (interlaces) per meter.

Uster ® TENSORAPID 5C (multifilament)

- ✓ Multifilament elongation and tenacity, modulus, fatigue testing, cyclic loading, intermingling (interlaces).

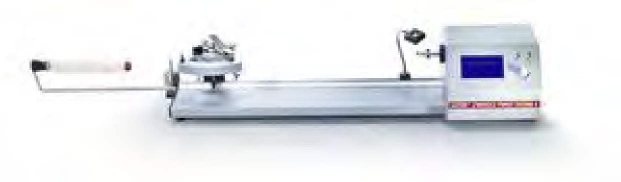
Selected qualitative characteristics - Uster ® Statistic

Uster ® TESTER 6, AUTOSORTER 6 (yarn, multifilament)

- ✓ Yarn count.

Uster ® ZWEIGLE TWIST TESTER 6 (yarn, multifilament)

- ✓ Yarn twist.



Uster ® TESTER 6 (yarn):

- ✓ Yarn unevenness and faults (thin and thick places, neps) trash and dust, yarn diameter and hairiness index, summation criteria of yarn hairiness, (can be used also for conductive yarn).

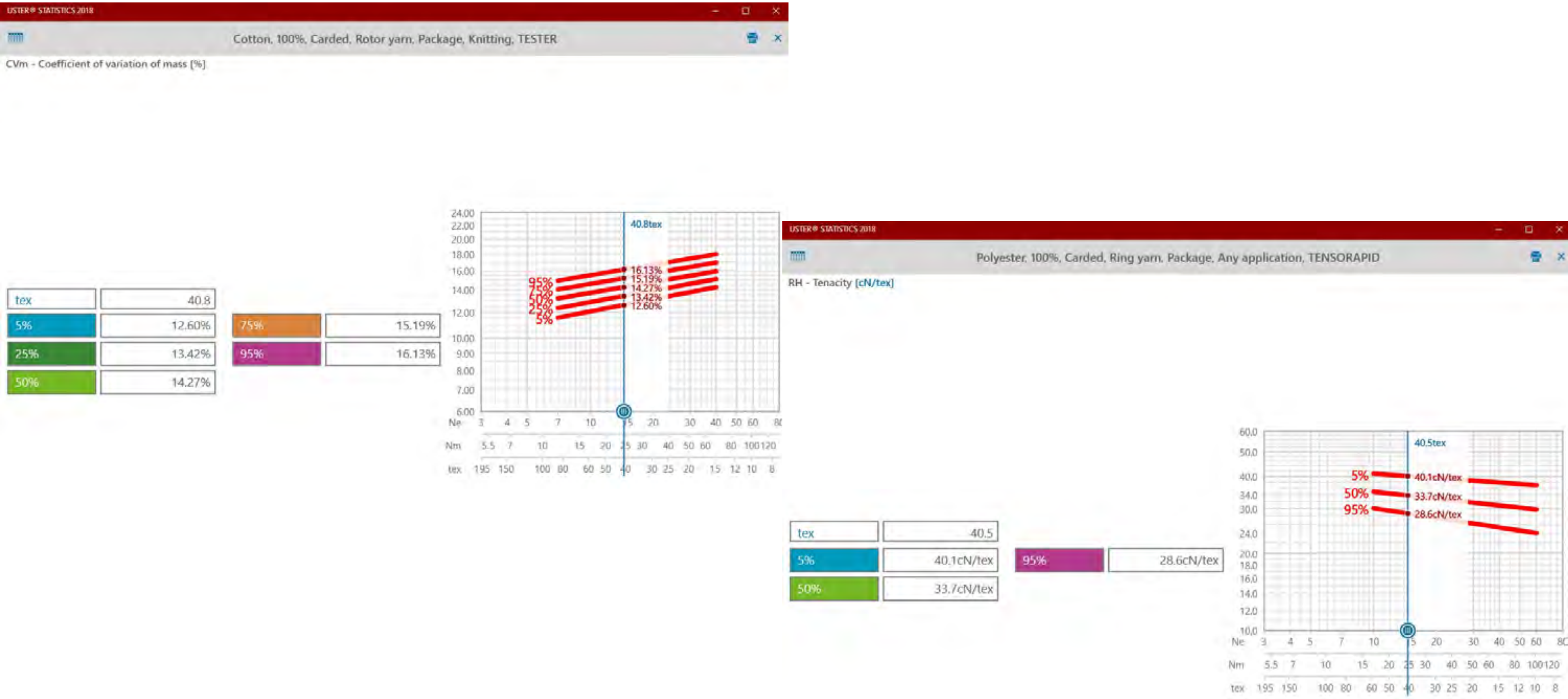
Uster ® CLASSIMAT (yarn):

- ✓ Outliers for periodic faults, evenness, imperfections and hairiness are pinpointed, as well as the standard analysis of thick and thin places which is already essential in yarn trading.

Uster ® TENSORAPID 5 A TENSOJET 5 (yarn)

- ✓ Elongation and tenacity.

Selected qualitative characteristics - Uster ® Statistic



USTER® STATISTICS 2018

Cotton, 100%, Carded, Rotor yarn, Package, Knitting, TESTER

CVm - Coefficient of variation of mass [%]

tex	40.8		
5%	12.60%	75%	15.19%
25%	13.42%	95%	16.13%
50%	14.27%		

USTER® STATISTICS 2018

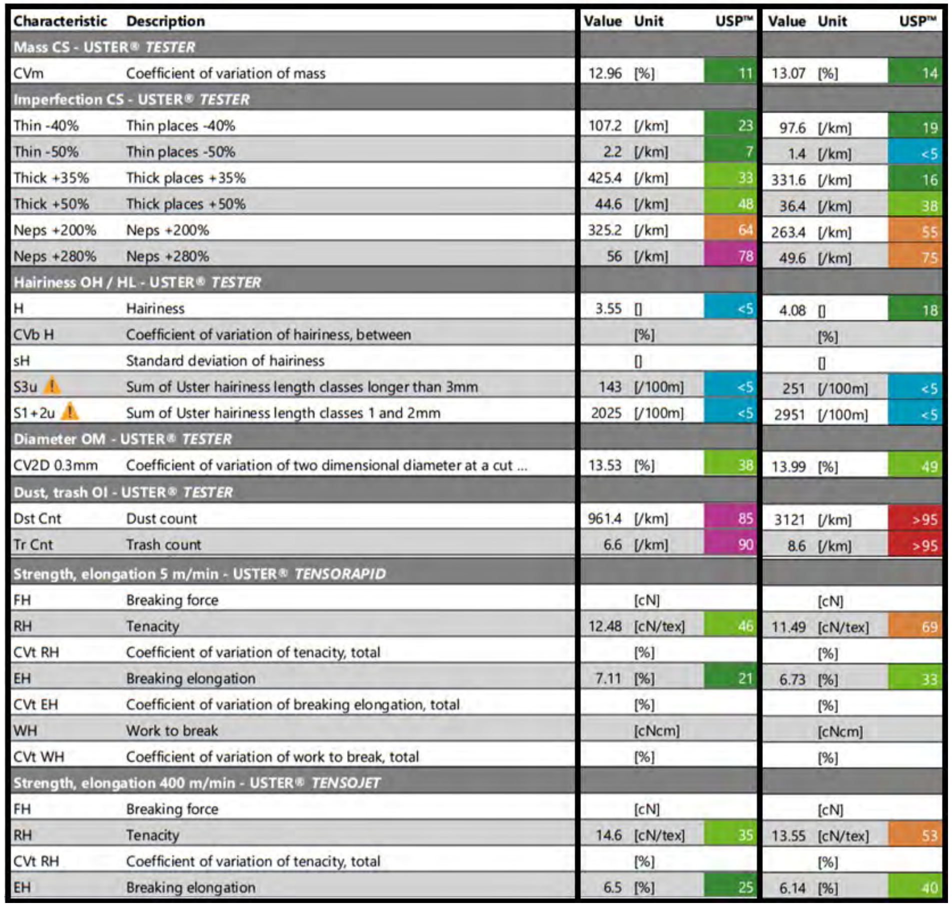
Polyester, 100%, Carded, Ring yarn, Package, Any application, TENSORAPID

RH - Tenacity [cN/tex]

tex	40.5		
5%	40.1cN/tex	95%	28.6cN/tex
50%	33.7cN/tex		

Fig. 18 Uster ® Statistic an example for staple yarn

Selected qualitative characteristics - Uster ® Statistic

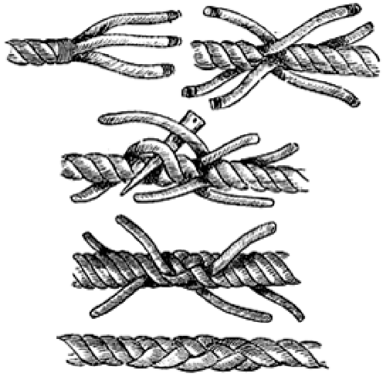


Characteristic	Description	Value	Unit	USP™	Value	Unit	USP™
Mass CS - USTER® *TESTER*							
CVm	Coefficient of variation of mass	12.96	[%]	11	13.07	[%]	14
Imperfection CS - USTER® *TESTER*							
Thin -40%	Thin places -40%	107.2	[/km]	23	97.6	[/km]	19
Thin -50%	Thin places -50%	2.2	[/km]	7	1.4	[/km]	<5
Thick +35%	Thick places +35%	425.4	[/km]	33	331.6	[/km]	16
Thick +50%	Thick places +50%	44.6	[/km]	48	36.4	[/km]	38
Neps +200%	Neps +200%	325.2	[/km]	64	263.4	[/km]	55
Neps +280%	Neps +280%	56	[/km]	78	49.6	[/km]	75
Hairiness OH / HL - USTER® *TESTER*							
H	Hairiness	3.55	[]	<5	4.08	[]	18
CVb H	Coefficient of variation of hairiness, between		[%]			[%]	
sH	Standard deviation of hairiness		[]			[]	
S3u ⚠	Sum of Uster hairiness length classes longer than 3mm	143	[/100m]	<5	251	[/100m]	<5
S1+2u ⚠	Sum of Uster hairiness length classes 1 and 2mm	2025	[/100m]	<5	2951	[/100m]	<5
Diameter OM - USTER® *TESTER*							
CV2D 0.3mm	Coefficient of variation of two dimensional diameter at a cut ...	13.53	[%]	38	13.99	[%]	49
Dust, trash OI - USTER® *TESTER*							
Dst Cnt	Dust count	961.4	[/km]	85	3121	[/km]	>95
Tr Cnt	Trash count	6.6	[/km]	90	8.6	[/km]	>95
Strength, elongation 5 m/min - USTER® *TENSORAPID*							
FH	Breaking force		[cN]			[cN]	
RH	Tenacity	12.48	[cN/tex]	46	11.49	[cN/tex]	69
CVt RH	Coefficient of variation of tenacity, total		[%]			[%]	
EH	Breaking elongation	7.11	[%]	21	6.73	[%]	33
CVt EH	Coefficient of variation of breaking elongation, total		[%]			[%]	
WH	Work to break		[cNcm]			[cNcm]	
CVt WH	Coefficient of variation of work to break, total		[%]			[%]	
Strength, elongation 400 m/min - USTER® *TENSOJET*							
FH	Breaking force		[cN]			[cN]	
RH	Tenacity	14.6	[cN/tex]	35	13.55	[cN/tex]	53
CVt RH	Coefficient of variation of tenacity, total		[%]			[%]	
EH	Breaking elongation	6.5	[%]	25	6.14	[%]	40

Fig. 19 Uster ® Statistic an example for staple yarn 100% CO 29,5 tex OE (cotton waste)

≤5%	6-25%	26-50%	51-75%	76-95%	>95%

Splicing of staple yarn



Splicing, piecing, knotting:

- ✓ It is joining two yarn ends during winding;
- ✓ Start of spinning , breaks during production, rewinding, preparation for weaving;
- ✓ The basic methods of knotless splicing are pneumatic, mechanical, water, electrostatic, heat joining. The type of knotless splicing is chosen with respect to the type of fibrous material and technology where knotless splicing is required. Special equipment must be used, for example, for elastic materials or high-strength materials.
- ✓ As standard, pneumatic splicing is used for knotless splicing of yarns made of 100% CO, VS, PES and their mixtures;

Manufacturers of knotless joining devices (examples):

- ✓ Savio, Uster, Mesdan, Schlafhorst Saurer Örlicon, Murata …

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Lord P. R. *Handbook of yarn production: Technology, Science and Economics*. Woodhead Publishing Limited, 2005.

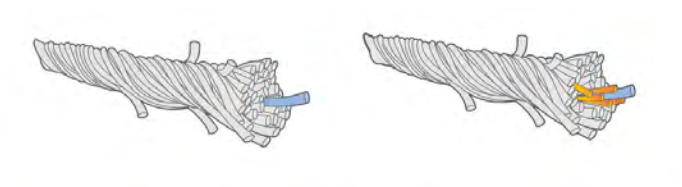
Uyanik S. A research on determining optimum splicing method in terms of fiber type and yarn count. *Tekstil ve Konfeksiyon* 29(1), 2019.

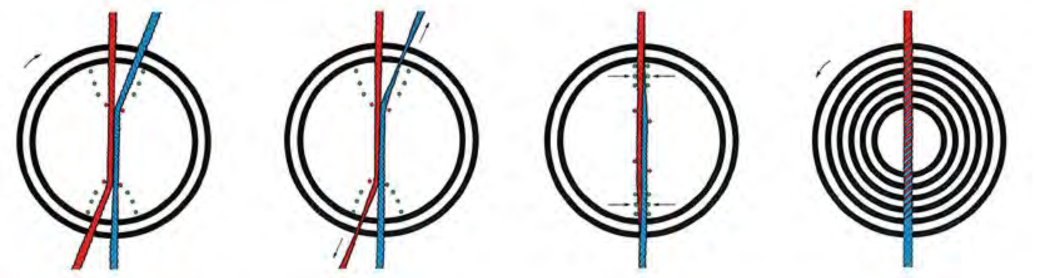
Khaled I., Nagahashi H. Detection and classification of the spliced yarn joint using vector quantization and dynamic time warping. *Journal of the Textile Institute* 99(4), 2008.

Kaushik R. C. D., Hari P. K., Sharma I. C. Mechanism of the splice. *Textile Research Journal 58(5),* 1988.

Kaushik R. C. D., Sharma I. C., Hari P. K. Effect of fiber/ Yarn variables on mechnaical properties of spliced yarn. *Textile Research Journal 57(8),* 1987.

Splicing of staple yarn





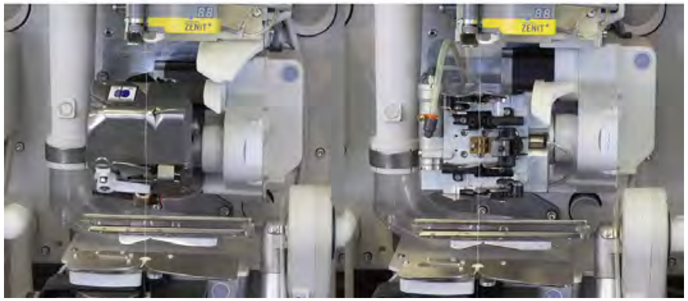
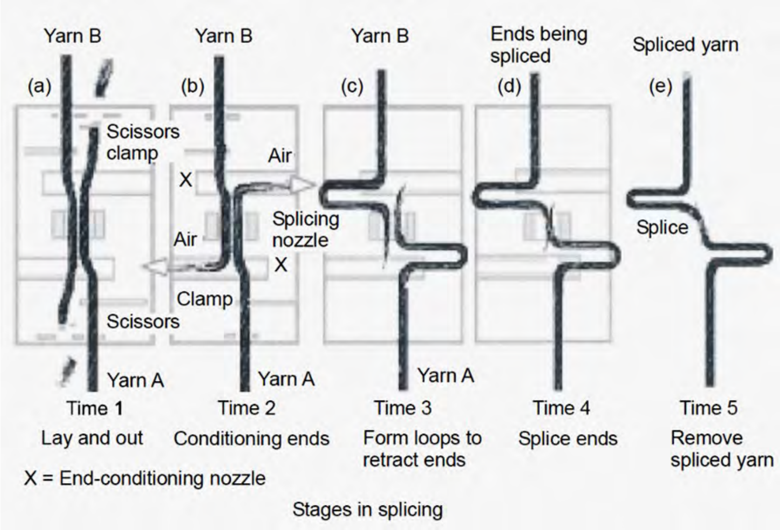
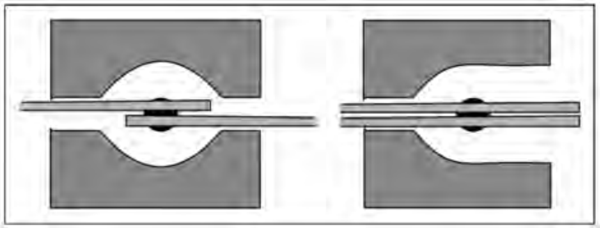


Fig. 20 Phases of mechanical knotless splicing formation - TWINSPLICER®Savio (suitable also for denim yarns)

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Lord P. R. *Handbook of yarn production: Technology, Science and Economics*. Woodhead Publishing Limited, 2005.
Uyanik S. A research on determining optimum splicing method in terms of fiber type and yarn count. *Tekstil ve Konfeksiyon* 29(1), 2019.
Khaled I., Nagahashi H. Detection and classification of the spliced yarn joint using vector quantization and dynamic time warping. *Journal of the Textile Institute* 99(4), 2008.
Kaushik R. C. D., Hari P. K., Sharma I. C. Mechanism of the splice. *Textile Research Journal 58(5),* 1988.
https://www.saviotechnologies.com/en/
https://saurer.com/en/products
www.mesdan.it/en/

Splicing of staple yarn





[Örlicon Saurer Schlafhorst]

[Savio MoistAir 6901]

Fig. 21 Fáze tvorby bezuzlového spoje Air splicer, způsob uložení konců

Splicing operation:

- ✓ Yarn take-in and cutting ends; untwisting; joint appearance during splicing (cutting and entangling of yarn ends, form a loops to rectract ends, twisting both ends together, splicing completing).

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Khaled I., Nagahashi H. Detection and classification of the spliced yarn joint using vector quantization and dynamic time warping. *Journal of the Textile Institute* 99(4), 2008.
Kaushik R. C. D., Hari P. K., Sharma I. C. Mechanism of the splice. *Textile Research Journal 58(5),* 1988.
De Meulemeester S., Malengier B., Van Langenhove L. Experimental investigation and optimization of ends-together pneumatic splice chambers. *Textile Research Journal* 86(17), 2016.
https://www.saviotechnologies.com/en/
https://saurer.com/en/products
www.mesdan.it/en/

Splicing of staple yarn

[Rieter Ring Robo spin (piecing)](#)

[Rieter OE Robo spin (piecing)](#)

[Rieter AirJet 20 (piecing)](#)

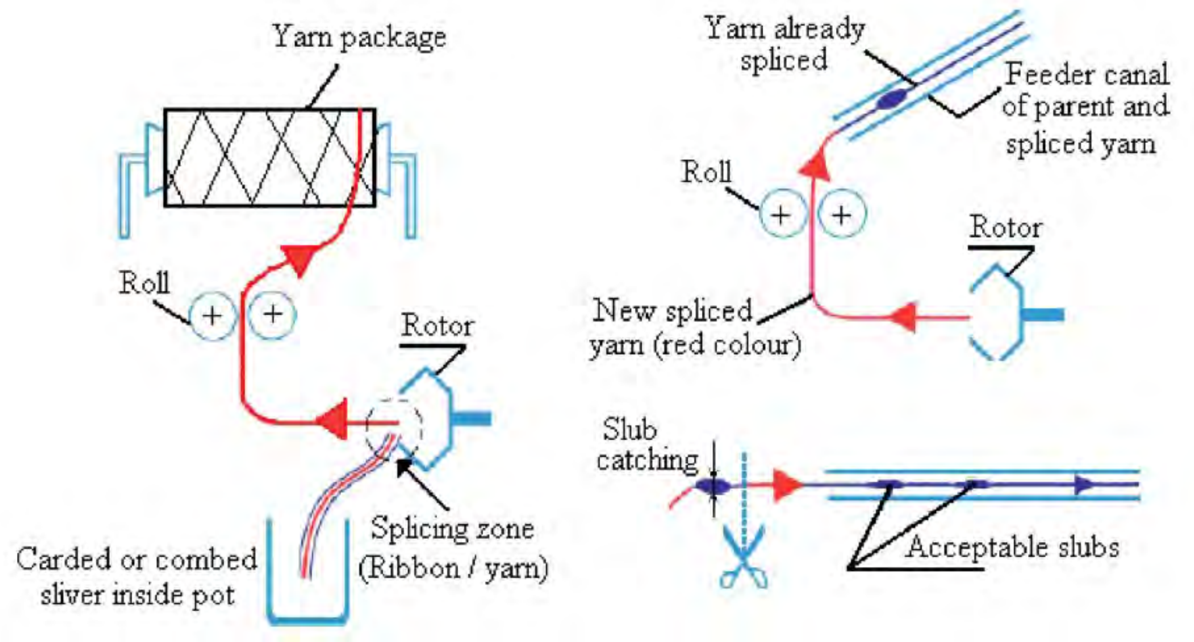


Fig. 22 Schema of OE technology piecing

Piecing operation:

- ✓ Video for ring, open end and AirJet technology.

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Jaouachi B. Evaluation of spliced open end yarn perfomances using fuzzy method. *Journal of Natural Fibers* 9, 2012.
Jaouachi B., Shnoun M. Impact of the splicer parameters on the spliced open end denim spun yarns physico mechanical performances. *Autex Research Journal* 9(3), 2009.
https://www.saviotechnologies.com/en/
www.riter.com

Splicing of staple yarn

Quality assessment of splicing (piecing):

- ✓ Splice diameter, splice length, splice appearance, splice strength and elongation, bending rigidity, abrasion resistance;
- ✓ Eventually the proportion of splice diameter and yarn diameter, proportion of mechanical parameter of slice and yarn, distance of yarn centre part in case of core yarn splicing…

Uyanik S. A research on determining optimum splicing method in terms of fiber type and yarn count. *Tekstil ve Konfeksiyon* 29(1), 2019.

Khaled I., Nagahashi H. Detection and classification of the spliced yarn joint using vector quantization and dynamic time warping. *Journal of the Textile Institute* 99(4), 2008.

Kaushik R. C. D., Hari P. K., Sharma I. C. Mechanism of the splice. *Textile Research Journal 58(5),* 1988.

Jaouachi B. Evaluation of spliced open end yarn perfomances using fuzzy method. *Journal of Natural Fibers* 9, 2012.

Jaouachi B., Shnoun M. Impact of the splicer parameters on the spliced open end denim spun yarns physico mechanical performances. *Autex Research Journal* 9(3), 2009.

Cheng K. P. S., Lam H. L. I. Strength of pneumatic spliced polyester/ cotton ring spun yars. *Textile Research Journal* 70(3), 2000.

Cheng K. P. S., Lam H. L. I. Evaluating and comparig the physical properties of spliced yarns by regression and neural network techiques. *Textile Research Journal* 73(2), 2003.

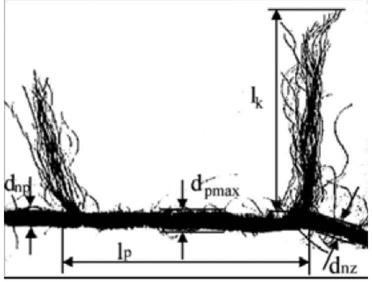
Ünal P. G., Arikan C., Özdil N., Taskin C. The Effect of Fiber Properties on the Characteristics of Spliced Yarns Part I: Prediction of Spliced Yarns Tensile Properties. *Textile Research Journal* 80(5), 2010.

Ünal P. G., Arikan C., Özdil N., Taskin C. The effect of fiber properties on the charactristics of spliced yarn. Part II: Prediction of retained splicer diameter. *Textile Research Journal* 80(17), 2010.

Drobina R., Wlochowicz A, Machnio M. S. Mulssti criterion assessment of pneumatically spliced cotton combed ring spun yarns. *Fibers and Textile in Eastern Europe* 16, 5(70), 2008.

Moqeet A., Jabbar A., Hussain T., Ali Z., Ul Haq Z. Influence of splicing parameters on retained splice strength elongation and appearance of spliced cotton/ flax blended yarn. *Indian Journal of Fiber and Textile Research* 38(1), 74-80.

Splicing of staple yarn



Factors influencing splice quality:

- ✓ Type and quality of fibrous material, especially in terms of fiber length (in the case of cotton also short fiber content), fiber fineness and friction, yarn fineness, direction and number of twists, in case of blended or core yarn the blending proportion, type of core and sheet parameters; the yarn production technology setting.
- ✓ Type of knotless splicing technology and its settings (e.g. in the case of automatic pneumatic knotless splicing the air pressure and time used for untwisting and re-twisting, the way in which the ends are take into the connection position - large overlap of the ends leads to undesired defective connections).

Ünal P. G., Arikan C., Özdil N., Taskin C. The Effect of Fiber Properties on the Characteristics of Spliced Yarns Part I: Prediction of Spliced Yarns Tensile Properties. *Textile Research Journal* 80(5), 2010.

Ünal P. G., Arikan C., Özdil N., Taskin C. The effect of fiber properties on the charactristics of spliced yarn. Part II: Prediction of retained splicer diameter. *Textile Research Journal* 80(17), 2010.

Das A., Ishtiaque S.M., Parida, J.R. Effect of fiber friction, yarn twist, and splicing air pressure on yarn splicing performance. *Fibers and Polymers* 6, 2005.

Das A., Ishtiaque S.M. & Nagaraju V. Study on splicing performance of different types of staple yarns. *Fibers and Polymers* 5, 2004.

Ben Hassen M., B. Jaouachi, Sahnoun M., Sakli F. Mechanical properties and appearance of wet-spliced cotton/elastane yarns, *The Journal of The Textile Institute 99(2)*, 2008.

De Meulemeester S., Malengier B., Van Langenhove L. Experimental investigation and optimization of ends-together pneumatic splice chambers. *Textile Research Journal* 86(17), 2016.

Splicing of staple yarn

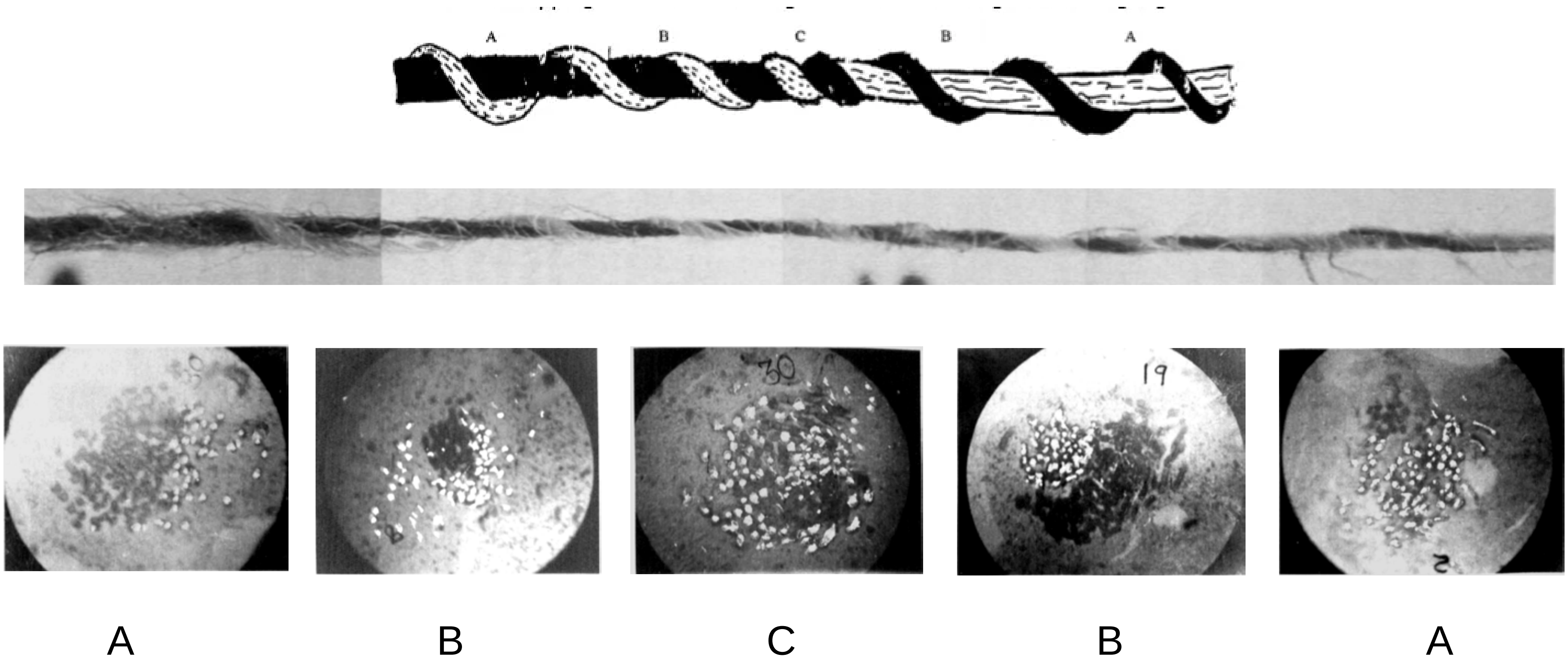


Fig. 23 Structure of splice

A wraping, B twisting, C tucking/ intermingling

Khaled I., Nagahashi H. Detection and classification of the spliced yarn joint using vector quantization and dynamic time warping. *Journal of the Textile Institute* 99(4), 2008.

Kaushik R. C. D., Hari P. K., Sharma I. C. Mechanism of the splice. *Textile Research Journal 58(5),* 1988.

Drobina R., Wlochowicz A, Machnio M. S. Multi criterion assessment of pneumatically spliced cotton combed ring spun yarns. *Fibers and Textile in Eastern Europe* 16, 5(70), 2008.

Splicing of staple yarn

A piecing can be intuitively defined as a certain section of rotor yarn with a greater accumulation of fibers with regard to the yarn section without a piecing. It can be assumed that the perpendicular distance of the borders of the piecing body is always greater that the perpendicular distance of the borders of the yarn body without a piecing, i.e. yarn diameter.

Geometrical parameters of piecing in a rotor yarn evaluation:

- ✓ The principle of the test is scanning of 5 cm longitudinal views on the single yarn with a piecing by using optical system and NisElements (setting of optical system is necessary - brightness, contrast, intensity, time of scanning, resolution, calibration, …).
- ✓ Image processing is realized in external macro in MatLab (colour images are converted to the grey images and by Otsu methods to Binary images).
- ✓ The largest object in the given image is found out (for the case that there are impurities in the image separately from the body of the piecing).
- ✓ Object orientation (piecing part) is found out with regard to the x-axis. If it is not zero, the object is properly rotated into a parallel position relative to the x-axis.

IS 32-102-02/01Geometrical parameters of a piecing in the rotor yarn. Research Centre Textile, FT TUL, 2009.
Khaled I., Nagahashi H. Detection and classification of the spliced yarn joint using vector quantization and dynamic time warping. *Journal of the Textile Institute* 99(4), 2008.
Drobina R., Wlochowicz A, Machnio M. S. Mulssti criterion assessment of pneumatically spliced cotton combed ring spun Yarns. *Fibers and Textile in Eastern Europe* 16, 5(70), 2008.

Splicing of staple yarn

Geometrical parameters of piecing in a rotor yarn evaluation:

- ✓ Each image is transformed into a vertical position.
- ✓ It is made the opening and subsequent closure (morphological modifications of the binary image which will dispose it of projections – hairiness and it will smooth the surface unevenness) by a structural element in the shape of a disc of a 5 pixels radius (chosen entirely intuitively).
- ✓ It is calculated the yarn width in all lines of the image. The value of widths is compared with the value of yarn diameter. There are determined points where yarn width is less or equal to the yarn diameter (these intersections are shown with green crosses in the graph).
- ✓ After drawing the graph, the user will determine the beginning and end of the piecing according to the position of intersections and as per his or her considering the beginning and end of the piecing by two clicks.

Fig. 24 An example of longitudinal views of yarns with piecing each 5 cm length

IS 32-102-02/01Geometrical parameters of a piecing in the rotor yarn. Research Centre Textile, FT TUL, 2009.

Splicing of staple yarn

With the proper piecing it is worked as follows:

- ✓ Interleaving (smoothing) the polynomial functions through the upper and lower limit of the piecing.
- ✓ Determining the diameter of the smallest cylinder into which the piecing will fit D_z.
- ✓ Determining length L_z and piecing area (the area between two curves) S_z.
- ✓ Determining the proportion of areas (surfaces) P_S.
- ✓ Determining the proportion of diameters P_D.

$$P_{D[-]} = \frac{D_{p[mm]}}{D_{z[mm]}}$$

$$P_{S[-]} = \frac{D_{p[mm]} L_{z[mm]}}{S_{z\left[mm^2\right]}}$$

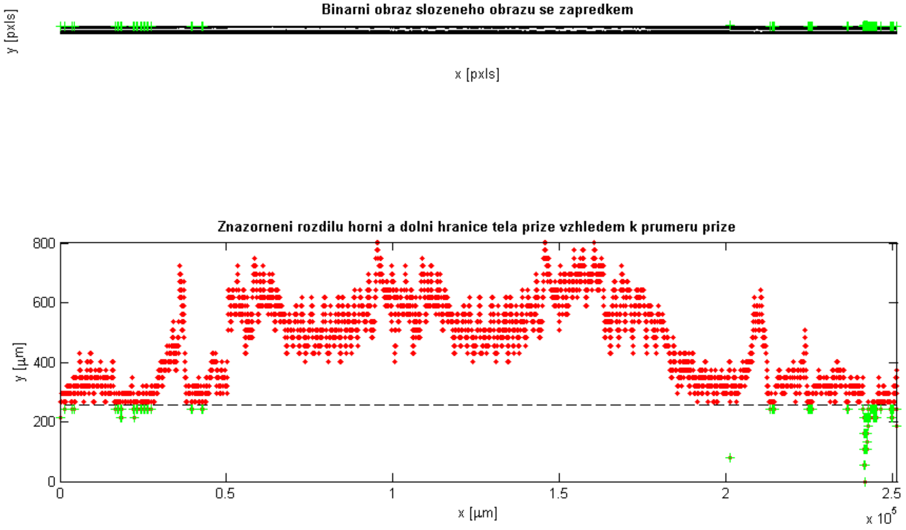
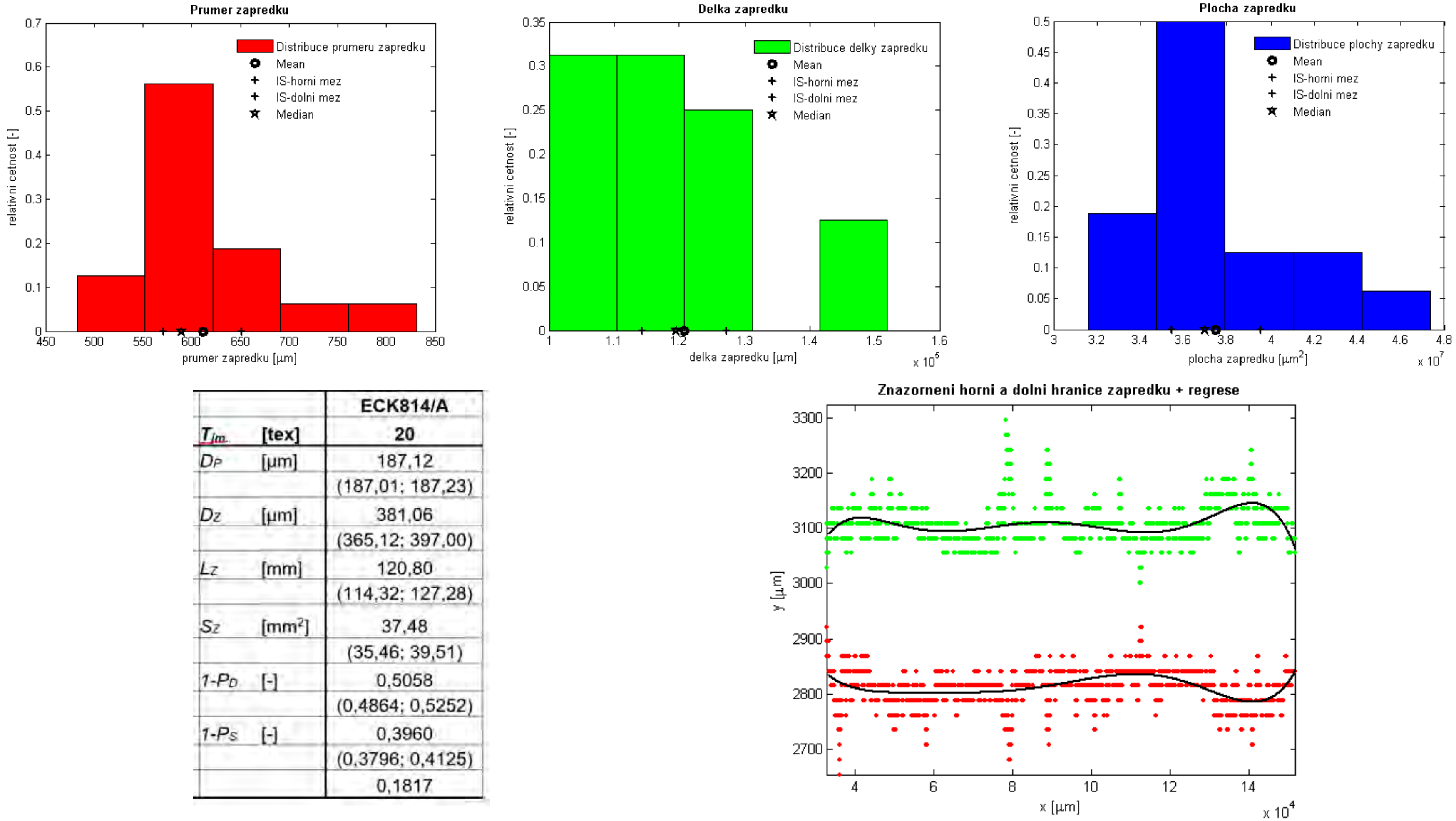


Fig. 25 An example the binary image of the whole piecing and at the same time the yarn width with a piecing and yarn diameter (horizontal dashed black line) with marked intersections – green crosses)

IS 32-102-02/01Geometrical parameters of a piecing in the rotor yarn. Research Centre Textile, FT TUL, 2009.

Splicing of staple yarn

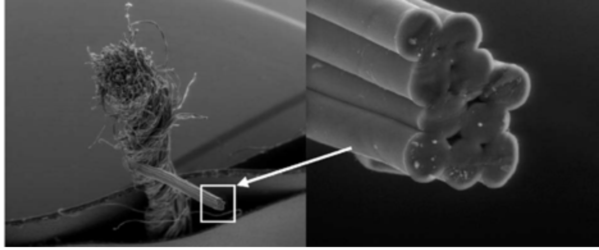


		ECK814/A
T_{jm}	[tex]	**20**
D_P	[μm]	187,12
		(187,01; 187,23)
D_Z	[μm]	381,06
		(365,12; 397,00)
L_Z	[mm]	120,80
		(114,32; 127,28)
S_Z	[mm^2]	37,48
		(35,46; 39,51)
$1\text{-}P_D$	[-]	0,5058
		(0,4864; 0,5252)
$1\text{-}P_S$	[-]	0,3960
		(0,3796; 0,4125)
		0,1817

Fig. 26 An example of results for 100% CO 20 tex OE together with the boundary of splice (image No. 1, 5 cm length of longitudinal view of yarn)

IS 32-102-02/01Geometrical parameters of a piecing in the rotor yarn. Research Centre Textile, FT TUL, 2009.

Splicing of staple yarn



Core yarn splicing – an example:

- ✓ Preparation of core yarn cross sections and its scanning; transformation all images to the binary form.
- ✓ Separation of all objects from the background, finding of centre of gravity of all fibers and also of disc containing 95% of fibers – yarn axis.
- ✓ Evaluation of gravity centre of core yarn $G_{1,2}$ distance from yarn axis.

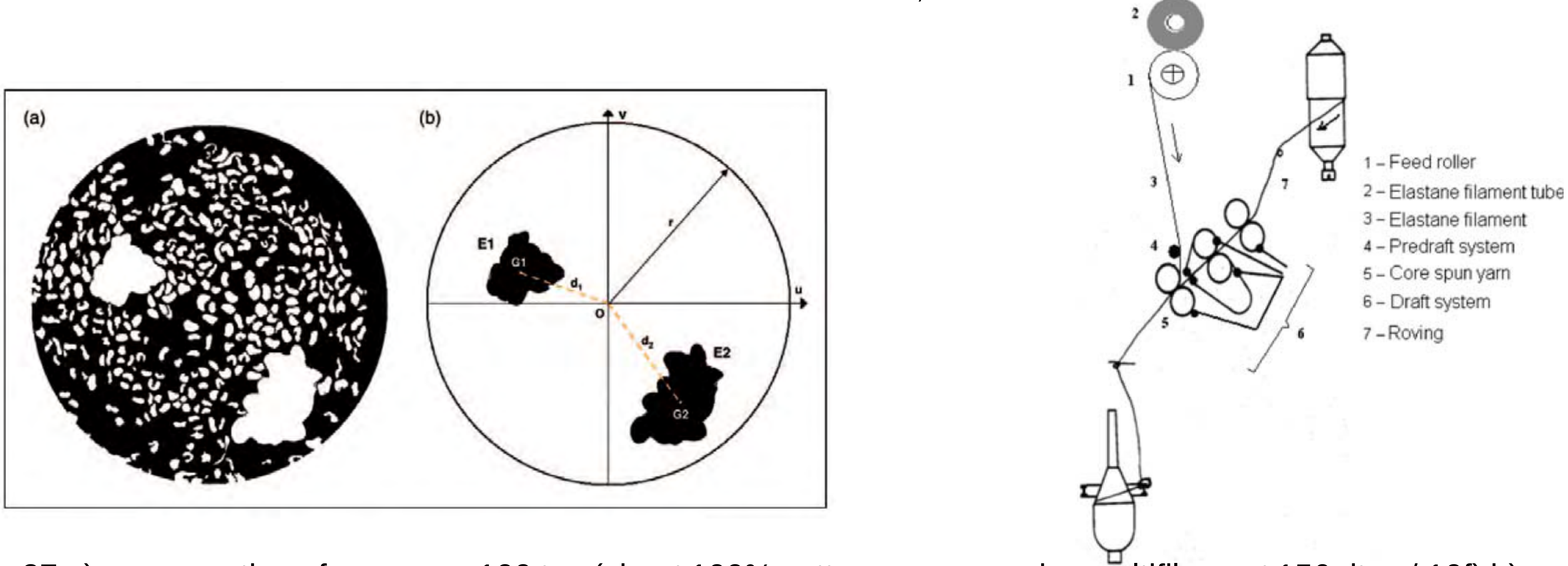


Fig. 27 a) cross section of core yarn 100 tex (sheet 100% cotton, core spandex multifilament 156 dtex / 10f) b) evaluation of gravity centre of core yarn $G_{1,2}$ distance from yarn axis *o* c) schema of core yarn production

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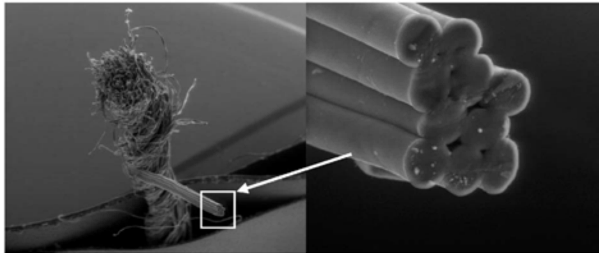
Jaouachi B., Moussa A., Hassen M. B. Image analysis of the elastane position effect on the appearance of wet pneumatic spliced elastic core-spun yarn. *Textile Research Journal* 81(14), 2011.

Splicing of staple yarn



Core yarn splicing – an example:

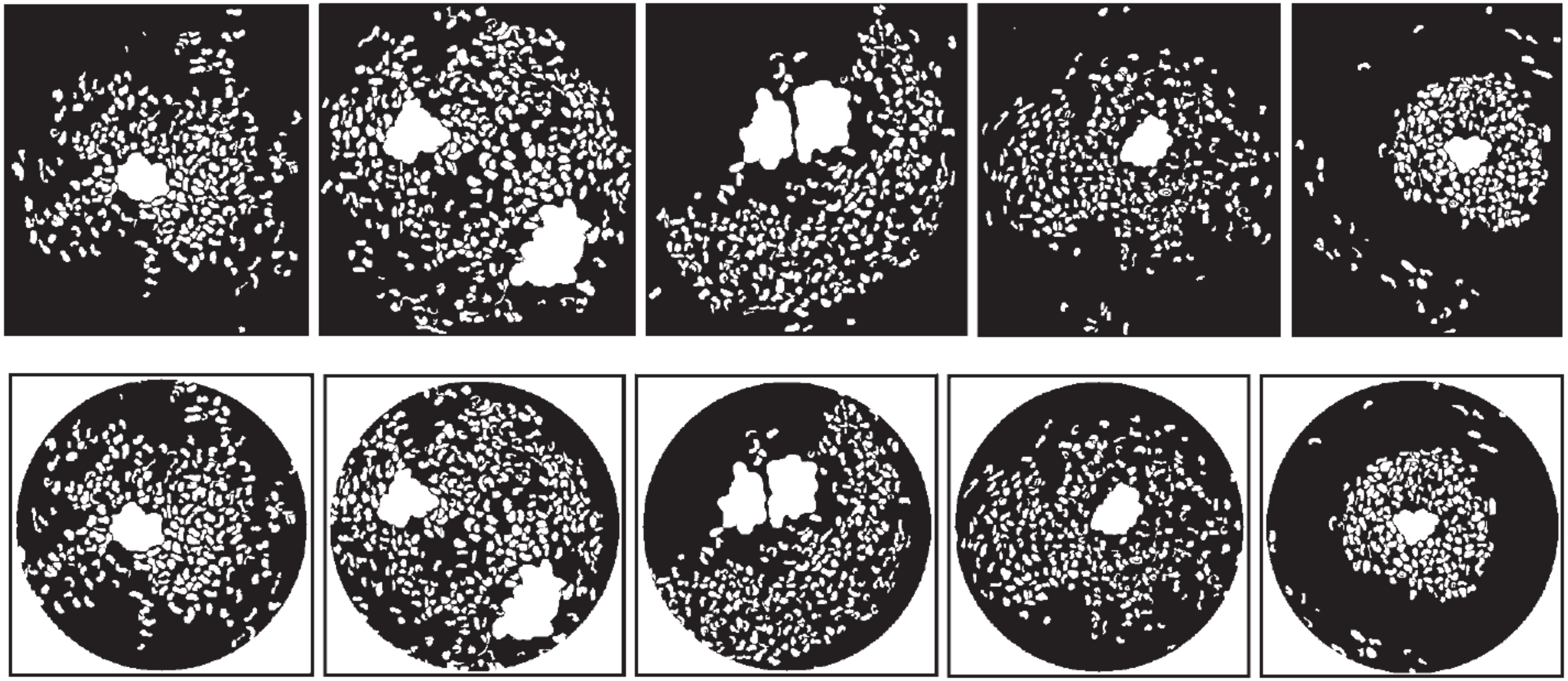


Fig. 28 Cross sections of core yarn along the piecing (sheet 100% cotton, core spandex multifilament 156 dtex / 10f) a) Binary image of initial cross-sections, b) Binary images in disc form containing 95 % of fibers

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Jaouachi B., Moussa A., Hassen M. B. Image analysis of the elastane position effect on the appearance of wet pneumatic spliced elastic core-spun yarn. *Textile Research Journal* 81(14), 2011.

Discussion and conclusion

Based the earlier experience and research it can be concluded:

- ✓ The parameters of the fibre material affect the evaluated properties of the yarns in a certain way. In most cases, it is possible to find a shift in the observed properties of the yarn with the material composition of the yarn. The interaction between the fineness of the fibers (respectively the diameter and density of the fibers), the length of the fibers and the surface friction between the fibers seams to be decisive.
- ✓ In general, yarns spun from the same fiber material, with the same technology, with same yarn count and twist coefficient, also have the same level of yarn packing density, diameter, hairiness and strength. Coarse yarns made off the same material spun by the same technology are spun with a higher twist coefficient but with a lower twist due to a higher number of fibers in yarn cross-section, and therefore the packing density decreases, the diameter and hairiness increases, the relative strength is at the same level or slightly decreases.
- ✓ The influence of fibre material and geometric characteristics of yarn is more significant in the case of conventional ring spun yarns. Rotor yarns have generally a lower level of hairiness than ring yarns and the main reason is the different structure of rotor yarns given by the production technology and the higher degree of twist, which is usually used in their production.

Discussion and conclusion

- ✓ The production process is a complex system, where the functionality of the sub-segments and the overall adjustment play a major role. The technology can be assessed as a whole or the effects of individual parts of the process or used components can be evaluated.
- ✓ Conventional ring yarns are characterized by a well-arranged structure with a good level of yarn unevenness, a certain level of hairiness, a relatively high strength. They can be used for wide range of applications.
- ✓ Compact yarns are usually made of a higher quality raw material. While the same material and technology parameters is used, than they will have a better ordered structure compared to ring yarns, which will take effect in better yarn unevenness, lower hairiness and higher strength. This is most likely due to a more uniform tension in the twist triangle and better control of the fibers in drafting zone.
- ✓ Rotor yarns are characterized by a less ordered internal structure with wraps (belt fibers) on the yarn surface, higher diameter, lower hairiness and strength than ring yarns at the same level of twist. For this reason, rotor yarns are produced with a higher twist, so that their mechanical properties correspond to conventional yarns. The properties of rotor yarns can be varied on demand by the type of used parts and the adjustment of the machine (unevenness, bulkiness, hairiness, strength).

Discussion and conclusion

- ✓ Solospun and Sirospun technologies allow better control of fiber drafting zone and ensure a more even tension of the fibers in the twist triangle. The quality of Solospun yarns is partly comparable to two folded yarns. If they are made from the same type of raw material, then they have slightly worse unevenness, lower hairiness, higher strength and elongation, slightly worse abrasion resistance compared to two folded yarn with significant savings in production costs for fine yarns.
- ✓ Jet Ring technology seeks to make it easier to set twists by using a nozzle. The use of air flow with standard types of yarn production will allow better control of twisting and obtaining of more organized yarn structure and easier processing of lower quality roving.
- ✓ There are a large number of innovations in terms of technology. They are progressively evolving. Some of them is moving from laboratory to pilot or fully industrial use for certain types of yarn for specific purposes (core yarns, wrapped yarns, hybrid yarns, wrapped yarns, yarns with elastic component, …).

An Example - Discussion and conclusion

Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn

Tab 1a Basic specification of cotton fibers HVI

yarn set	fibres	upper half mean length	index of staple uniformity	mean length of fibers	short fiber index	micronaire	strength	elongation	utility value	Korickij criterion
		UHM [mm]	*UI* [%]	*ML* [mm]	*SFI* [%]	*MIC* [-]	*STR* [cNtex^{-1}]	*EL* [%]	*U* [-]	*IG a*
5x3x2 P	CH combed	36,2	86	32,10	6,1	4,44	32,2	5,23	0,845	13,87
5x3x2 P	KH carded	34,6	85	29,60	6,5	4,70	29,8	5,67	0,776	12,68
5x3 N	MII čes Egypt Giza70	36,5	87	31,91	7,4	4,40	33,7	5,99	0,899	14,09
5x3 BD	AI myk Řecko	31,0	84	26,40	9,4	4,20	29,8	5,13	0,788	11,51

Tab 1b Basic specification of cotton fibers Vibroskop, Vibrodyn

yarn set	fibres	colour	fineness	density	length [2]	diameter [3]	bending rigidity	strength	relative strengt	elongation
			t_{jm}/ t_{exp} [dtex]	ρ_v [kgm^{-3}]	*ML, l* [mm]	*d* [mm]	R_f [mNmm^{2}tex^{-1}]	*p* [cN]	*f* [cN/tex]	ε_v [%]
5x3P	KH carded	natural	1,75	1520	30	0,012	0,19	5,05	28,93	5,52
			(1,63; 1,86)					(4,51; 5,59)	(26,17; 31,69)	(4,93; 6,11)
5x3P	CH combed	natural	1,91	1520	30	0,013	0,19	4,67	24,8	5,12
			(1,78; 2,04)					(4,14; 5,20)	(22,22; 27,37)	(4,6; 5,6)
5x3P, 5x3BD	PES	white	1,3/ 1,4	1360	38	0,011	0,3	7,42	53,32	17,51
			(1,36; 1,45)					(7,20; 7,64)	(51,67; 54,98)	(16,27; 18,74)
5x3P, 5x3BD	PAN	white	0,9/ 1,17	1170	38	0,0099	0,33-0,48	3,97	33,97	31,86
			(1,13; 1,21)					(3,81; 4,14)	(32,85; 35,08)	(30,63; 33,08)
5x3P, 5x3BD	VSs	dark blue	1,3/ 1,34	1520	38	0,0104	0,19	4	17,56	30,05
			(1,30; 1,37)					(3,87; 4,14)	(16,77; 18,34)	(29,11; 30,99)

[2] fiber length is relevant to mean length of cotton fibers *ML* and nominal length *l* of synthetic fibers

[3] fibre diameter *d* is calculated by using fibre fineness *t .*

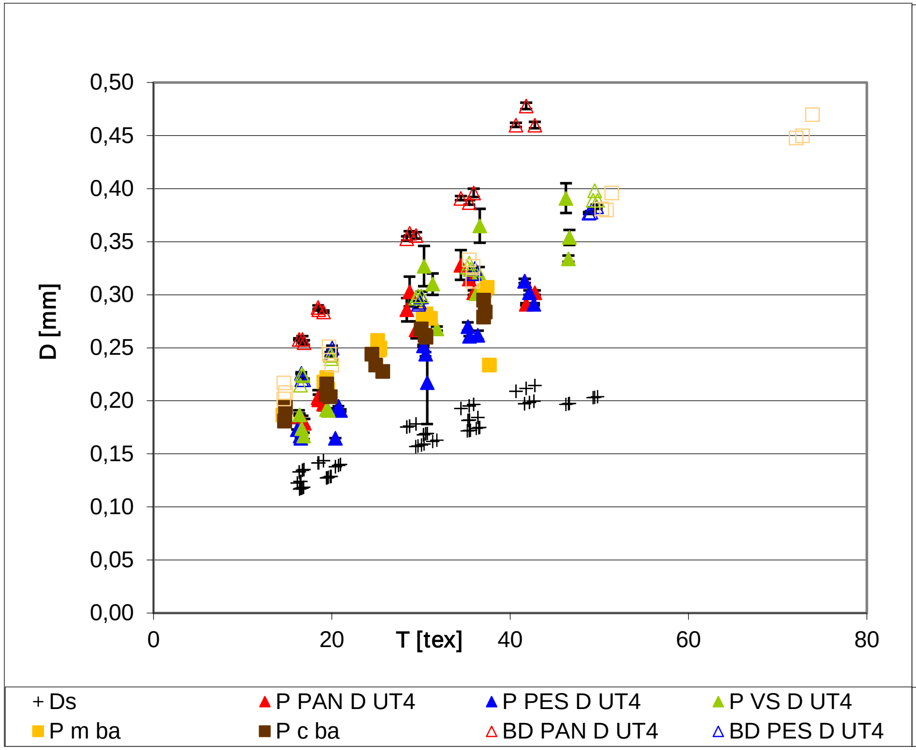
An Example - Discussion and conclusion

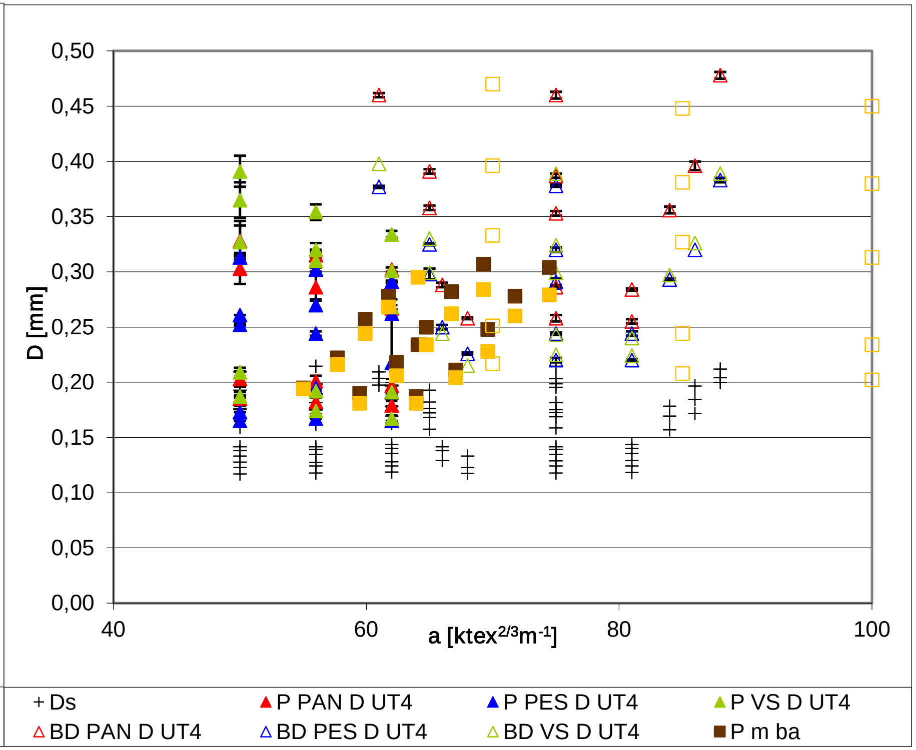
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn
Tab 2 Basic specification of yarns

set of yarn	technology	range of yarn count *T*	range of Phrixova twist coefficient *a*	fibres	number of yarns
5x3x2P	P m (carded), P č (combed)	14,79tex až 74,48tex	3 levels for each yarn count	100% CO	30
5x3N	N	7,4tex až 20tex	3 levels for each yarn count	100% CO	15
5x3BD	BD	14,5tex až 72tex	3 levels for each yarn count	100% CO	15
5x3P	P	16,5tex až 42tex	3 levels for each yarn count	100% PES	15
5x3P	P	16,5tex až 42tex	3 levels for each yarn count	100% PAN	15
5x3P	P	16,5tex až 42tex	3 levels for each yarn count	100% VS	15
5x3BD	BD	16,5tex až 50tex	3 levels for each yarn count	100% PES	15
5x3BD	BD	16,5tex až 50tex	3 levels for each yarn count	100% PAN	15
5x3BD	BD	16,5tex až 50tex	3 levels for each yarn count	100% VS	15

An Example - Discussion and conclusion

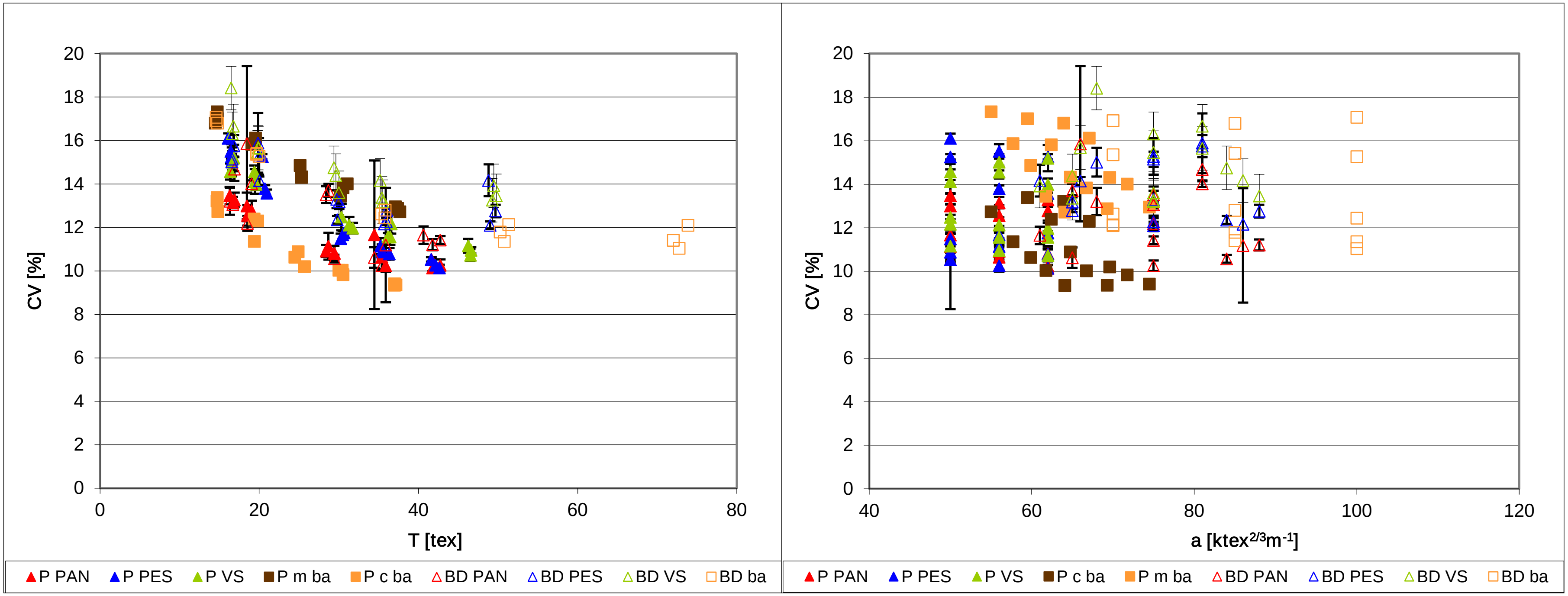
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
D yarn diameter





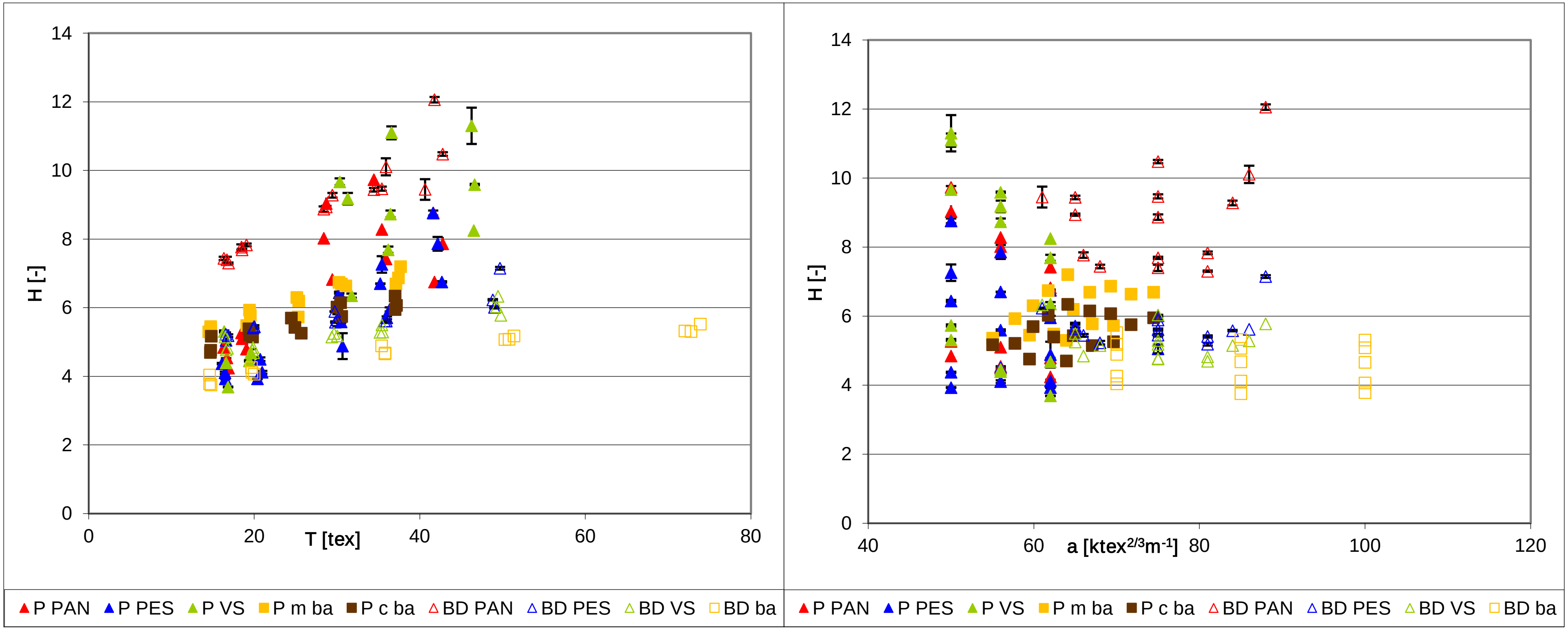
An Example - Discussion and conclusion

Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
CV yarn unevenness



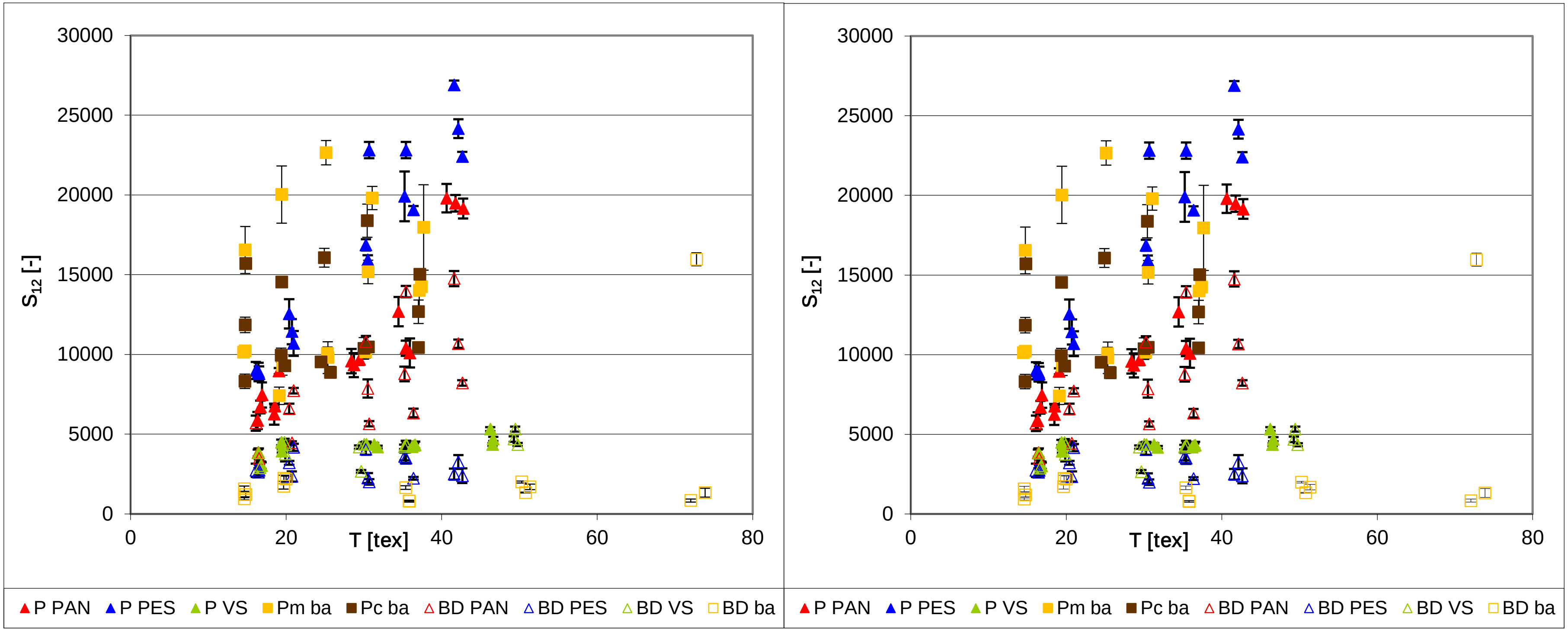
An Example - Discussion and conclusion

Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
H yarn hairiness index



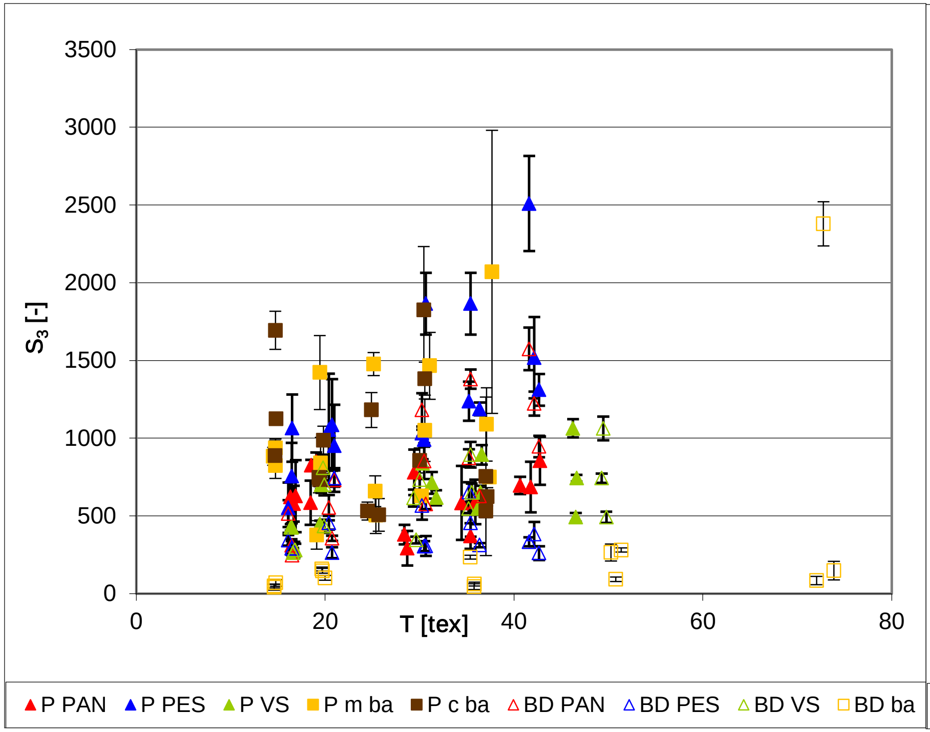
An Example - Discussion and conclusion

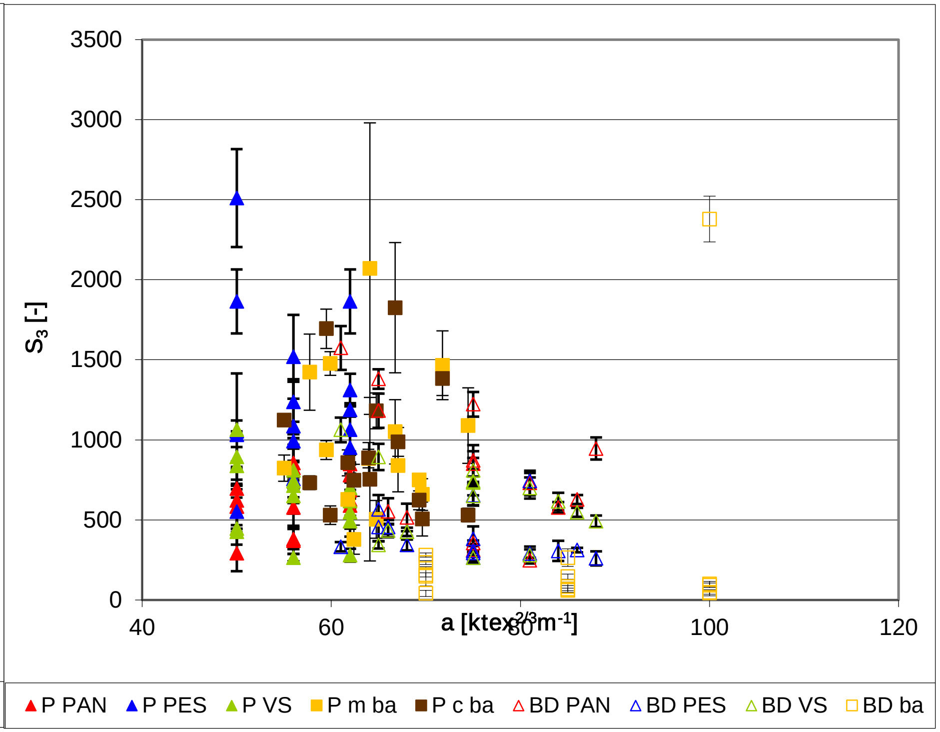
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn. S_{12} sum criterion of hairiness



An Example - Discussion and conclusion

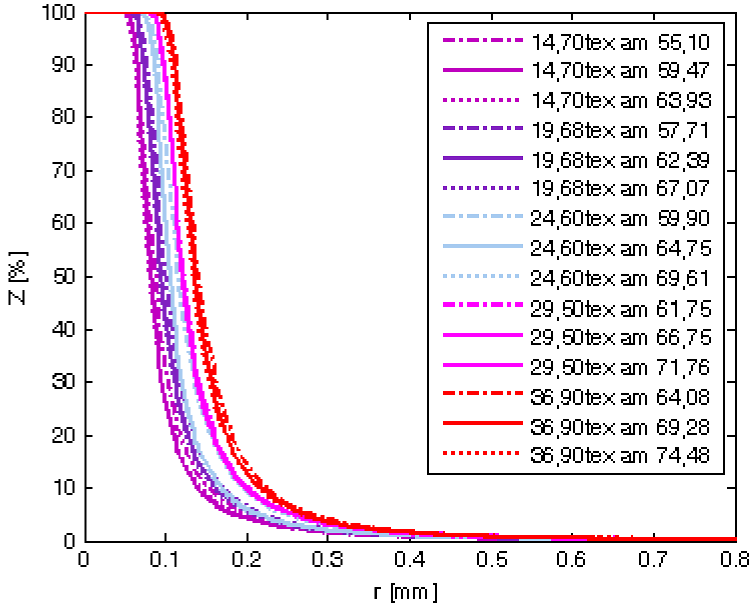
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
S_3 sum criterion of hairiness

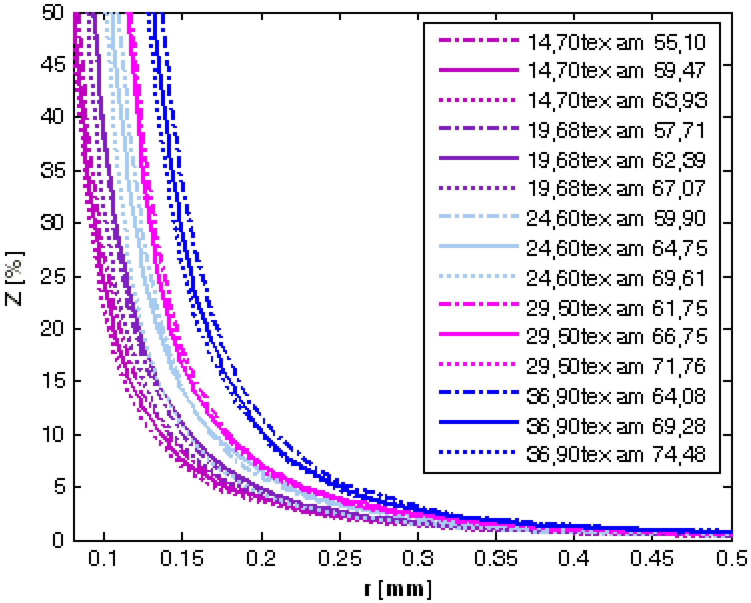




An Example - Discussion and conclusion

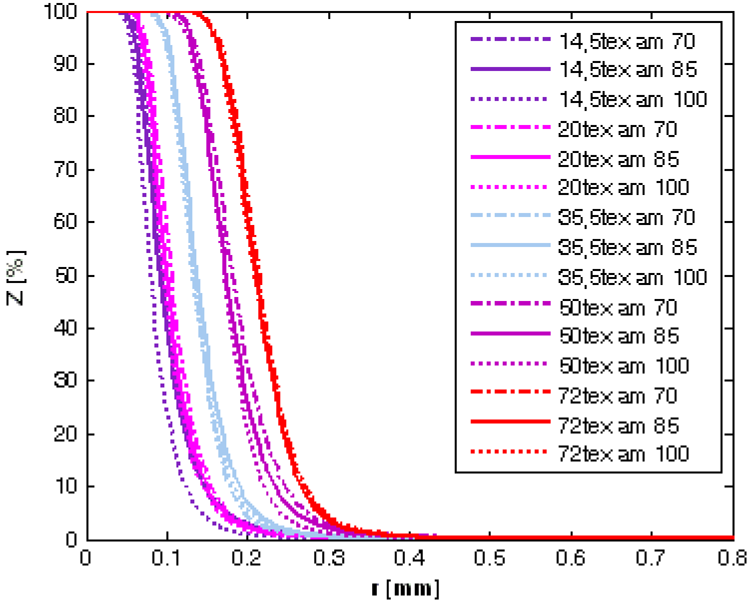
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
Z hairiness curve – blackening function and its detail

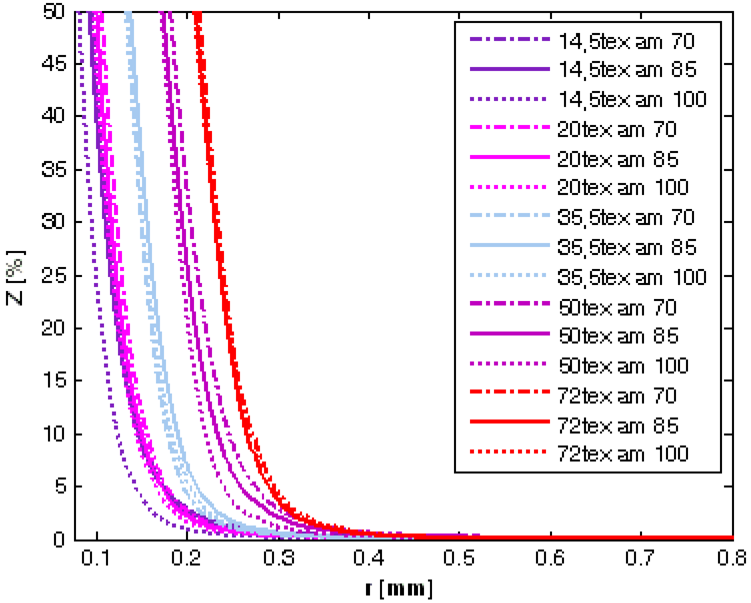




An Example - Discussion and conclusion

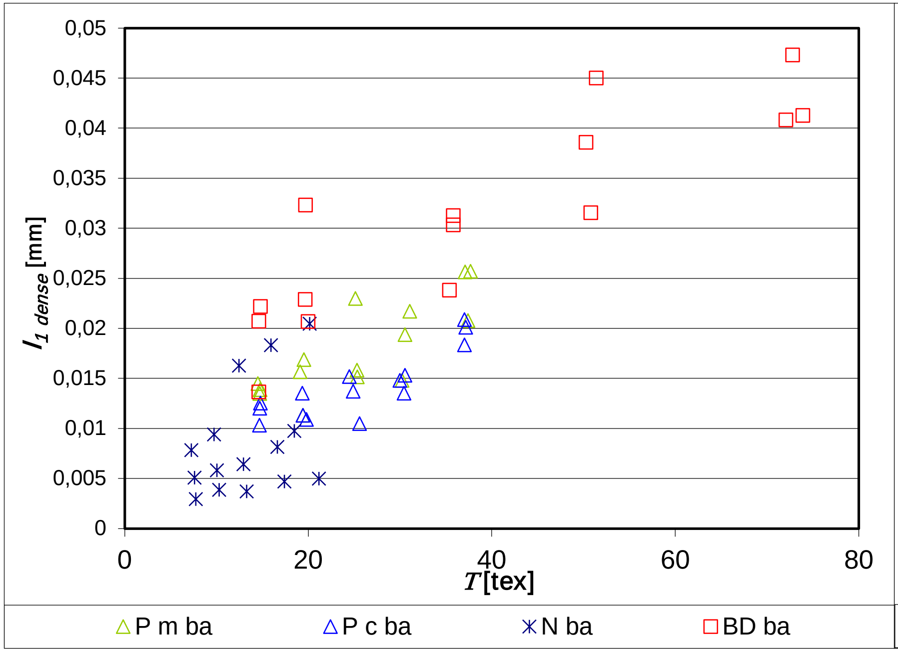
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
Z hairiness curve – blackening function and its detail

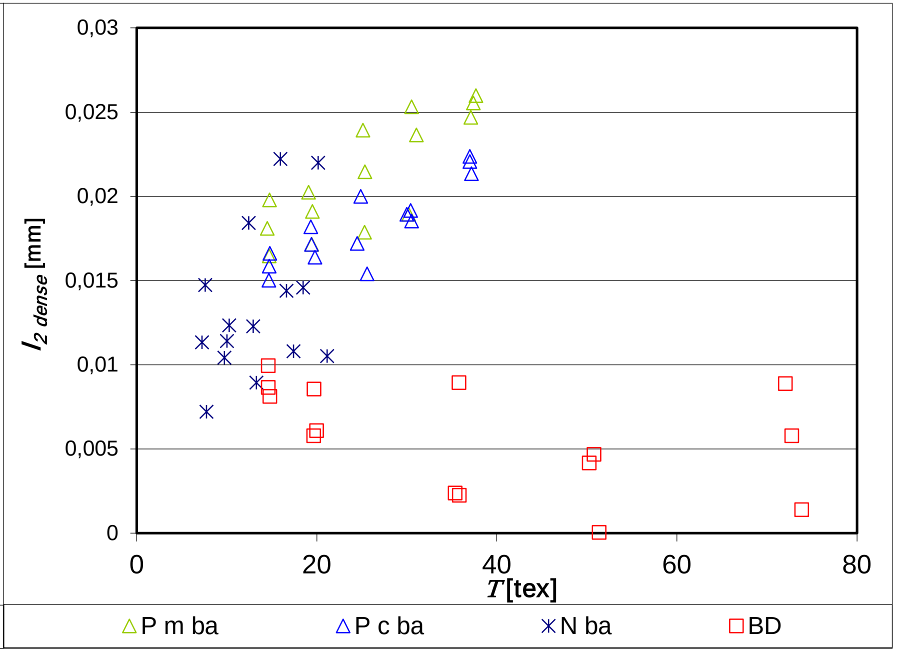




An Example - Discussion and conclusion

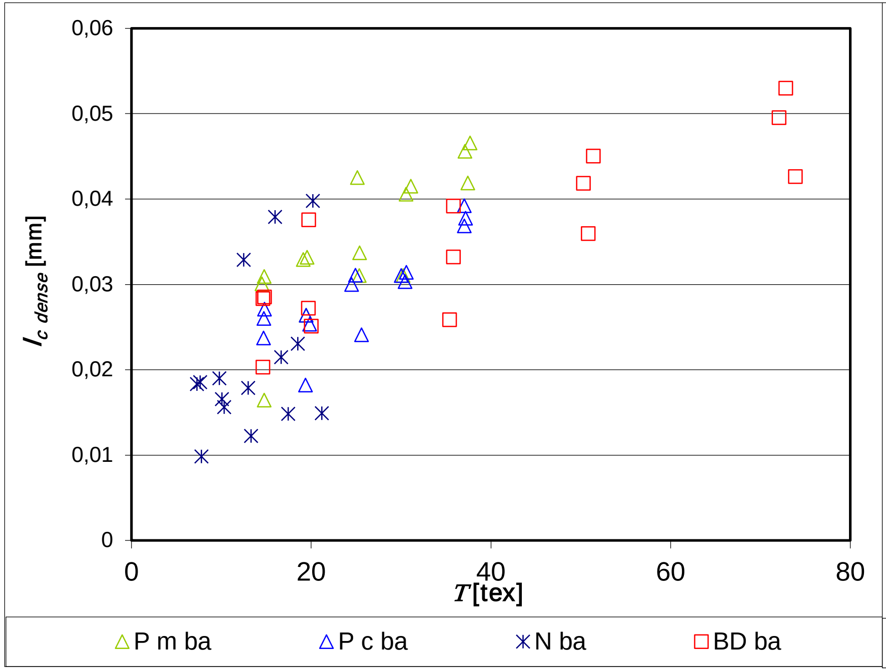
Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
I_1, I_2 integral characteristics of hairiness

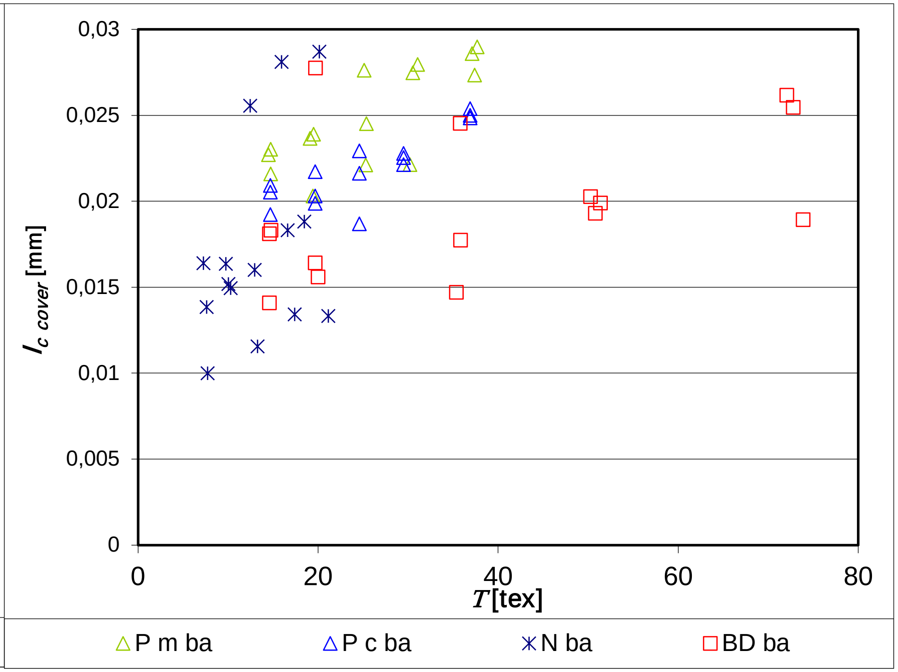




An Example - Discussion and conclusion

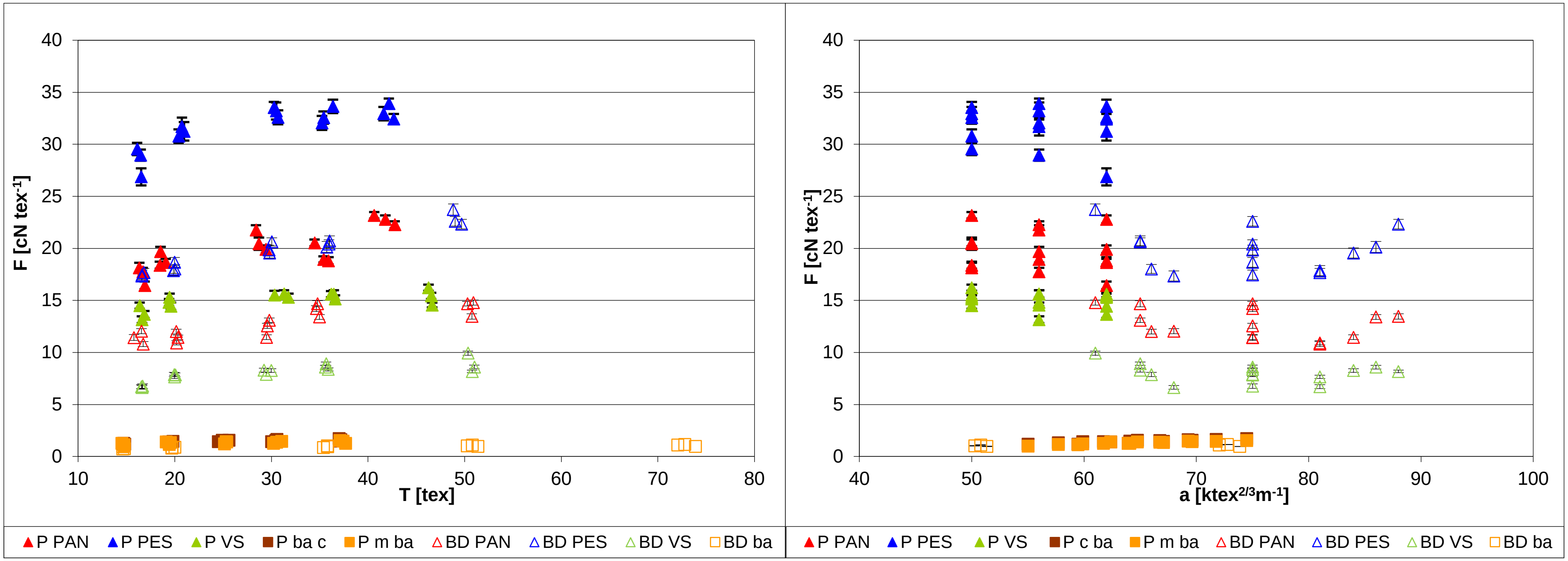
Evaluation of influence of fibre material, T, Z and spinning technology of yarn.
I_c integral characteristics of hairiness





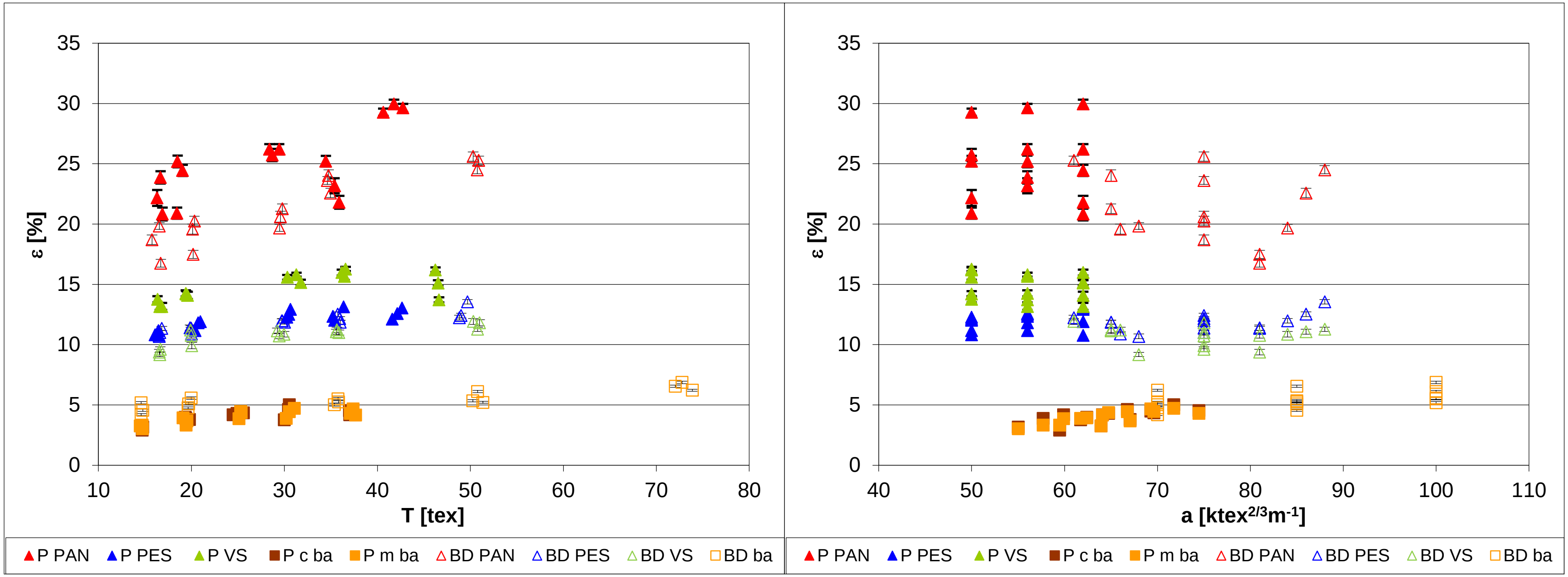
An Example - Discussion and conclusion

Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
F relative strength



An Example - Discussion and conclusion

Evaluation of influence of fibre material, *T*, *Z* and spinning technology of yarn.
ε elongation



An Example - Discussion and conclusion

- ✓ In most cases, the highest hairiness values are reached by yarns from 100% PES, followed by yarns from 100% PAN, 100% VS and 100% CO.
- ✓ As the yarn count increases, the number of fibers in the yarn increases, the yarn diameter increases, the yarn packing density decreases, the unevenness decreases, the number of faults decreases, the hairiness increases and the strength increases.
- ✓ As the twist coefficient increases, the concentric pressure increases, which is induced by the surface layers of the fibers in the yarn. The connection with the intensity of the twist or the inclination of the surface fibers is also evident. The yarn diameter decreases, the packing density increases, the yarn hairiness decreases, and the yarn strength increases.
- ✓ Ring yarns are usually used as a comparison standard. They have a good level of material unevenness, hairiness and a certain degree of strength.
- ✓ Novaspin yarns appear to be bulkier with a looser arrangement of fibers in the surface areas of the yarn, they show slightly higher diameter and hairiness, slightly lower strength, but with the usual degree of twist it is possible to achieve comparable results with conventional yarns. Currently, this technology is only in experimental form.

An Example - Discussion and conclusion

Other relevant references:

Altas S., Kadoglu H. Comparison of Conventional Ring, Mechanical Compact and Pneumatic Compact Yarn Spinning Systems. *Journal of Engineered Fibers and Fabrics* 7(1) · 2012.

Göktepe F., Yılmaz D., Göktpe ,Ö. A comparison of compact yarn properties produced on different systems. *Textile Research Journal*, 76(3) 2006.

Basal G., Oxenham W. Comparison of properties and structures of compact and conventional spun yarns. *Textile Research Journal*, 76(7) 2006.

Ahmed S. Syduzzaman M., M. S. Mahmud, Ashique S. M. comparative study on ring, rotor and air jet spun yarn. *European Scientic Journal* 1 (3) 2015.

Soe A. K., Takahashi M., Nakajima M. Structure and properties of MVS Yarn in comparison with ring yarns and open end rotor spun yarns. *Textile Research Journal*, 74(9) 2004.

Zeng Y. C. Yu C. W. Numerical and experimental study on reducing yarn hairness with the JetRing and JetWind. Textile Research Journal 74(3) 2004.

Cheng K. P. S. Li C. H. L. JetRing and its influence on yarn hairiness. *Textile Research Journal*, 72(12) 2002.

Mohamed M. H. Lord P. R., Saleh H. A. A comparison of the hairiness and diameter of ring and openend yarns. *Textile Research Journal*, 45(5) 1975.

Chasmawala R. J. , Hasen S. M., Jaqraman S. Structure and properties of air jet spun yarns. *Textile Research Journal*, 60(2) 1990.

Chang L., Wang X. Comparing the hairiness of solospun ad ring spun worsted yarns. *Textile Research Journal*, 73(7) 2003.

Questions for knowledge verification and repetition

- ✓ How are the technological parameters T [tex], Z [m-1] defined and what is their connection with the yarn diameter D [mm] and the twist coeficient ([ktexm$^{-1/2}$], a [ktexm$^{-2/3}$], κ [-])?
- ✓ What technologies of staple yarn production do you know, how do they differ and how do they affect the degree of arrangement of fibers in the yarn and thus its quality?
- ✓ What methodologies and procedures for determining T [tex], D [mm], Z [m-1] do you know and how is it realized?
- ✓ What is Uster ® Statistic and what is its purpose, which properties are usually used to compare the quality of staple yarns?
- ✓ What factors generally affect the quality of yarn in terms of CV [-], number of faults [km^{-1}], μ [-], D [mm], H [-] , S_{12} [100 m^{-1}] , S_3 [100 m^{-1}] , F [N tex^{-1}] , ε [%] ?

Thank you for your attention…

CHLUPATOST PŘÍZE/ HAIRINESS OF YARN

Ing. Gabriela Krupincová, Ph.D. / Department of technologies and structures

Aims and motivation

Motivation:

- ✓ Yarn hairiness is a typical property of staple materials and significantly affects subsequent processes.
- ✓ The bibliography search provides comprehensive information resulting from previous experience, there are a number of sophisticated methodologies, equipment for yarn hairiness evaluation and some are available at FT TUL.
- ✓ Theoretical models and experience with advanced statistical data analysis are available, which allows modelling and prediction of yarn hairiness.
- ✓ Industrial practice uses this characteristic as a key parameter of quality assessment. Produces of staple yarn and their customers together with machine manufactures are interested in assessment of changes of yarn quality in connection with innovations resulting from technological improvements.

Aims and motivation

The study of yarn hairiness allows to:

- ✓ understand the context and deepen knowledge about the yarn structure,
- ✓ describe the connections among the yarn hairiness and other yarn fundamental characteristics (indirectly assess the degree of fibre arrangement in the yarn),
- ✓ name the factors influencing the yarn hairiness and use this knowledge for its modelling,
- ✓ understand how it affects process-ability (dyeing, sizing, weaving) and how it affects the user properties of fabrics (porosity, breathability, hand, thermal conductivity, piling ability, appearance,…), cost and quality of the final textile product.

An overview of the current state and possibilities at FT TUL

- ✓ Definition of yarn hairiness
- ✓ Principles of measurement - methodologies and instruments
- ✓ Factors affecting yarn hairiness
- ✓ Possibilities of yarn hairiness modeling

Definition of yarn hairiness

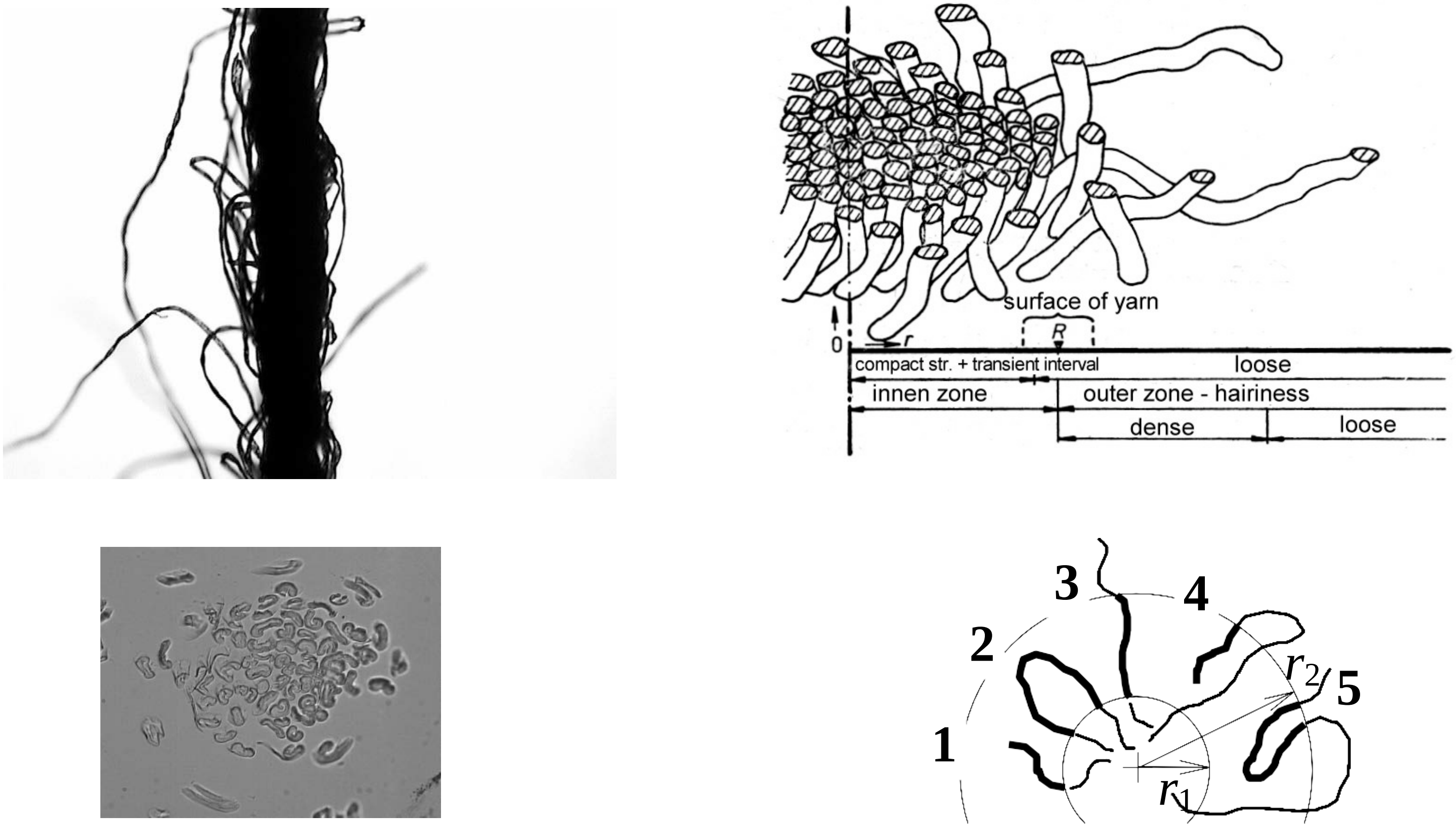


Fig. 1 Area of yarn hairiness – type of fiber segments

Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. *7th International conference Strutex*. Technical University of Liberec, Czech Republic 2000, ISBN: 80-7083-442-0.

Definition of yarn hairiness

- ✓ Yarn hairiness is a typical property of staple materials.
- ✓ It is mostly characterized by the number, length or area of fibre ends or fiber loops on the yarn surface resp. in the area of hairiness.
- ✓ Yarn hairiness is not a strictly separate property. It is related to the characteristics of the fibers, the geometry of the yarn and the parameters of spinning process.
- ✓ It is a qualitative indicator of yarn that can be evaluated easily.

Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. *7th International conference Strutex*. Technical University of Liberec, Czech Republic 2000, ISBN: 80-7083-442-0.

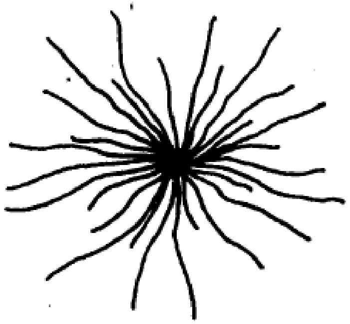
Barella A. Yarn Hairiness. *Textile Progress*, 43(1), The Textile Institute 1983.

Manuál přístroje Uster Tester 4 firmy Zelweger. www.uster.com.

Manuál přístroje Uster Zweigle HL 400. www.uster.com.

Approaches to the evaluation of hairiness

Basic principles and methodologies:



- ✓ - optical methods
- ✓ 1. direct optical methods (longitudinal views of the yarn, projection of the yarn into the yarn axis)
- ✓ 2. photographic methods (counting of protruding fibers)
- ✓ 3. methods based on transverse yarn scanning
- ✓ 4. methods using laser
- ✓ 5. methods based on image analysis using CCD cameras

- photoelectric and related methods
- methods based on electrical conductivity
- methods based on weight change due to singeing

- other methods and their combinations

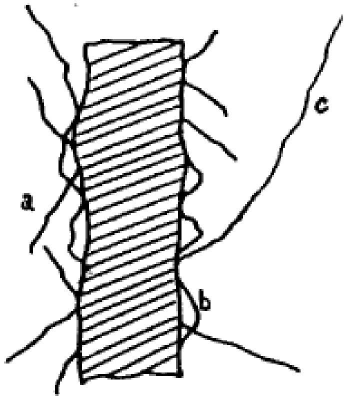


Fig. 2 Yarn projection a) into yarn axis b) 2D longitudinal view

Barella, A. Yarn Hairiness, *Textile Progress*, 13(1), The Textile Institute 1983.

Approaches to the evaluation of hairiness

The main differences between methodologies:

✓different approach to yarn detection, which is related to the used measurement principle (cost and possibilities of testing in practice),

✓various characteristics used for yarn hairiness description (yarn hairiness index *H*, length of protruding fibers L_i or number of fibers in a given category from the surface of the yarn n_i, ...),

✓different accuracy of measurements and provided results related to the measured yarn length, the method of data processing, and limitations given by the state of the art (e.g. resolution of cameras, resolution of photo sensors and their sensitivity).

Commercial testing equipment:

Uster ® Tester 4, Premier Tester 7000, Zweigle G 566, Zweigle ® Uster HL 400, Shirley Yarn Friction / Hairiness Meter, Toray F Index tester Hairiness Counter, Criter Dam II, Special device based on Chamberlain photometer, Keisokki Laserspot LST, YHM 4 (American manufacturer Mainers - Del),…

Laboratory methods of evaluation: IS 22-102-01/01 Hairiness and diameter of yarns and many others.

Barella, A. Yarn Hairiness, *Textile Progress*, 13(1), The Textile Institute 1983.

Historical approaches to the evaluation of hairiness

Lapage and Onionse: The yarn is guided into the measuring zone, where it is illuminated and, thanks to the lens system, an enlarged image is obtained. The grey image is projected on a screen equipped with a moving photoelectric sensor that is able to detect protruding fibers due to different light intensities at different distances from the yarn surface. The grey values corresponding to the fibers and the yarn body are given by internal convention. If the photoelectric sensor detects the occurrence of a fiber, the electrical circuit generates an electrical pulse. Pulses amplified by the amplifier are counted with respect to the distance from the yarn axis, which can be changed or operated in a defined sector. The output is information of fiber occurrence and the yarn unevenness depending on the distance from the yarn axis.

It is similar to methodologies using OA or e.g. Zweigle G 567 and other series of measuring devices used commercially.

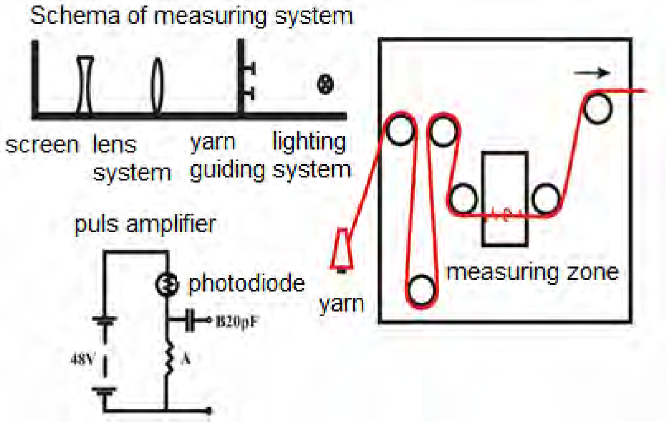


Fig. 6 Principal of hairiness measurement according to Lapage a Onionse

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Suh M. W., Jasper W., Gunay M. 3-D Electronic imaging of fabric qualities by on line yarn data. National Textile Center, Project.

S01-NS12, Annual report, November 2004, dostupné z http://www.ntcresearch.org/.

Historical approaches to the evaluation of hairiness

CRITTER DAM I: the yarn was guided by a high-voltage cylindrical electric field. The protruding fibers were straightened due to contact with the inner surface of the first electrode and an electrostatic charge was induced in them. By passing the yarn through the second electrode, the charge in the protruding fibers was eliminated. Hairiness was assessed according to the size of the induced charge, where the higher charge is given by the higher frequency of protruding fibers. The results were strongly dependent on the humidity, the type of examined material and the limited 5mm diameter of the cylindrical electrode. The results could not be interpreted regardless of the yarn count. In the case of fine yarns, only long fibers were charged, and in the case of coarse yarns, even short fibers could be exposed to contact with the electrode.

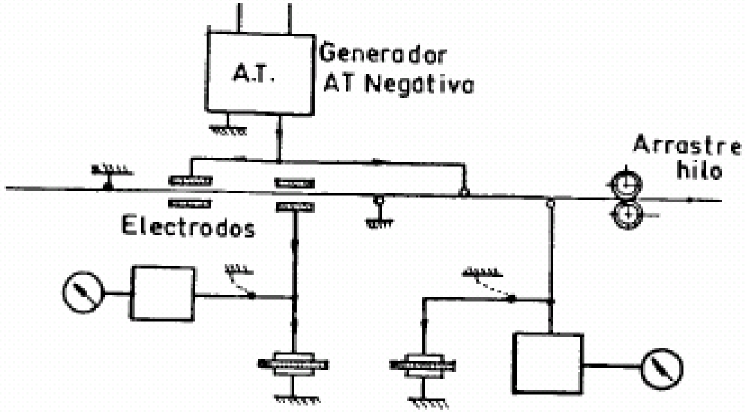


Fig. 7 Principal of hairiness measurement
CRITER DAM I

Barella A. The hairiness of yarn: The review of the literature and a survey of the present position. *Journal of Textile Institute*, 57(10),1966.

Historical approaches to the evaluation of hairiness

CRITTER DAM II: The second version of the device was modified, the yarn passed through a planar electrostatic field during the measurement, where the protruding fibers of the examined yarn were straightened and their number was recorded at a distance of 3 mm from the yarn axis thanks to a photoelectric sensor. In both cases, the light intensity corresponding to the initial state without yarn was compared with the light intensity during the measurement. According to Barella, the device was later supplemented with other photo-sensitive sensors and the frequencies of the fibers could be detected at distances of 2, 3, 4, 5, 6 and 7 mm from the yarn surface.

It is partly similar to the Zweigle G 567 and other commercial devices.

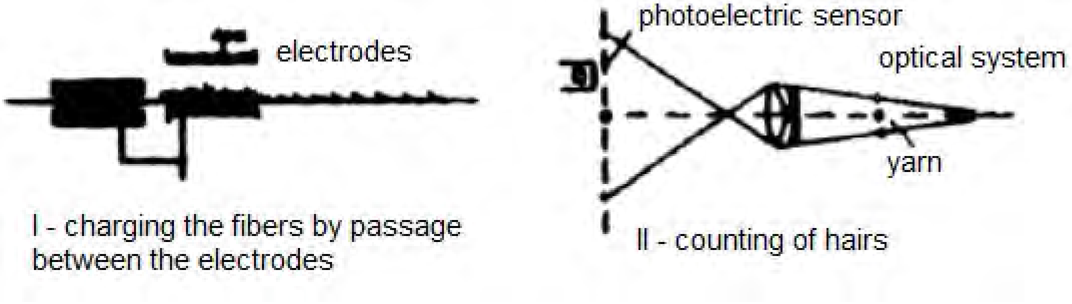


Fig. 8 Principal of hairiness measurement CRITER DAM II

Barella A. Recent developments in yarn – hairiness studies. *Journal of Textile Institute*, 64(10),1973.
Barella A. The hairiness of yarn: The review of the literature and a survey of the present position. *Journal of Textile Institute*, 57(10),1966.

Measuring principle of hairiness - Uster ® Tester 4SX

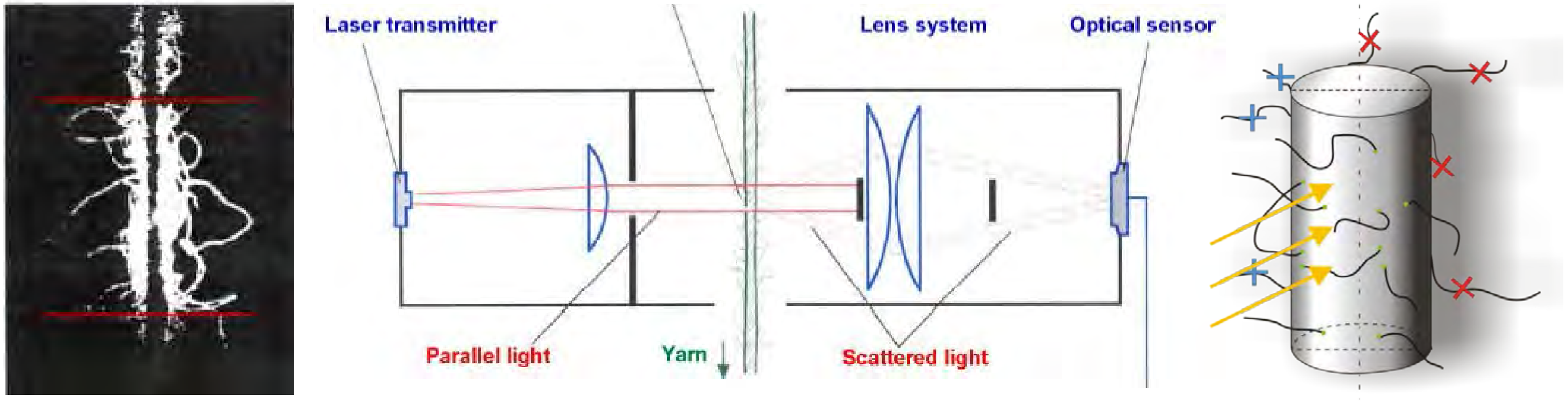


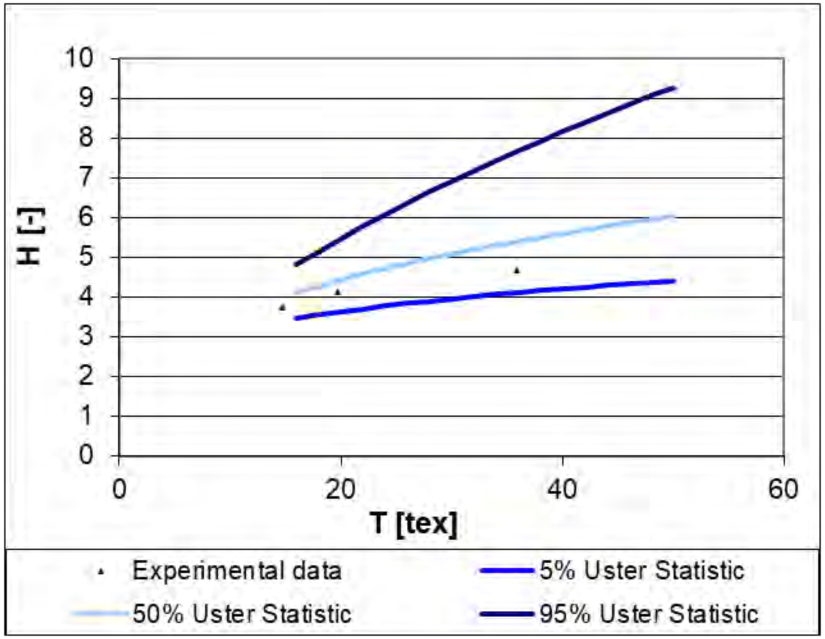
Fig. 9 Principal of hairiness measurement Uster ® Tester

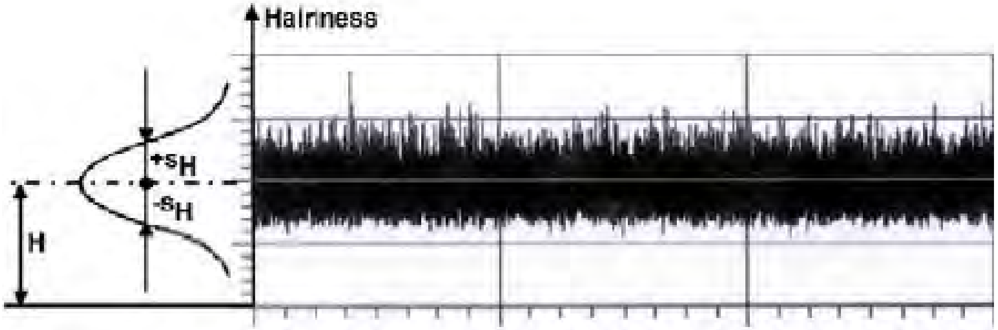
Outputs: hairiness index *H*, standard deviation of yarn hairiness *sh* and other parameters of yarn (optical sensor: two dimensional yarn diameter D_{UT4}, capacity sensor: yarn packing density μ_{UT4}, yarn unevenness *CV*, number of faults *Thin-40%*, *Thin-50%*, *Thick+35%*, *Thick+50%*, *Neps +200%*, *Neps +280%*, shape of yarn, Uster ® Statistic, …).

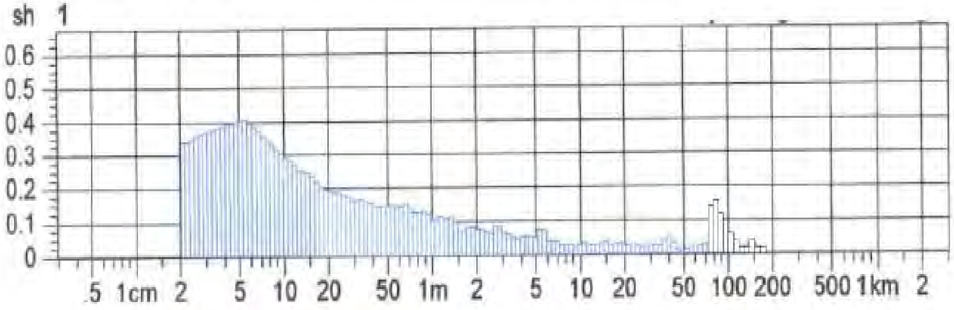
Manual of Uster Tester 4 of Zelweger Company (5 2002). www.uster.com
Steadman R. G. Cotton Testing. *Textile Progress*, 27(1). The Textile Institute 1997.

Measuring principle of hairiness - Uster ® Tester 4SX (example of outputs)

a	**[ktex$^{2/3}$m^{-1}]**	**85**	**85**	**85**
$T_{exp.}$	[tex]	14,78	19,71	35,82
		(14,57; 14,99)	(19,37; 20,04)	(35,29; 36,34)
D_{UT4}	[mm]	0,208	0,244	0,327
H	[-]	3,75	4,12	4,68







Similar testing principle as Premier Tester 7000.

Measuring principle of hairiness – Zweigle G 567

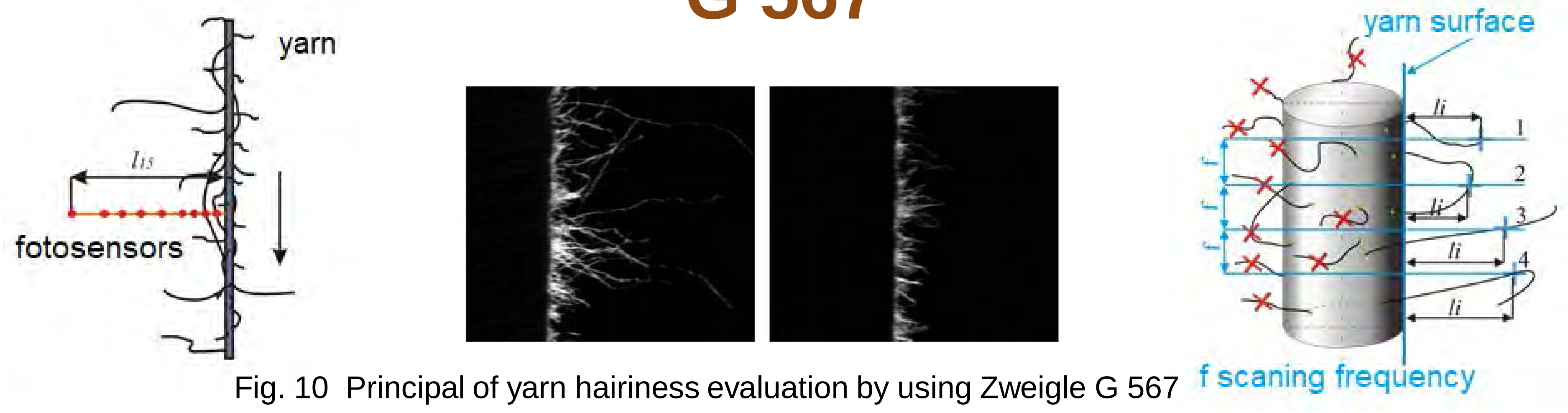


Fig. 10 Principal of yarn hairiness evaluation by using Zweigle G 567

$$S_{12} = \sum_{i=1}^{i=2} n_i, \qquad S_3 = \sum_{i=3}^{i=k} n_i,$$

$$K_1 = \frac{\sum_{i=1}^{k} n_i l_i}{L}, \qquad K_2 = \frac{\sum_{i=1}^{k} n_i l_i d}{L\; l_{15}}.$$

$i=1,2,3 \ldots k$

d [mm] ... fibre diameter,

n_i [-]... relative occurrence of fiber ends,

l_i [mm]... length of fibres (for given length category),

L [mm] ... measured length of yarn,

l_{15} [mm]... max. distance from yarn surface (15mm)

Outputs: histogram of fibre end occurrence of fiber ends depending on the distance from the yarn surface, sum criteria of yarn hairiness S_{12}, S_3, S, length criterion of hairiness K_1 and areal criterion of hairiness K_2.

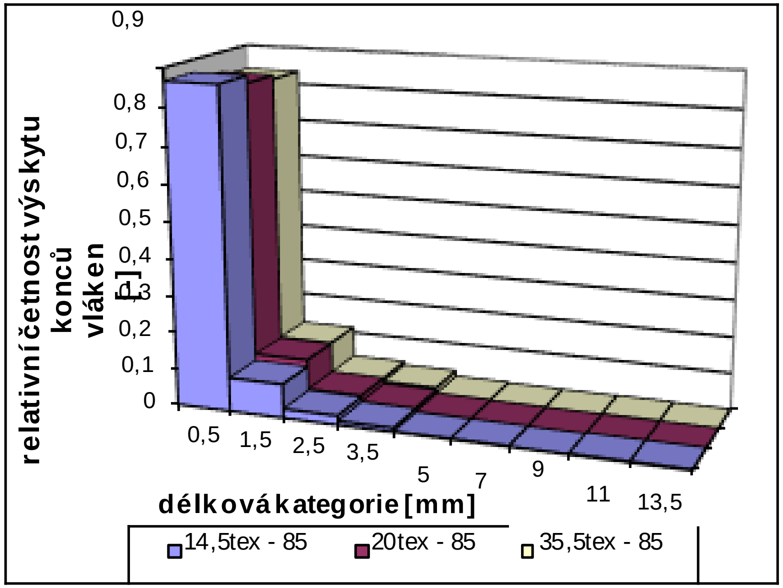
Manual of Zweigle G 567.

Saville B. P. Physical Textile Testing. Published by Woodhead Publishing Limited in association with The Textile Institute 1999.

IS 42-102-01/01 Evaluation of yarn hairiness. Research Centre Textile, FT TUL 2009.

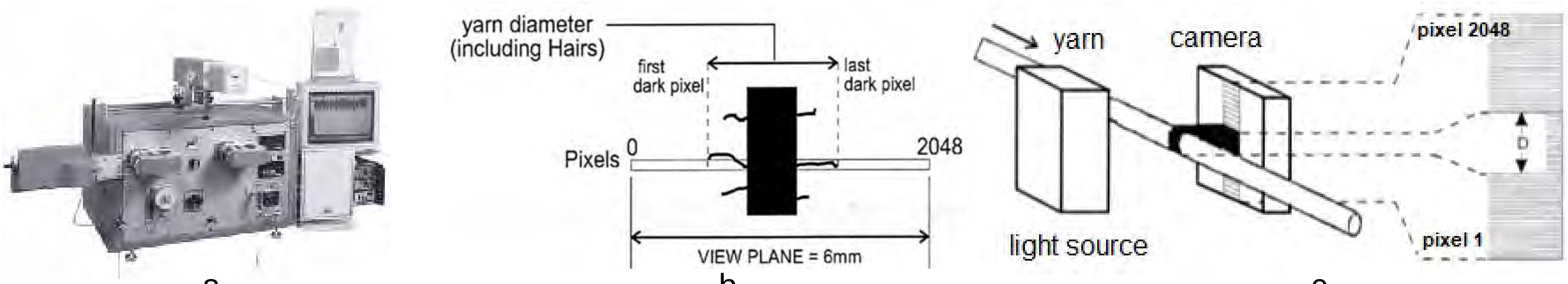
Measuring principle of hairiness – Zweigle G567 (example of outputs)

$T_{jm.}$	**[tex]**	**14,5**	**20**	**35,5**
a	**[ktex$^{2/3}$m^{-1}]**	**85**	**85**	**85**
$T_{exp.}$	[tex]	14,78	19,71	35,82
		(14,57; 14,99)	(19,37; 20,04)	(35,29; 36,34)
S_{12}	[-]	1201	2236	783
		(1069; 1333)	(1980; 2493)	(734; 831)
S_3	[-]	69	146	61
		(47; 90)	(116; 176)	(48; 73)
S	[-]	1270	2383	844
		(1119; 1420)	(2111; 2654)	(791; 896)



Similar testing principle as Zweigle ® Uster HL 400, Shirley hairiness tester, Toray F Index tester Hairiness Counter.

Measuring principle of hairiness – Lawson Hemphil YAS (Yarn appearance and hairiness tester)



a b c

Fig. 11 Principal of yarn hairiness evaluation by CTT

- ✓ It enables the evaluation of yarn hairiness at six different distances from the yarn surface together with the analysis of yarn diameter variability, yarn unevenness and number of faults (thick and thin places, neps).
- ✓ Outputs: basic information about the evaluated quantities, including data about their variability and graphical dependence of evaluated parameters on the measured length.
- ✓ Hairiness is expressed as the total number of protruding fibers. It is possible to analyse staple yarns as well as multifilament at the speed up to 400 mmin^{-1}, but 100 mmin^{-1} is used as the standard testing speed.

Steadman R. G. Cotton Testing. *Textile Progress*, 27(1). The Textile Institute 1997.
Das D., Ishtiaque S. M.: Application of artificial neural network to predict rotor spun yarn properties. *Meliand International*, 10 (9), 2004.
Lawson Hemphill. CTT Constant Tension Transport: User Manual. Swansea, USA.

Measuring principle of hairiness – Lawson Hemphil YAS (Yarn appearance and hairiness tester)

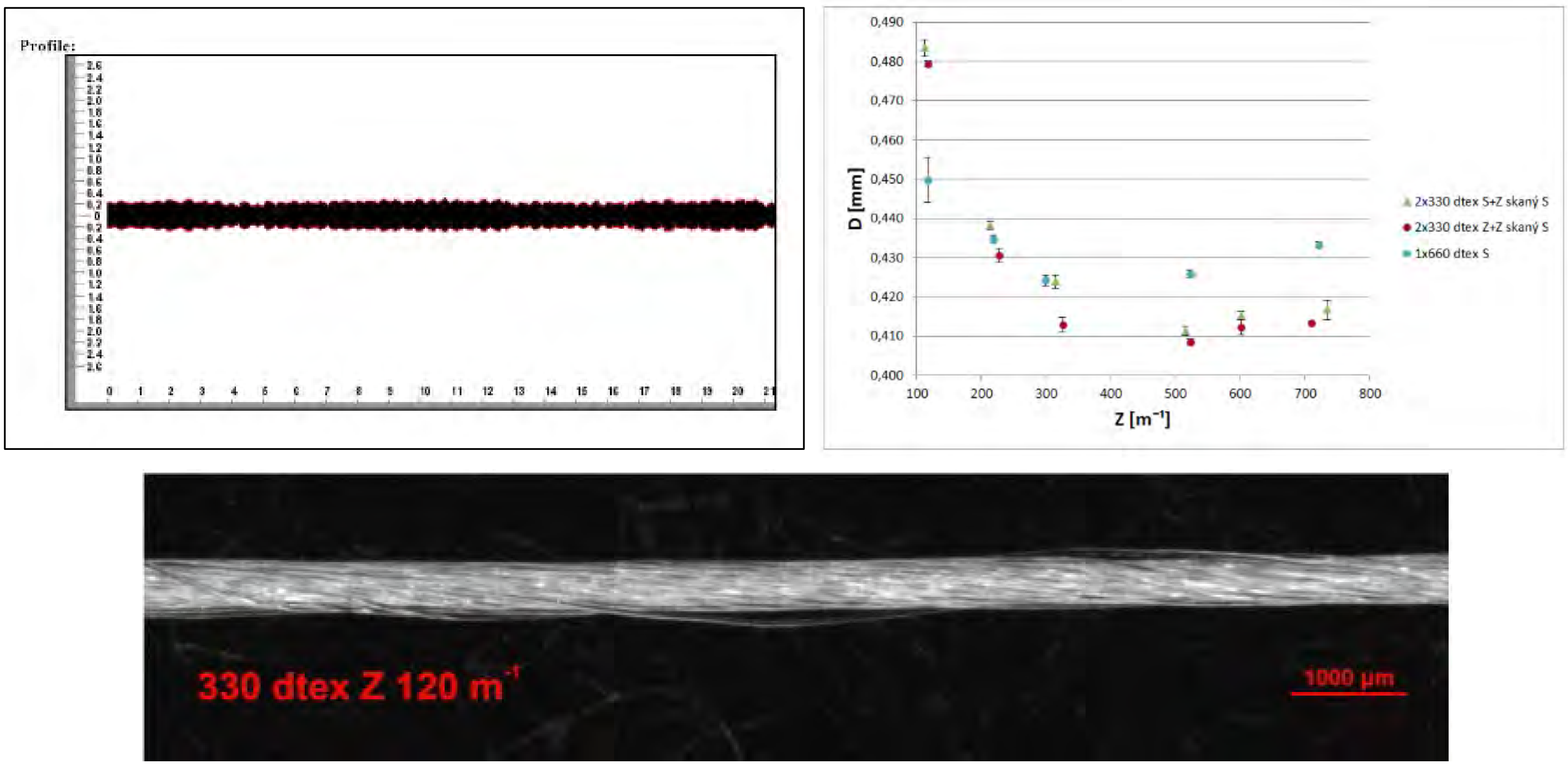


Fig. 12 Example of outputs CTT YAS – diameter of two folded multifilament (each multifilament 33 tex protective twist Z direction, two folded multifilament with a twist 120 m^{-1} S direction, *D* = 0,479 mm (0,478 mm; 0,480 mm), *CV* = 10,71 % (10,44 %; 10,97 %)

Lawson Hemphill. CTT Constant Tension Transport: User Manual. Swansea, USA.

Martínek O. Influence of twist on geometric and mechanical - physical properties of multifil. DP FT TUL 2018. (In Czech).

Other commercial equipment

Fig. 13 Shirley Yarn Hairiness Tester

It evaluates only a part of the yarn projection, yarn hairiness is defined as the number of protruding fibers at a given distance from the yarn surface (0 mm and 10 mm).

Saville B. P. *Physical testing of textiles*. The Textile Institute, Woodhead Publishing Ltd and CRC Press, 2000. ISBN 0-8493-0568-3.

Barella A. The hairiness of yarn: The review of the literature and a survey of the present position. *Journal of Textile Institute*, 57(10),1966.

Barella A. Yarn Hairiness: A survey of resent literature and a description of a new instrument for measuring yarn hairiness. *Journal of Textile Institute*, 61(9), 1970.

Barella A. Recent developments in yarn – hairiness studies. *Journal of Textile Institute*, 64(10), 1973.

Other commercial equipment

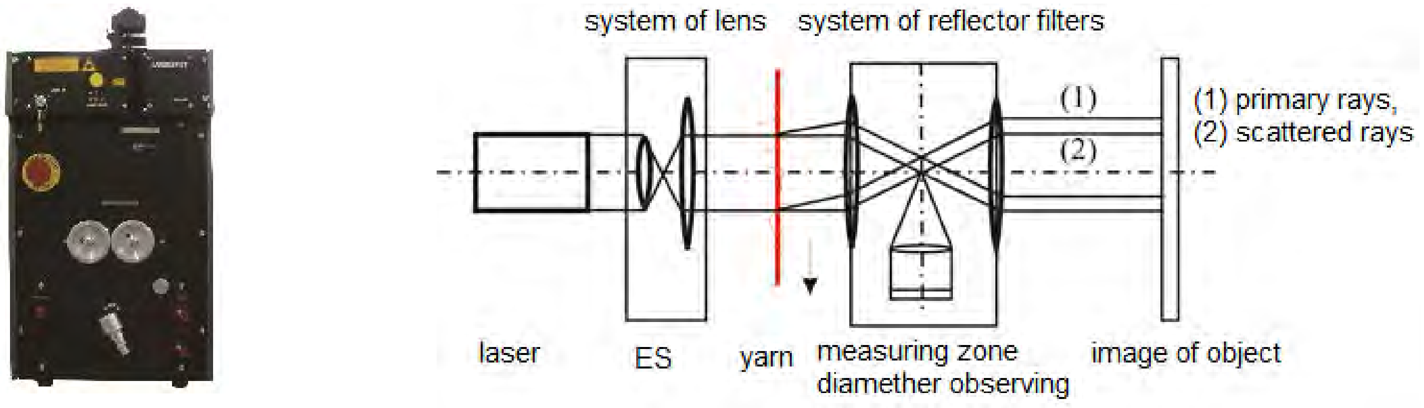


Fig. 14a) Keisoki Laserspot LST b) principal of measurement

- ✓ The yarn is illuminated by a laser beams. Part of rays are absorbed by the densely arranged yarn body and part of rays are diffracted according to Fraunhofer's theory depending on the homogeneity of the yarn surface. Diffusion zones appear when there are fiber loops and protruding fiber ends on the yarn surface.
- ✓ A lens system is used to separate the individual components. The first zone of the filters is located behind the observed object, thanks to which it is possible to optically evaluate the yarn diameter. Subsequently, the beam system is reconnected and the result can be converted to a hairiness index. The outputs are mean value together with data variability. Measurements can be realized at speed up to 400 mmin^{-1}, but 100 mmin^{-1} is used as the standard test speed.
- ✓ The results of testing are strongly dependent on the calibration of the measuring system, which is performed using a thin metal wire of the prescribed composition, defined diameter with a circular cross-section.

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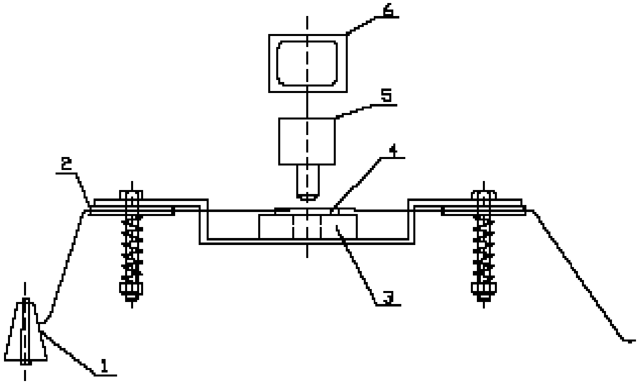
http://www.keisokki.com

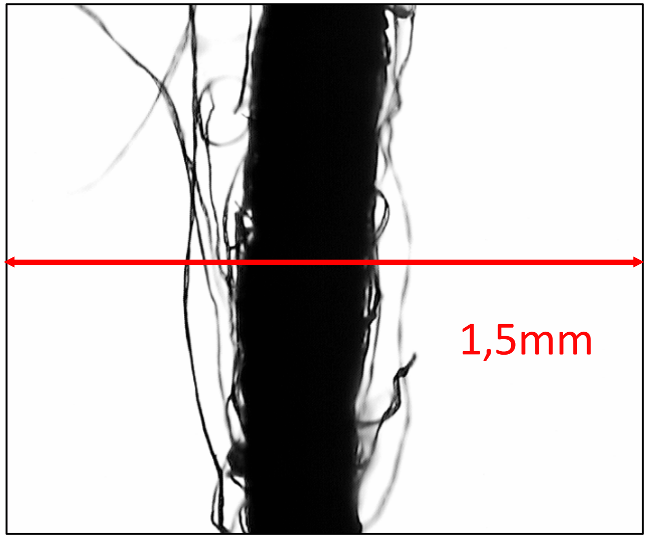
Barella A., Manich A. M.. Yarn Hairiness: A Further Update. *Textile Progress*, 31(4). The Textile Institute 2002. ISBN: 1 87037 249 2.

Measurement principle - IS - 22-10-01 / 01

1. yarn bobbin
2. disk tensioning device
3. yarn guide
4. microscope or macro-scope
5. camera
6. PC



Resolution of images
548 pxl x 704 pxl, **Common calibration** method 1 - 2,23mm for 1pxl method 2 - 8,6mm for 1pxl



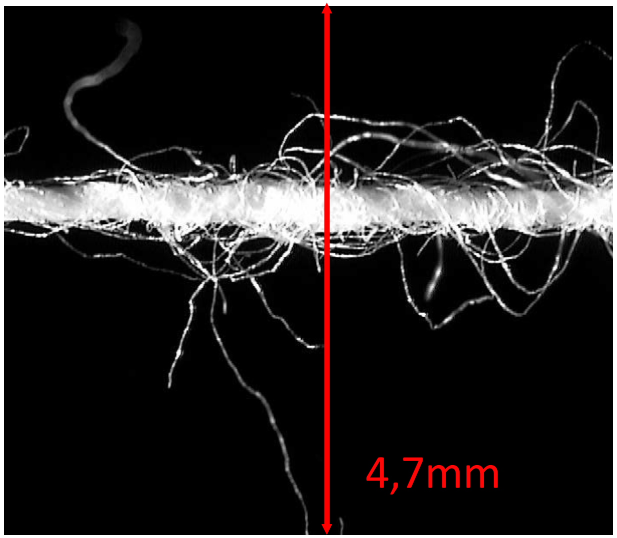


Fig. 15a) Experimental setup – scanning of yarn longitudinal views b) c) longitudinal views of yarn (open end yarn 72 tex am 85 ktex$^{2/3}$m^{-1})

Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. *7th International conference Strutex*. Technical University of Liberec, Czech Republic 2000, ISBN: 80-7083-442-0.
IS 22-102-01/01 Yarn diameter and hairiness. Research Centre Textile, FT TUL 2004.

Measurement principle - IS - 22-10-01 / 01

- ✓ Capturing the recommended number of colour images (800) at optimal resolution and magnification.
- ✓ Conversion of colour images over a grayscale to a binary form according to an objectively determined threshold.

Fig. 16 longitudinal view of yarn – colour image
(open end yarn 72 tex am 85 ktex$^{2/3}$m^{-1})

Measurement principle - IS - 22-10-01 / 01

- ✓ Elimination of hairs by morphological operation (erosion).
- ✓ First estimation of yarn axis position by using histogram of occurrence “yarn pixels“. (It is set in the middle of the first and the last coordinates where the occurrence of “yarn pixels” is equal to the maximum).

Fig. 17a, b partial processing of images – binary images
(open end yarn 72 tex am 85 ktex$^{2/3}$m^{-1})

Measurement principle - IS - 22-10-01 / 01

- ✓ Determining the position of the yarn axis as half of the longest area of pixels with the value corresponding to the yarn (second estimation of the axis position).
- ✓ Comparison of yarn axis position estimation and its determination for individual rows of images (convention D / 4).
- ✓ Determination of relative frequency of pixels belong to yarn.

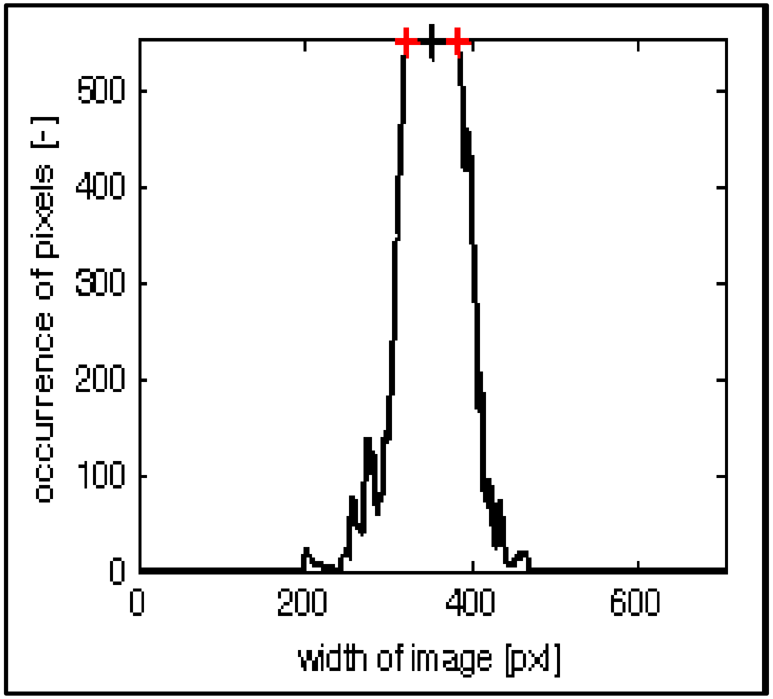
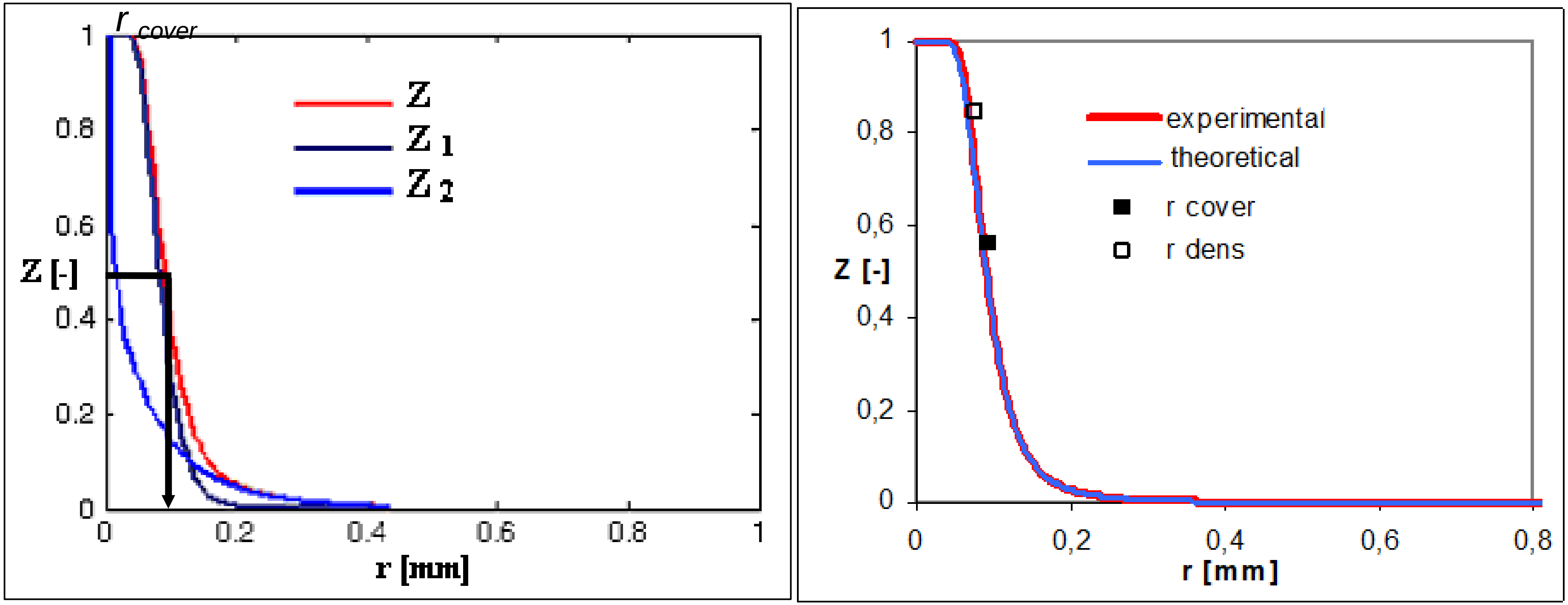


Fig. 18 Relative occurrence of pixels belong to yarn, red cross is used to mark the boundary of yarn body (open end yarn 72 tex am 85 ktex$^{2/3}$m^{-1})

Measurement principle - IS - 22-10-01 / 01

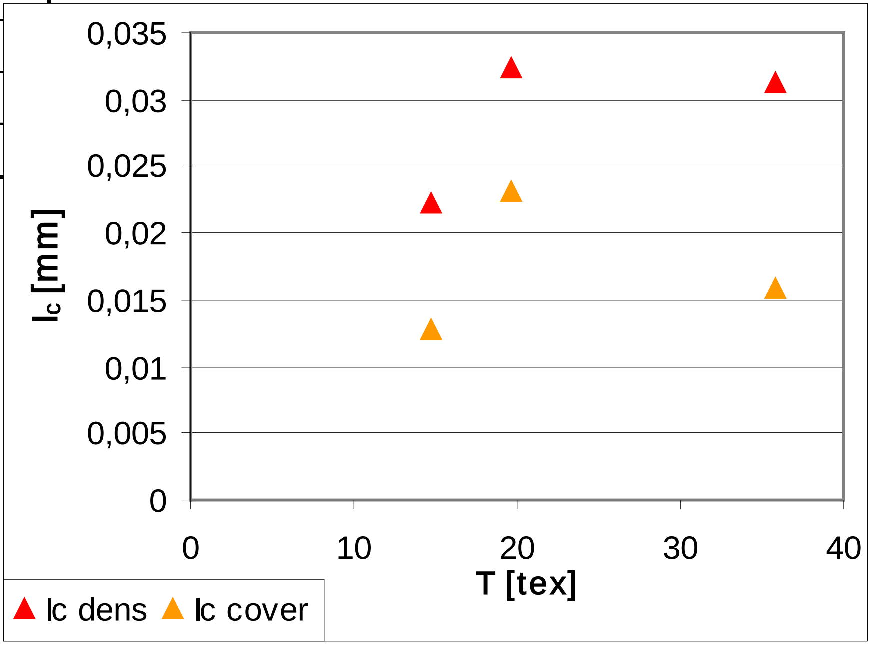
- ✓ Applying the double exponential Neckar's model (thanks to fitting experimental data by the double exponential model it can be obtain four parameters of theoretical hairiness carve).
- ✓ Computing parameters describing hairiness with using two convention (dens and cover).



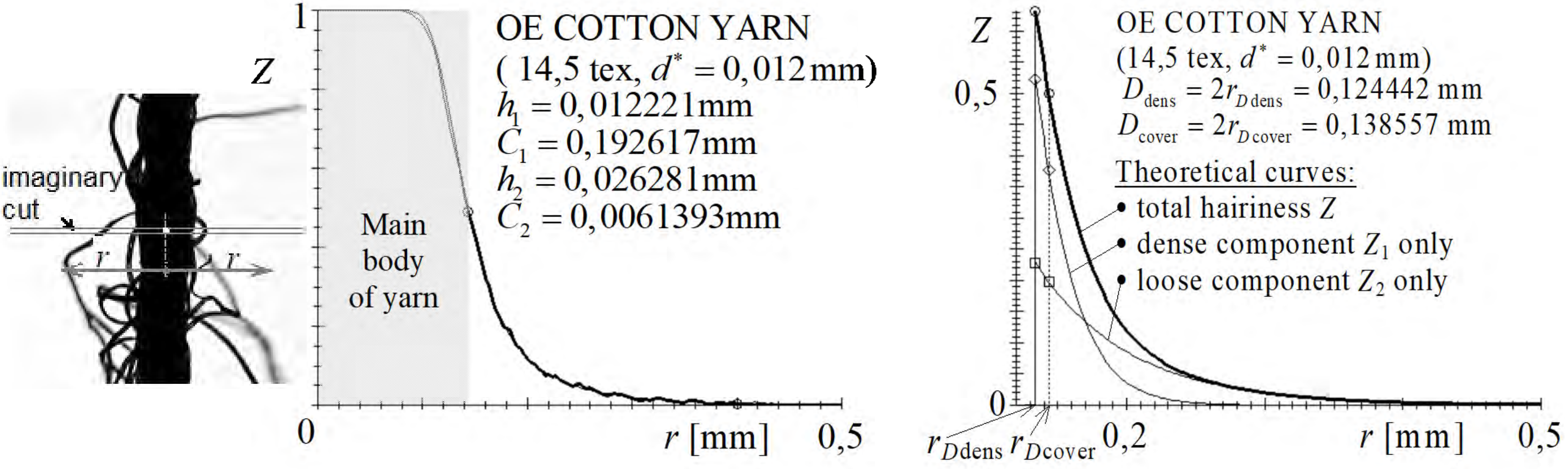
An example of hairiness curve (blackening function – *Z(r)*: convention for yarn diameter finding is Z_{cover} = 0,5 and $\propto_{D\ dens}$ = 0,11

Measurement principle - IS - 22-10-01 / 01

$T_{jm.}$	[tex]	14,5	20	35,5
a	**[ktex$^{2/3}$m^{-1}]**	**85**	**85**	**85**
T_{exp}	[tex]	14,78	19,71	35,82
		(14,57; 14,99)	(19,37; 20,04)	(35,29; 36,34)
D_{dens}	[mm]	0,1508	0,1671	0,228
D_{cover}	[mm]	0,1838	0,1985	0,2751
l_{1dens}	[mm]	0,0081	0,0086	0,0023
$l_{2\ dens}$	[mm]	0,0183	0,0278	0,0177
$l_{c\ dens}$	[mm]	0,0222	0,0323	0,0313
$l_{1covers}$	[mm]	0,0065	0,0067	0,002
$l_{2\ cover}$	[mm]	0,00002	0,00006	0,00007
$l_{c\ cover}$	[mm]	0,0127	0,0232	0,0158



Measurement principle - IS - 22-10-01 / 01



a) theoretical and experimental curve of hairiness *Z(r)* b) detail of hairiness curve – partial hairiness component (dense and loose)
Fig. 19 Yarn hairiness curve evaluation

Outputs: „the hairiness curve" *Z (r)*, yarn diameter (D_{dens}, D_{cover}), integral hairiness characteristics ($I_{1\ cover}$, $I_{2\ cover}$, $I_{c\ cover}$, $I_{1\ dens}$, $I_{2\ dens}$, $I_{c\ dens}$), estimation of yarn packing density trend $\mu(r)$, fiber packing density in the area of hairiness ($\mu_{1\ cover}$, $\mu_{2\ cover}$, $\mu_{c\ cover}$, $\mu_{1\ dens}$, μ_{2dens}, $\mu_{c\ dens}$).

Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. 7th *International conference Strutex*. Technical University of Liberec, Czech Republic 2000.

Measurement principle - IS - 22-10-01 / 01

Reasons for modification and problematic part of the current methodology:

- ✓ the need to verify the methodology on a large number of different types of yarns (the reproducibility and repeatability of measurements),
- ✓ to compare the results with other available methods for yarn hairiness assessment,
- ✓ to analyse variability sources of obtained data.

Fig. 20 An example of creating a sum matrix for hairiness curve - the influence of method used for yarn axis determination

If the first and second estimation of yarn axis position differs more than ½ of fiber diameter, the correction is necessary. The diversity can be given by rotation of yarn sample during scanning. If the yarn is not correctly pre-stressed and its longitudinal view is curved, than the image is excluded from the evaluation.

Measurement principle - IS - 22-10-01 / 01

The method of the image thresholding, way of finding the yarn axis position, choosing the magnification and resolution of the image, the total "processed yarn length" and assessing the variability of the results.

Fig. 21 An example of yarn axis position estimation - original and modified methodology

Measurement principle - IS - 22-10-01 / 01

The method of the image thresholding, way of finding the yarn axis position, choosing the magnification and resolution of the image, the total "processed yarn length" and assessing the variability of the results.

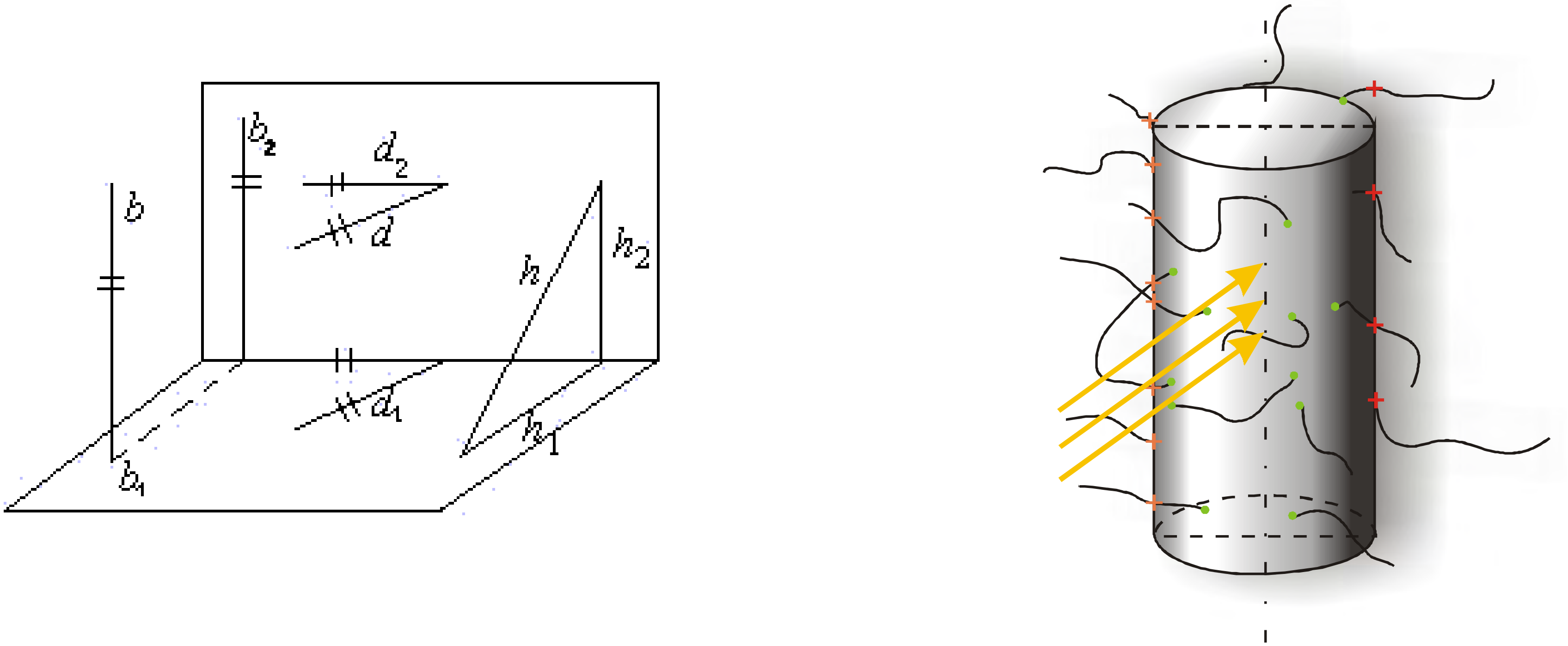
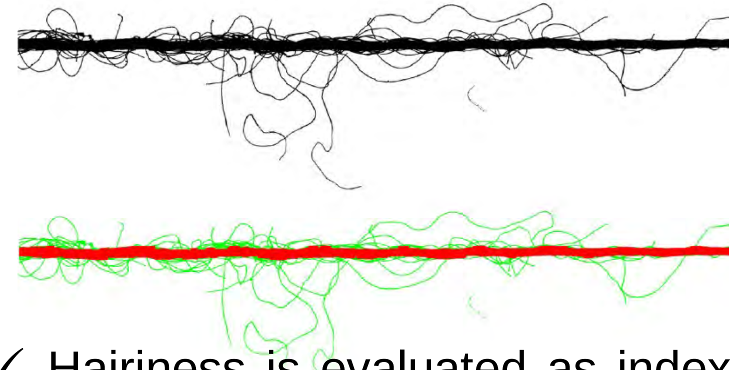


Fig. 22 Monge's projection and definition of "hairiness"

Other measuring systems



$$H_{[-]} = \frac{S_{\text{whole yarn}}\left[mm^2\right]}{S_{\text{hairs}}\left[mm^2\right]}$$

Fig. 23 An example of Binary image

a) longitudinal view of yarn
b) area of yarn hairiness – green (area of yarn body - red)

- ✓ Hairiness is evaluated as index based on proportion of the area of the protruding fibers out of yarn surface and area of yarn body. Yarn body is defined as the compact part of the yarn. The obtained colour images of longitudinal yarn views are transformed into a binary form and morphological operations allow to the define yarn body via dilation, erosion, sceletonization, opening and closing of the image, filling of holes…etc.

Ozkaya Y., Acar M., Jackson M. R. Digital image processing and illumination techniques for yarn characterization. *Journal of Electronic Imaging* 14(2), 2005.

Wang R., Zhou J., Yu L., Xu B. Fusing multifocal images for yarn hairiness measurement. Optical Engineering 53(12), 2014. Guha A., Amarnath C., Pateria S., Mittal R. Measurement of yarn hairiness by digital image processing. *The Journal of The Textile Institute*, 101(3) 2010.

Fabijánska A., Jackowska-Strumillo L. Image processing and analysis algorithms for yarn hairiness determination. *Machine Vision and Applications* 2012.

Carvalho V., Soares F., Vasconcelos R., Belsley M., Goncalves N. *Yarn hairiness determination using image processing techniques*. IEEE EFTA 2011, Toulouse, 2011.

Yuvaraj D. a Nayar R. Ch. A simple yarn hairiness measurement setup using image processing techniques. Indian *Journal of Fiber and Textile Research*, 37 (12), 2012.

Sharma S., Shinde S. Yarn hairiness determination using image processing. *IOSR Journal of Electronics and Communication Engineering*, 11(5), 2016.

Cybulska M. Assessing yarn structure with image analysis methods. *Textile Research Journal* 69(5), 1999.

Other measuring systems

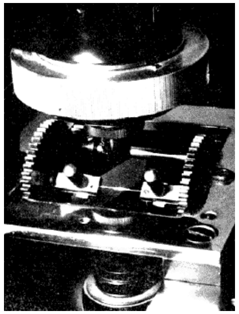
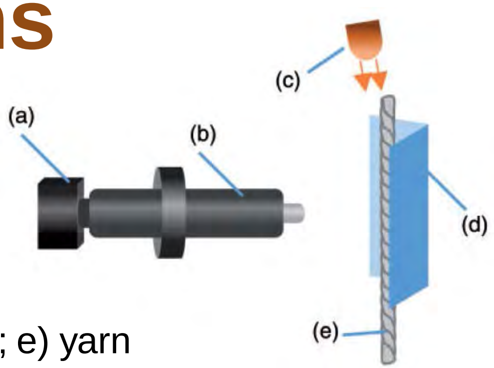


Fig. 24 Photometer Zeis – methodology of Ronse

Fig. 25 Experimental set up
a) camera; b) microscope;
c) lighting system; d) mirrors; e) yarn



- ✓ Optical methods based on scanning yarn from multiple directions, definition of hairiness with respect to the obtained spatial data. Possibility to use focusing in multiple planes, composition of 3D image.
- ✓ Ronse methodology: The yarn is clamped in a special device that allows it to rotate around the axis. The samples are measured in twelve planes, perpendicular to the yarn axis. For simplicity, the convention establishes three basic areas of yarn - the yarn body (90% absorbency), the area of frequent occurrence of fibers (30% absorbency) and the area of occurrence of long protruding fibers (10% absorbency).
- ✓ Processing of two perpendicular projections using two CCD cameras for evaluation of the yarn profile, detection of diameter fluctuations and material non-uniformity of the yarn depending on the measured length. The hairiness of the yarn could be evaluated by modifying the existing system of obtained images.

Wang L., Xu B., Gao W. Multi-perspective measurement of yarn hairiness using mirrored images. *Textile Research Journal* 88(6), 2018.

Gordon S. The effect of short fibre and neps on Murata Vortex spinning. *The Australian Cottongrower*, 23(1), 2002., available http://www.greenmountpress.com.au/cottongrower/.

Dennard J. ITMA 2003 Exhibitors*. Textile World*, 153(9), 2003.

Methods of yarn hairiness evaluation

All methodologies and devices have their own limitations!

- ✓ Uster ® tester, Premier Tester 7000 and Kaisoki Laserspot provide only a cumulative hair index and hair diagram.
- ✓ Zweigle G567 hairiness tester, Zweigle ® Uster HL 400 and Criter Dam II neglect the occurrence of fibers near the yarn surface and focus only on fibers at greater distances from the yarn detected only from a limited section of space (total hairiness criterion S_3).
- ✓ All commercial devices are used in practice, they are able to measure continuously at a high speed, usually 400 $mmin^{-1}$, ensuring the repeatability and reproducibility of measurements, stability of results. The obtained measured data are usually processed by standard statistical analysis and interpreted in tables and graphs.
- ✓ Laboratory methods allow to get broader context. They often provide more information or allow to detect more types of hairiness parameters. The yarn scanning and image processing is realized by image analysis associated with the camera and optical elements. The method of data evaluation can provide and summarize results in a standardized way or offer other characteristics. Measurements is usually provided in the laboratory or online on production machine.

Factors affecting yarn hairiness

- ✓ **fiber properties** (type, length, fineness, resp. diameter and shape of cross-section, flexural and torsional rigidity, strength and elongation at break, coefficient of friction; for cotton fibers also the purity of the raw material and for wool or synthetic fibers the degree of crimp and resistance to compression),

- ✓ **geometric parameters of the yarn** (yarn count, twist, or mixed proportion, type of length fabric in terms of - single, two or more folded, fancy yarn),

- ✓ **yarn production technology** (type of production and its setting, post processing technology influencing the arrangement of the fibers in the yarn),

- ✓ the results obtained may be influenced by the type of used instrument, the measurement methodology, the procedure for results evaluation, the parameters used for characterizing the abrasion resistance, the testing conditions (humidity, speed, number of measurements) and the sampling method.

Factors affecting yarn hairiness

Quality and type of fibrous material

- ✓ The quality of the fibrous raw material affects the quality of the yarns, but it is not very significant for yarn hairiness, the interaction among the fineness of fibers (respectively diameter and density of fibers), the fiber length and the surface friction among fibers are more important.
- ✓ When comparing hairiness of yarns from various types of fibrous raw material with the same fiber fineness, it can be expected that with increasing fiber density, fibers have a lower diameter, what will result in a positive change of yarn unevenness, increase of strength and decrease of yarn hairiness.
- ✓ When comparing hairiness of yarn spun from various fibrous raw material with a fineness corresponding to the same fiber diameter for all compared materials, the effect of fiber diameter is eliminated and the resulting yarn quality will reflect only the nature of the material related to e.g. surface friction.
- ✓ Yarns made of synthetic materials show a slightly higher degree of hairiness than cotton yarns.

Steadman R. G. Cotton Testing. *Textile Progress*, 27(1). The Textile Institute 1997.

El Mogahzy Y. E., Broughton R. M. Jr. and Guo A. Cotton fiber Friction: The Unknown Quality of Cotton. *Proceeding of Beltwide Cotton Conferences*. January 7-10, 1997, New Orleans, Louisiana, USA, (online) www.cotton.org/beltwide/proceedings/1991-2004/data/conferences/1997/papers/594.pdf#page=1#page=1.

Jackovski T., Cyniak D., Czekalski J. The influence of the fibre parameters and the feeding stream on the quality of yarn of the cotton like type. *8th International Cotton Conference in Gdynia*, 22. 23. September 2005, Gdynia – Poland. Proceeding of Conference.

Barella A., Manich A. M. Yarn Hairiness Update. *Textile Progress*, 26(4). The Textile Institute 1997.

Factors affecting yarn hairiness

Geometric characteristics of yarn

- ✓ The results confirm the relationship among yarn count, packing density, diameter, hairiness and strength. In general, in the case of yarns spun from the same material, the similar technology, with constant yarn count and constant twist coefficient, is also the same level of packing density, diameter, hairiness and strength.
- ✓ With increasing yarn count, the number of fibers in the yarn cross section increases, the yarn diameter increases, the packing density decreases, the unevenness decreases, the number of faults decreases, the hairiness increases and the strength increases.
- ✓ As the twist coefficient increases, the concentric pressure increases, which is caused by the surface layers of the fibers in the yarn. The yarn diameter decreases, the packing density increases, the yarn hairiness decreases, and the yarn strength increases. The affect of twist is more visible in case of ring yarns because of open end spun yarn are usually produced with higher twist.

Steadman R. G. Cotton Testing. *Textile Progress*, 27(1). The Textile Institute 1997.
Barella A. Yarn – Hairiness Studies To – Day. *Journal of Textile Institute*, 66(10), 1975.
Krifa M., Ethridge M. D. A qualitative approach to estimating cotton spinnability limits. *Textile Research Journal*, 74(7), 2004.
Barella A., Manich A. M. Yarn Hairiness Update. *Textile Progress*, 26(4). The Textile Institute 1997.
Krupincová G., Křemenáková D., Neckář B., Voborová J., Das D.: Analysis of selected properties of Novaspin yarns. Research report, 29.3. 2005. Research Centre Textile I, LN 00B090 (Partly in Czech).

Factors affecting yarn hairiness

Yarn production technology

- ✓ The production process is a complex system, where the functionality of the sub-segments and the overall adjustment play a major role.

If the technology is considered as a whole, it can be expected:

- ✓ Ring yarns are characterized by a well-arranged structure, which relates with a good level of yarn unevenness, a certain level of hairiness, a relatively high strength.
- ✓ Compact yarns are characterized by a well-arranged structure, with an excellent level of yarn unevenness, relatively low level of hairiness and relatively high strength.

Barella A. Yarn Hairiness. *Textile Progress*, 43(1). The Textile Institute 1983.

Barella A., Manich A. M.. Yarn Hairiness: A Further Update. Textile Progress, Vo. 31, Nr. 4. The Textile Institute 2002, pp. 44,

Barella A. Yarn Hairiness: A survey of resent literature and a description of a new instrument for measuring yarn hairiness. Journal of Textile Institute, 61(9),1970.

Barella A. Recent developments in yarn – hairiness studies. *Journal of Textile Institute*, 64(10), 1973. ISSN: 0040-5000.

Basal G., Oxenham W. Comparison of properties and structures of compact and conventional spun yarns. *Textile Research Journal*, 76(7), 2006.

Barella A. Yarn – Hairiness Studies To – Day. *Journal of Textile Institute*, 66(10), 1975.

Militký, J. Complex Evaluation of Cotton Fibre Quality. Proc. *World Textile Congress*, Sri Lanka, March 2007. Proceeding of conference.

Thilagavathi G., Karthik T. *Process Control and Yarn Quality in Spinning*. Woodhead Publishing India PVT, 2015.

Factors affecting yarn hairiness

Yarn production technology

- ✓ The design of Novaspin technology is very close to ring technology. Novaspin yarns appear to be bulkier with a looser arrangement of fibers in the surface areas of the yarn, they show slightly higher diameter and hairiness, slightly lower strength, but with the usual degree of twist it is possible to achieve comparable results with conventional yarns.

- ✓ Rotor yarns are characterized by a less ordered internal structure with wraps (belt fibers) on the yarn surface, higher diameter, lower hairiness and strength than ring yarns at the same level of twist. For this reason, rotor yarns are produced with a higher twist, so that their mechanical properties correspond to conventional yarns.

Barella A., Manich A. M. Yarn Hairiness Update. *Textile Progress*, 26(4). The Textile Institute 1997.

SolospunTM Weavable Singles Yarn, Wronz Developments, Ltd. Wool Research Organization of new Zealand (Inc.). Internal promotional materials.

Rasesh J. Ch., Hansen S. M, Jazarman S. Structure and properties of AirJet spun yarns. *Textile Research Journal*, 60(2), 1990.

Soe A. K., Takahashi M., Nakajima M. Structure and properties of MVS Yarns in comparison with ring yarn and open-end rotor spun yarn. *Textile Research Journal*, 74(9), 2004.

Basal G., Oxenham W. Effect of some process parameters on the structure and properties of Vortex spun yarn. *Textile Research Journal*, 76(6), 2006.

Factors affecting yarn hairiness

Yarn production technology

When assessing the influence of individual processes or the type of used parts and their setting. Influencing factors include:

- ✓ Quality of input source - sliver/ roving.
- ✓ For ring spinning technology - type of traveller, setting of drafting zone and delivery speed.
- ✓ For rotor technology – size of rotor, surface treatment of a rotor and type of rotor groove, type of used navel and twist stop element.
- ✓ …

Chaudhuri A. Effect of spindle speed on the properties of ring spun acrylic yarn. *IE (I) Journal – TX,* 84, 2003.
Cheng K. P. S., Li C. H. L.: JetRing spinning and its influence on yarn hairiness. *Textile Research Journal*, 72(12), 2002. Patnaik A., Rengasamy R. S., Kothari V. K., Ghosh A., Punekar H. Hairiness reduction of yarns by nozzles at ring spinning airflow stimulation approach. *Journal of Textile and Apparel*, *Technology and Management,* 4 (4), 2005.
Owen P. New system promises fine worsteds at lower cost. *Textile World*, 150(11), 2000. Textile Industries Media Group, Billian Publishing, Inc.
Chang L., Wang X. Comparison the hairiness of solospun and ring spun worsted yarns. *Textile Research Journal*, 73(7), 2003. Lang J., Shukang Z., Pan N. Changing yarn hairiness during winding – analysing the trailing fiber ends. *Textile Research Journal*, 74(10), 2004.
Lang J., Shukang Z., Pan N. Change of yarn hairiness during winding process: Analysis of the protruding fiber ends. *Textile Research Journal*, 76(1), 2006.
Adanur S., Turel T.: Effects of air and yarn characteristics in Air-Jet filling insertion. Part II.: Yarn velocity measurements with profiled reed. *Textile Research Journal*, 74(8), 2004.

Modelling and prediction possibility of yarn hairiness

Neckar's probability model of hairiness:

- ✓ It is based on the idea of image processing by Lappage and Onions and Barella's methodology and it is developed into a theoretical probabilistic model of fiber distribution in the area of yarn hairiness.
- ✓ The inner (compact) part of the yarn is the result of mechanical compression of fibrous material in the twisting process. The compact part can be described by an imaginary cylinder, which also defines the yarn diameter D or yarn radius $r_D = ½ D$. The area of hairiness is placed on the radius $r > r_D$, it consists from fibre segments protruding from the yarn and it is randomly distributed in this sphere.
- ✓ The image of yarn longitudinal view can be divided by imaginary cuts at given distances $r > r_D$. The relative occurrence of fibers depending on the distance from the yarn axis (the proportion of absorbed light at the distance r from the yarn axis) can be determined.

Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. *7th International conference Strutex*. Technical University of Liberec, Czech Republic 2000, ISBN: 80-7083-442-0.

Modelling and prediction possibility of yarn hairiness

Neckar's probability model of hairiness:

- ✓ If the relative occurrence of fibers (fiber ends, loops, etc.) is random the exponential function can be used for description of fiber distribution in hairiness sphere. The function *P(r)* express probability that the light beam pass in given distance from yarn axis *r* and wouldn't be absorb by fibres. The function *Z(r)* is called hairiness curve (blackening function).

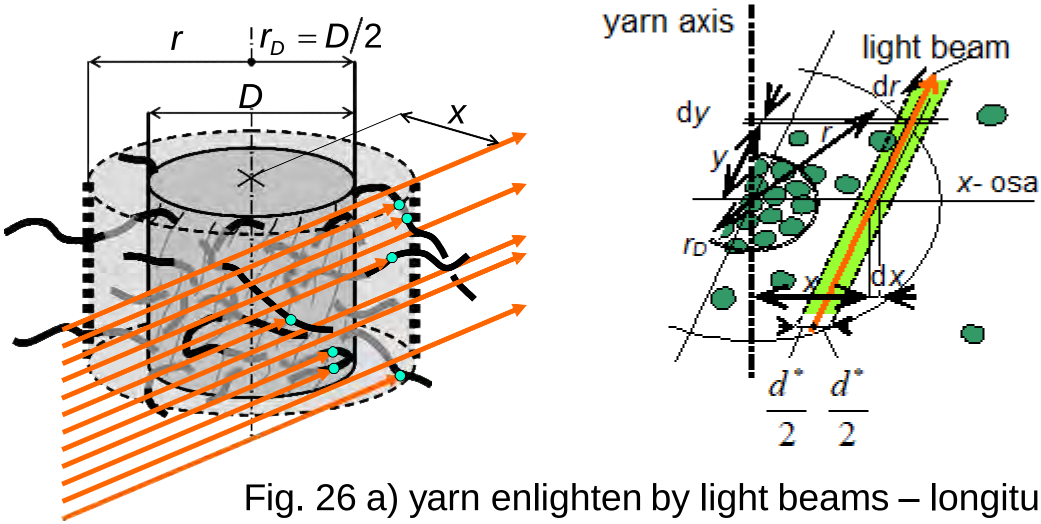


Fig. 26 a) yarn enlighten by light beams – longitudinal view

b) yarn enlighten by light beams – cross-section

Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. 7th *International conference Strutex*. Technical University of Liberec, Czech Republic 2000, ISBN: 80-7083-442-0.

Modelling and prediction possibility of yarn hairiness

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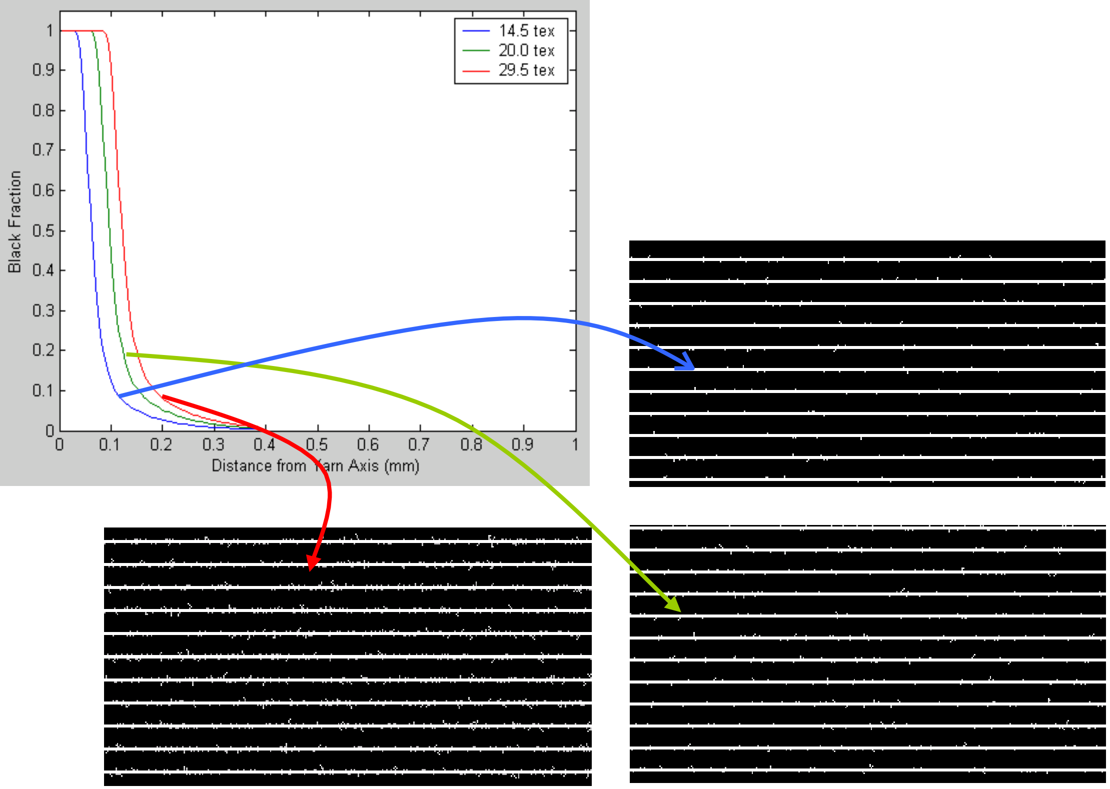
$$C_i = \mu_{hi}\, r\, 2^{\frac{r}{h_i}} \qquad I_H = -\ln(P_i) = \frac{8}{\pi d^2 \ln 2}\sum_{i=1}^{N} h_i C_i \left(\int_0^{\pi/2} 2^{-\frac{x-d/2}{h_i \cos\alpha}} d\alpha - \int_0^{\pi/2} 2^{-\frac{x-d/2}{h_i \cos\alpha}} d\alpha \right)$$

Ci yarn parameter, μ_{hi} packing density of hairs, h_i half decrease interval of number of protruding fibers, *r* yarn radius, I_H integral characteristic of hairiness, P_i probability that the light beam passes without problems at the distance *x*, *d* fibre diameter, α variable.

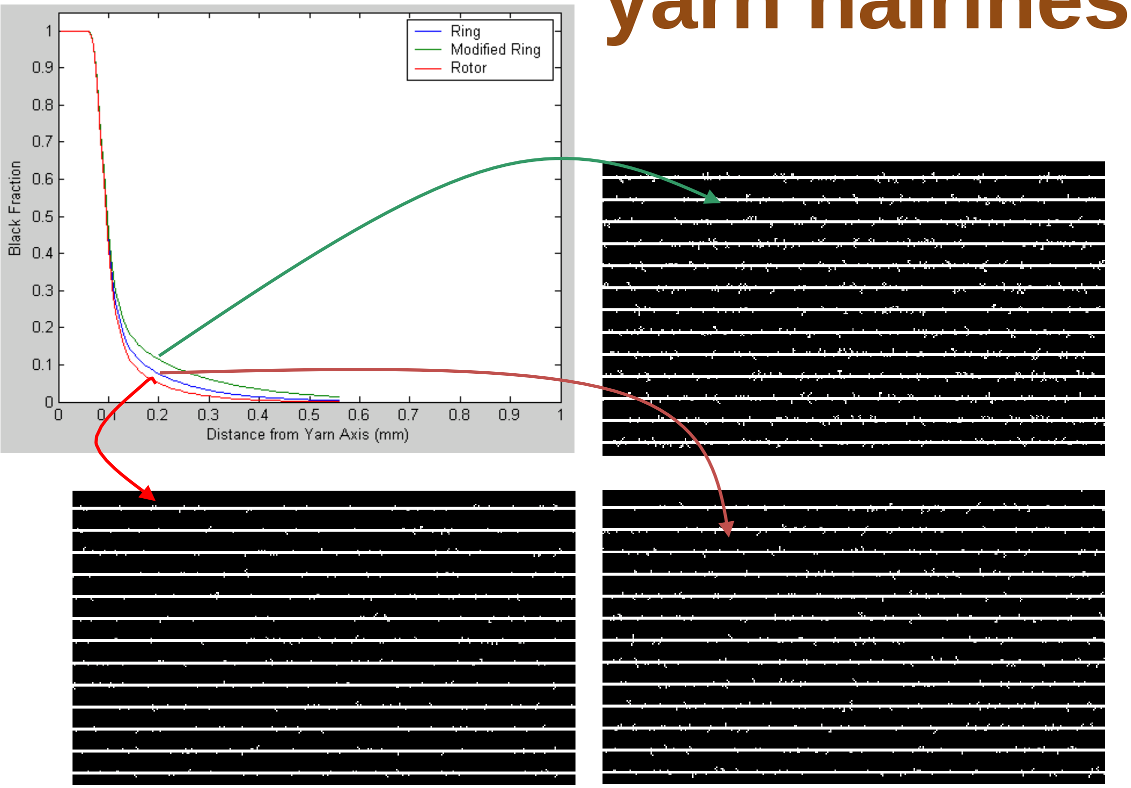
Neckář B. Yarn Hairiness, Part 1: Theoretical model of yarn hairiness. *7th International conference Strutex*. Technical University of Liberec, Czech Republic 2000, ISBN: 80-7083-442-0.

Modelling and prediction posibility of yarn hairiness



Outputs: trend of hairiness curve $Z(r)$, yarn diameter (D_{dens}, D_{cover}), integral characteristic of hairiness ($I_{1\ cover}$, $I_{2\ cover}$, $I_{c\ cover}$, $I_{1\ dens}$, $I_{2\ dens}$, $I_{c\ dens}$), trend of yarn packing density $\mu(r)$, yarn packing density of hairs ($\mu_{1\ cover}$, $\mu_{2\ cover}$, $\mu_{c\ cover}$, $\mu_{1\ dens}$, μ_{2dens}, $\mu_{c\ dens}$)

Modelling and prediction possibility of yarn hairiness



Outputs: trend of hairiness curve $Z(r)$, yarn diameter (D_{dens}, D_{cover}), integral characteristic of hairiness ($I_{1\ cover}$, $I_{2\ cover}$, $I_{c\ cover}$, $I_{1\ dens}$, $I_{2\ dens}$, $I_{c\ dens}$), trend of yarn packing density $\mu(r)$, yarn packing density of hairs ($\mu_{1\ cover}$, $\mu_{2\ cover}$, $\mu_{c\ cover}$, $\mu_{1\ dens}$, μ_{2dens}, $\mu_{c\ dens}$)

Modelling and prediction possibility of yarn hairiness

Stochastic modelling of yarn hairiness:

- ✓ It is possible to use statistical procedures based on time series processing and signal processing theory.
- ✓ Militký introduced a procedure consisting in the analysis of raw yarn hairiness data measured on the Uster®Tester 4. The obtained data are tested in terms of stationarity, independence, linearity, ergodicity and normality.
- ✓ Yarn hairiness is evaluated on the basis of three components: periodic variability, random variability and complexity. The Hurst exponent and fractal dimensions are calculated from the power spectral density PSD.
- ✓ Histogram with a constant or variable number of classes is used as an estimation of the empirical probability density function of hairiness. A combination of the densities of the normal Gaussian distribution can be used as replacement of the empirical probability density function of hairiness. From the available results, it is clear that the bimodal normal Gaussian model is usually suitable for the description of the empirical probability density, which indicates the occurrence of two types of hair.

Militký J., Křemenáková D. Comparison of Complex Indices for Cotton Fiber Quality Characterization. Proceeding of World Cotton Research Conference - 4. *Cotton High-Tech Fiber*. 10-14. September 2007, International Textile Center, Texas Tech University, Lubbok Memorial Civic Center, Lubbock, Texas USA.

Modelling and prediction possibility of yarn hairiness

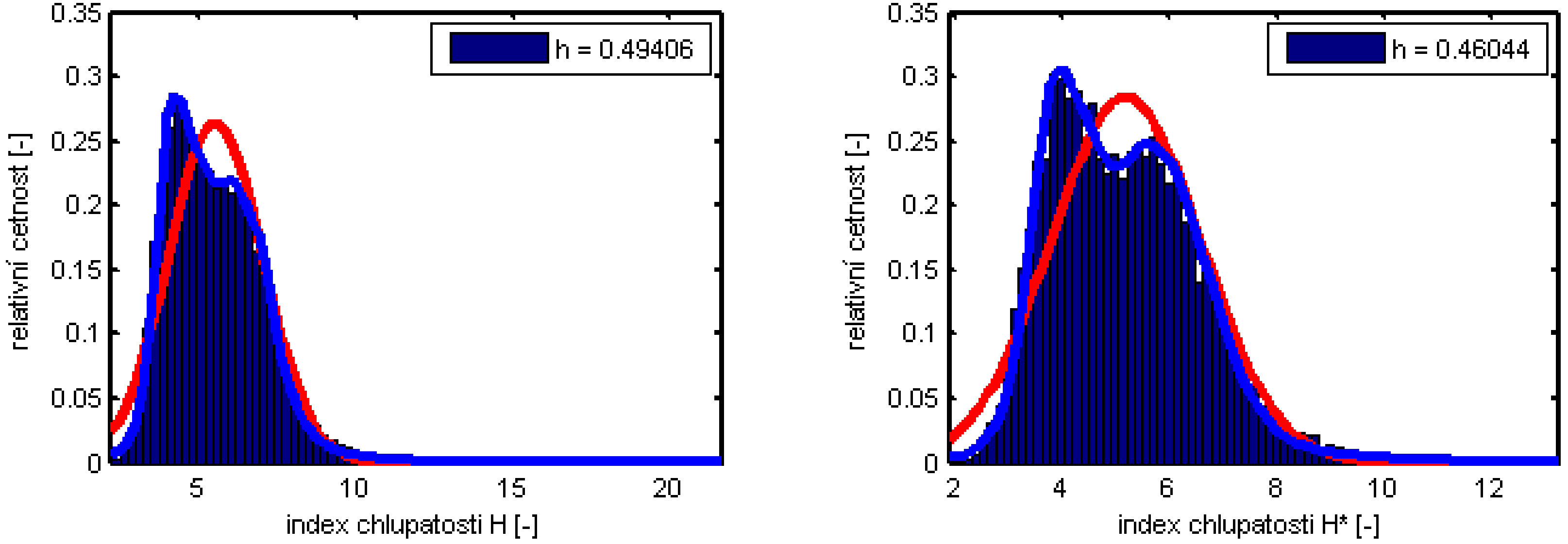


Fig. 27 a, b Histograms of yarn hairiness index *H* - ring spun yarn 19,8 tex 100 % CO carded

Outputs: yarn hairiness index *H, resp. H** and partial indexes of hairiness H_1, H_2, standard deviation of yarn hairiness index *sh* and standard deviations of hairiness indexes sh_1 a sh_2, portion of hairiness components $portion_1$, $portion_2$.

Militký J., Křemenáková D. Comparison of Complex Indices for Cotton Fiber Quality Characterization. Proceeding of World Cotton Research Conference - 4. *Cotton High-Tech Fiber*. 10-14. September 2007, International Textile Center, Texas Tech University, Lubbok Memorial Civic Center, Lubbock, Texas USA.

Modelling and prediction possibility of yarn hairiness

- ✓ The simplest model for the explained variable is proposed based on the explanatory variables. Usually the linear or non-linear regression models are used.

An example of linear regresion model for 100% CO yarn – Uster®Statistic.

Ring spun yarn - combed - $T < 15$tex

$H_{U\ 50\%} = 16{,}5993\ (590/\ T)^{-0{,}38018}$

$H_{U\ 5\%} = 5{,}9177\ (590/\ T\ )^{-0{,}18277}$

$H_{U\ 95\%} = 35{,}4762\ \ (590/\ T\ )^{-0{,}52115}$

Compact spun yarn - carded

$H_{U\ 50\%} = 19{,}6786\ \ (590/\ T)^{-0{,}50769}$

$H_{U\ 5\%} = 13{,}846\ \ (590/\ T\ )^{-0{,}44966}$

$H_{U\ 95\%} = 25{,}5793\ \ (590/\ T\ )^{-0{,}53828}$

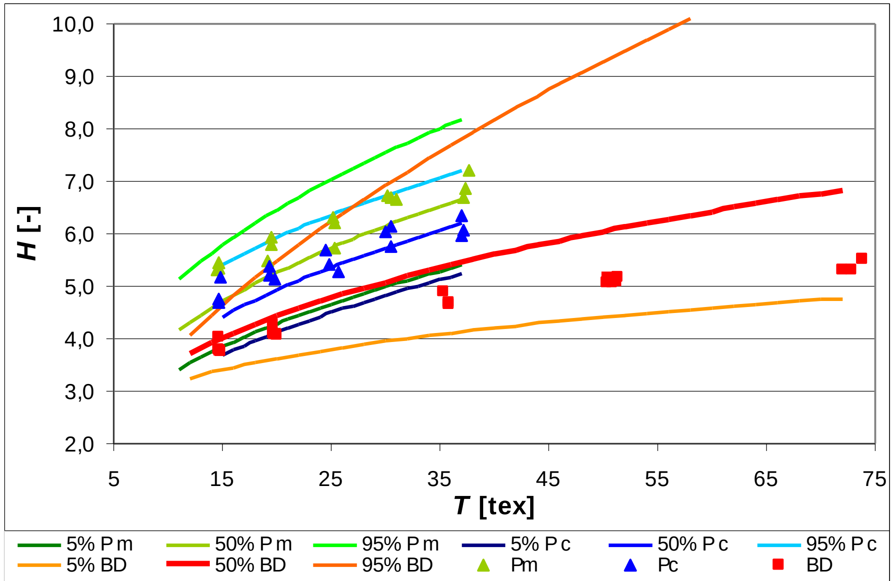
Open end spun yarn

$H_{U\ 50\%} = 13{,}9343\ \ (590/\ T)^{\ -0{,}33833}$

$H_{U\ 5\%} = 7{,}4797\ \ (590/\ T\ )^{-0{,}21373}$

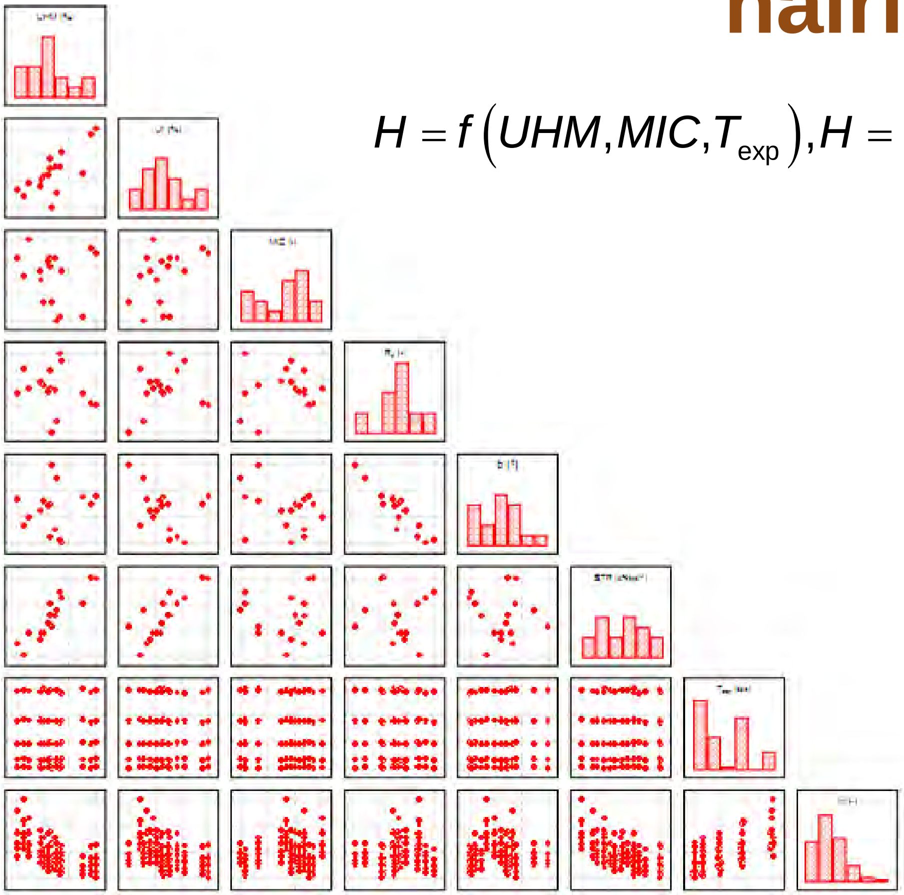
$H_{U\ 95\%} = 38{,}4026\ \ (590/\ T\ )^{-0{,}57526}$

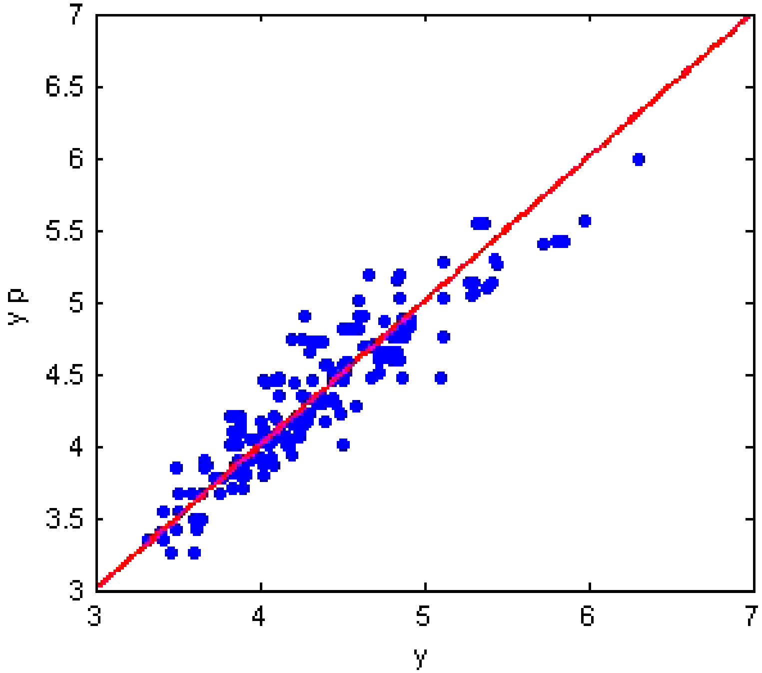
$$H = f\left(T\right) = b_1 T^{b_2}.$$



Modelling and prediction possibility of yarn hairiness

$$H=f\left(UHM,MIC,T_{\exp}\right),H=f\left(\frac{1}{UHM},MIC,T_{\exp}^{1/2}\right),H=f\left(\frac{1}{UHM},MIC,T_{\exp}^{2/3}\right).$$





An example of linear regression model for estimation of yarn hairiness index *H* for the set of open-end spun yarn 100% CO, scatter plot of selected properties of cotton fibers and yarn hairiness index *H,* comparison of predicted y_p and measured *y* yarn hairiness index *H*.

Questions for knowledge verification and repetition

- What methods are currently used for yarn hairiness evaluation and what kind of principles are they working on?
- What are the characteristics used for description of yarn hairiness?
- What factors affect the degree of yarn hairiness and how they influence the level of hairiness?
- Is it possible to estimate the level of yarn hairiness? If so, how?

Thank you for your attention…

FACULTY OF TEXTILE ENGINEERING TUL

CHARAKTER A POVRCHOVÁ STRUKTURA ROTOROVÝCH PŘÍZÍ/ CHARACTER AND SURFACE STRUCTURE OF OE YARNS

Ing. Gabriela Krupincová, Ph.D. / Department of technologies and structures

Aims and motivation

Motivation:

- ✓ Rotor technology is very flexible and used for the production of yarns, the aim is to ensure sufficient quality for the selected product segments or to approach the quality of ring yarn for selected types of products.
- ✓ The aim is to understand the production process, to understand and name the factors that affect the quality of this type of yarns and to enable its development thanks to this knowledge.

Aims and motivation

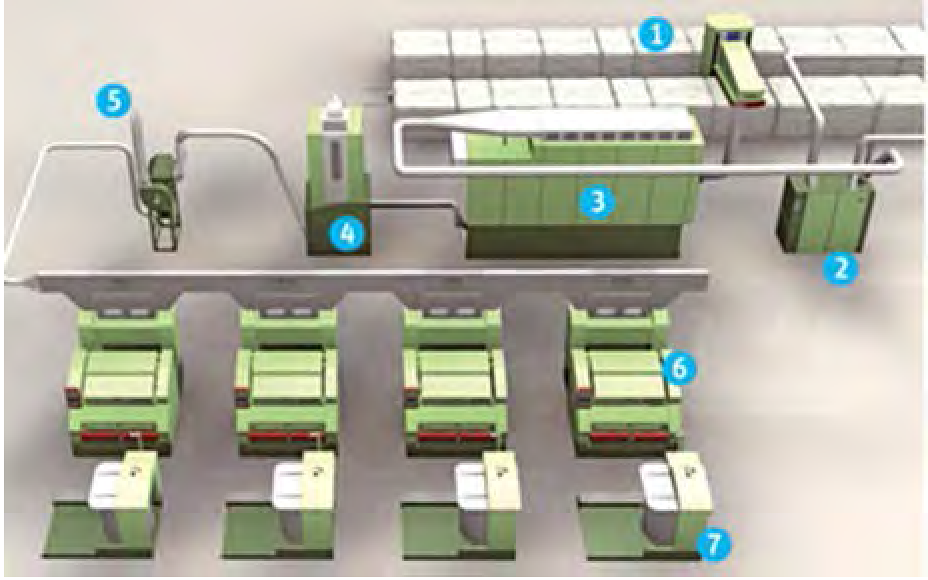
Study of the character and surface structure of rotor yarns allows:

- ✓ to describe important qualitative indicators of rotor spun yarns and find their limits.
- ✓ to make recommendations related to machine setup and the use of different types of machine parts.
- ✓ to provide feedback and verify the quality of the yarn and the production machine itself thanks to this research.
- ✓ indirectly, it provide information to understand the wear rate of machine parts that are in contact with the linear fabric and thus allow maintenance recommendations to be made.

Overview of the current state

- ✓ Basic principle of rotor yarn production - repetition
- ✓ Selected quality indicators of rotor yarns
- ✓ Factors influencing the quality of rotor yarns

Basic principle of rotor yarn production



Raw fibrous material
cotton

OPENING
1 Bale opener
UNIfloc A11 Rieter

CLEANING
2 Pre cleaner UNIclean B12 Rieter

MIXING
3 Homogenous mixer UNImix B75 Rieter
4 Storage and feeding machine UNIstore A78 Rieter
5 Condenser A21 Rieter

CARDING
6 Carding machine C60 Rieter

DRAWING AND DRAFTING
7 Sliver Coiler CBA 4
Draw frame with auto traveller RSB-D 50 Rieter

ROTOR SPINNING
Open end spinning machine R66 Rieter

ROTOR YARN

Carl A. Lawrence *Advances in Yarn Spinning Technology* pp. 261–273, Woodhead Publishing, Oxford 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Klein W. *The Technology of Short Staple Spinning - Manual of Textile Technology.* The Textile Institute, England 1993.

Basic principle of rotor yarn production

Rieter and Gildan spinning process from material preparation for spinning and final quality control

Rotor spinning principal

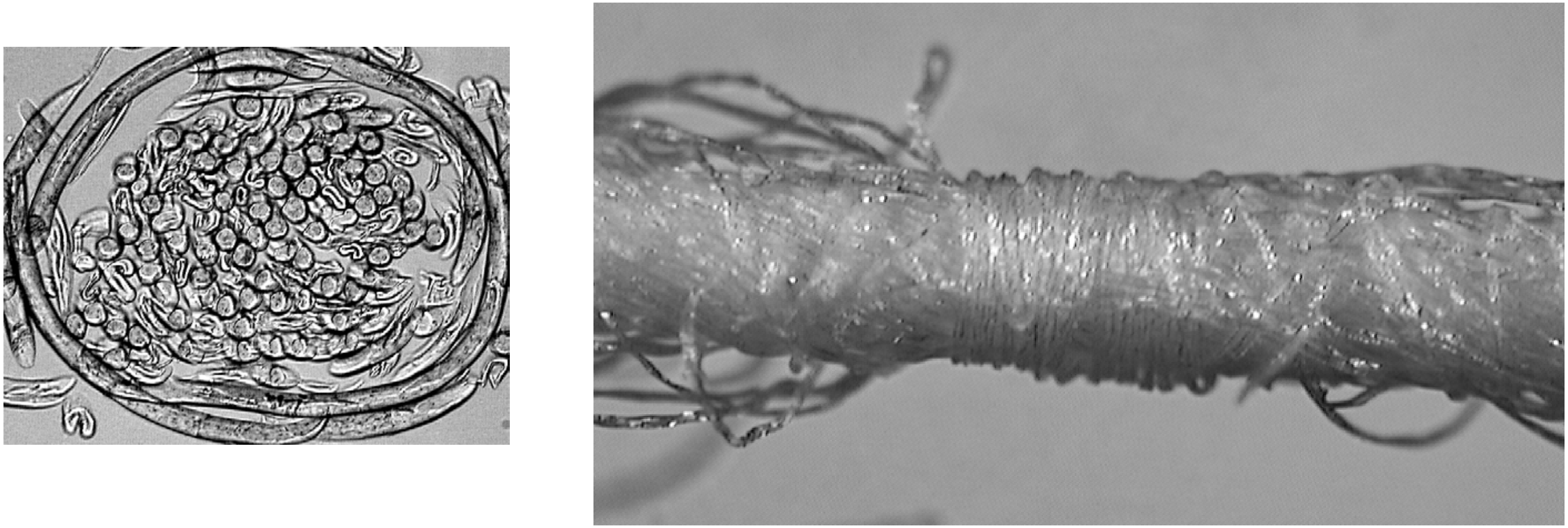


Fig. 2 An example of rotor spun yarn 50 CO /50 VS a) cross section b) longitudinal view

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www.rieter.cz

Svatý V., Hula K. Equipment for the continuous production of yarn. *CZ Patent No. 87947 CZ*, Czech Industrial Property Office, 1956.

Klein, W. *The Technology of Short Staple Spinning - Manual of Textile Technology*. The Textile Institute, England 1993.

Basic principle of rotor yarn production

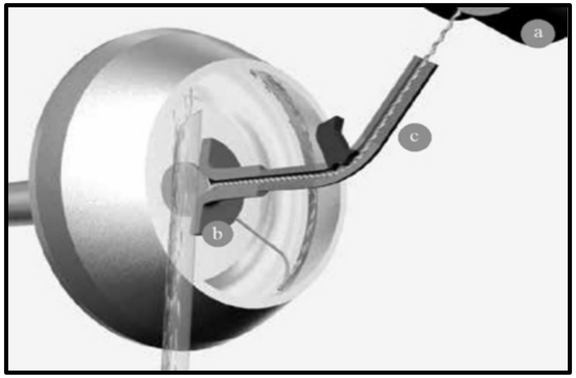


Fig. 3a delivery roller, b navel, c yarn

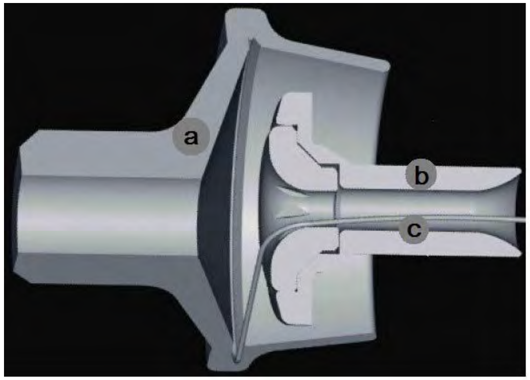


Fig. 4a rotor, b navel, c yarn

- ✓ Open end spinning generally consists of a drafting mechanism, a consolidation mechanism, and a winding mechanism. The drawn sliver is in this technology directly feed to the spinning process and the linkage between twisting and winding is braked. This fact enables higher production in comparison with classical ring spinning system. The sliver is open and individual fibers are fed by an air stream and guided to the rotor inner sliding wall surface. Twist is inserted by the rotation of the rotor making a yarn.
- ✓ To obtain a good spinning stability, the yarn must have sufficient twist at the peeling point where the yarn leaves the rotor groove. The rotation of the yarn around the inner functional wall/ area of draw off nozzle creates an additional false twist on the yarn between the rotor groove and the yarn draw off tube.

Heinz E. *The Rieter Manual of Spinning.* Winterthur: Rieter Machine Works Ltd., 2014.
Balasubramanian, N. Rotor Spinning: Effect of rotor, navel parameters, winding tension. *Bombay Textile Research Association (BTRA)*, 2013.

Basic principle of rotor yarn production

- ✓ The navel (draw off nozzle) selection have to be realized with regard to the processed fibrous material and the purpose of final yarn use (count range, twist level) in accordance with other settings of the spinning machine.
- ✓ It is possible to use the recommendations of machine manufacturers or machine component manufacturers.
- ✓ There are also special software based on optimization (Pareto optimization, MANOVA,…) which can help during decision of navel and other parts application and settings.

Moghassem A. R. Application of TOPSIS Approach on Parameters Selection Problem for Rotor Spinning Machine. *Fibers and Polymers*, 11 (4), 2010.

Moghassem A. R., Bahramzadeh H. Application of multi-criteria analysis for parameters selection problem in rotor spinning machine. *Textile Research Journal*, 80 (20), 2010.

Cheng, Y. S. J. a Cheng, K. P. S. Selecting Processing Parameters that Influence of Rotor Spun Yarn Formed on SDL Quickspin System. *Textile Research Journal*, 74 (9), 2004.

Roudbari B. Y. and Eskandarnejad S. Effect of Some Navels on Properties of Cotton/Nylon66 Blend (1:1) Rotor Spun Yarn and Wrapper Formation: A Comparison between Rotor and Ring Spun Yarn. *Journal of Textiles*, 2013.

Tyagi K., Choudhary A. K. and Varshney R. K. Contribution of draw-off nozzle profile to certain characteristics of acrylic-cotton rotor-spun yarns. *Indian Journal of Fibre & Textile Research*, 21 (12), 1996.

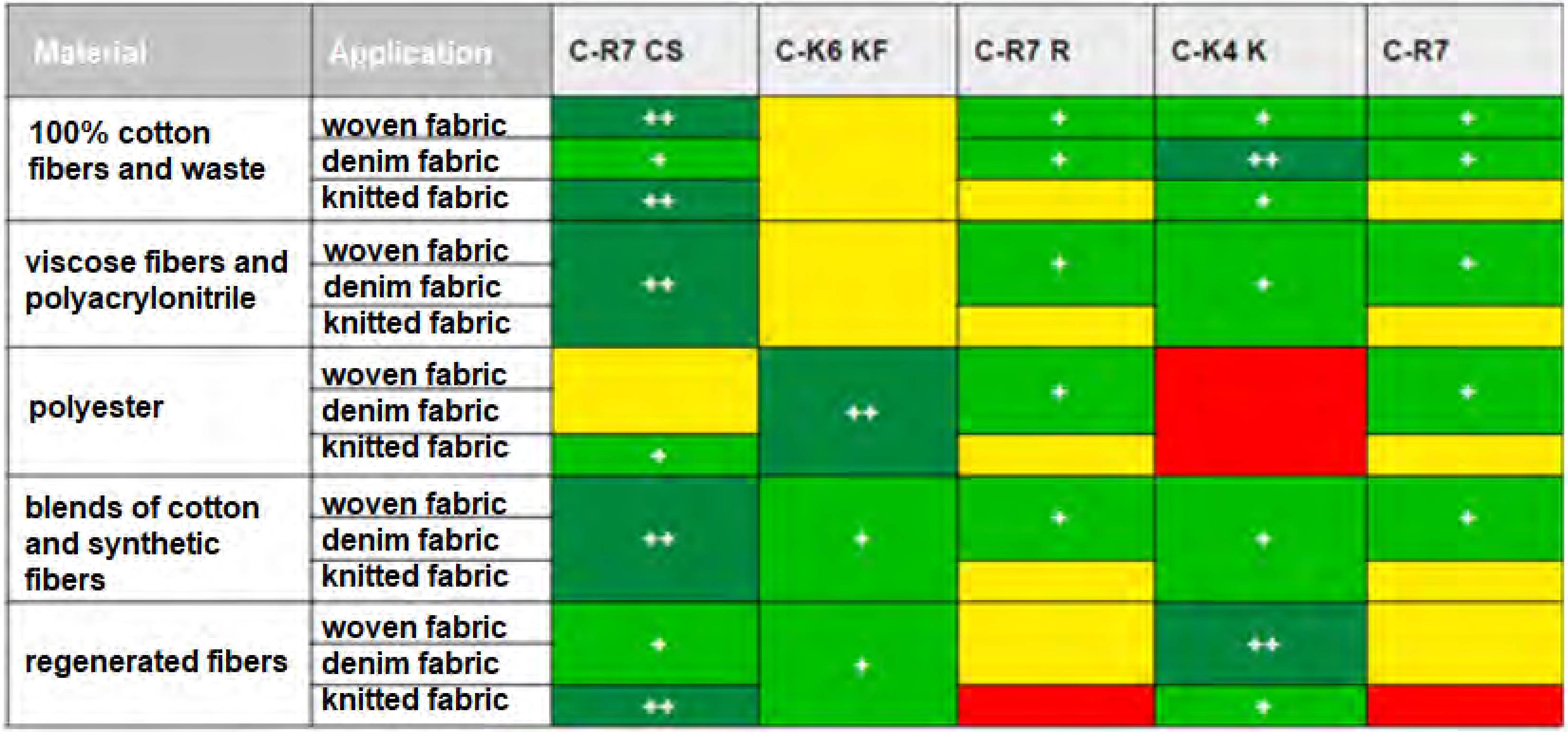
Erbil Y., Babaarslan O. a Baykal P. D. Influence of Navel Type on Hairiness of Rotor Spun Blend Yarns. *Fibres and Textiles in Eastern Europe*. 16 – 2 (67), 2008.

Esfahani, R. T. a Shanbeh, M. Effect of Navel and Rotor Type on Physical and Mechanical Properties of Viscose Rotor Spun Yarns. *Fibres & Textiles in Eastern Europe*. 105 (3), 2014.

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Basic principle of rotor yarn production

Tab. 1 An example of the recommended use of navel for the machine BT 927

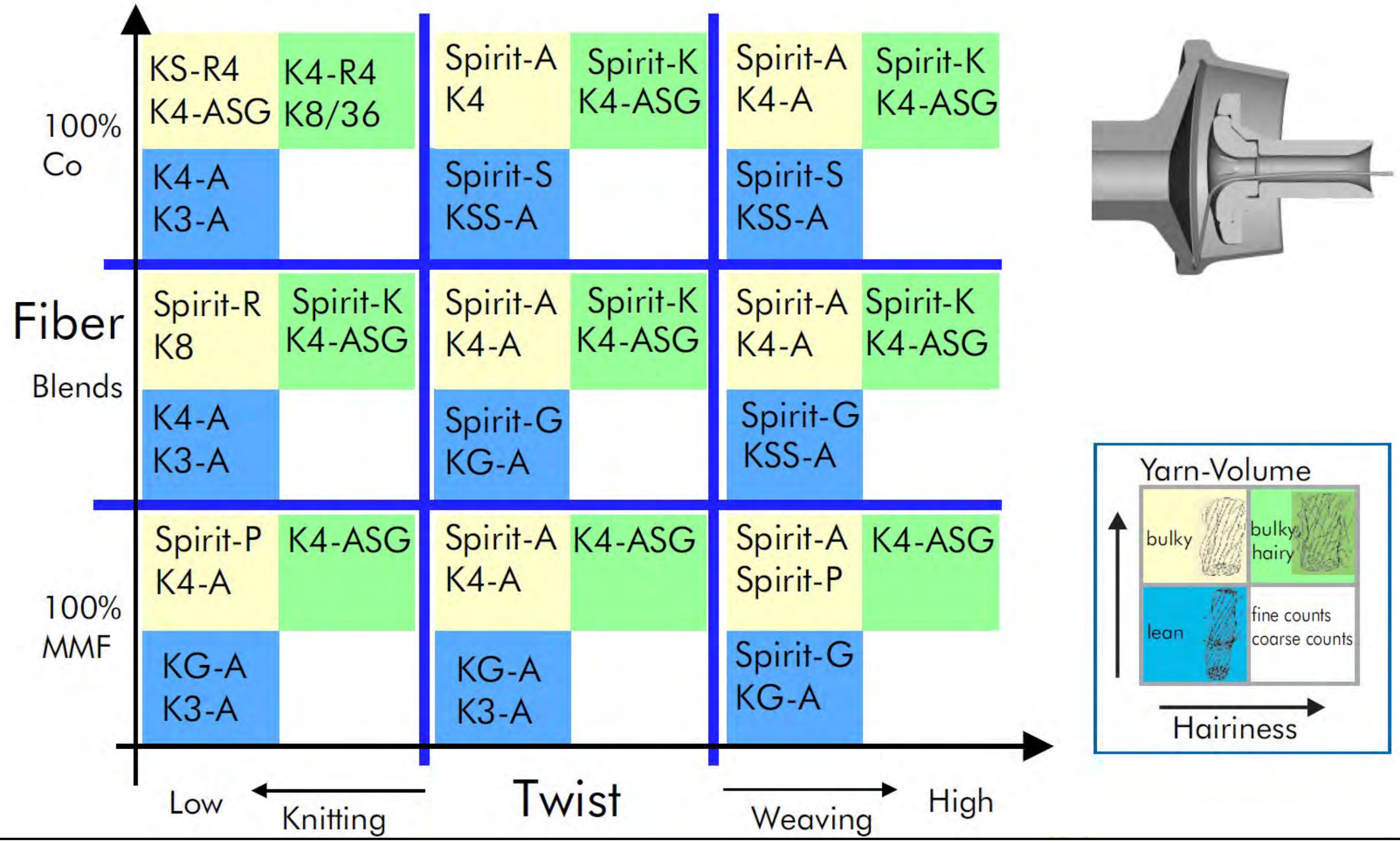


Material	Application	C-R7 CS	C-K6 KF	C-R7 R	C-K4 K	C-R7
100% cotton fibers and waste	woven fabric	++	🟨	+	+	+
	denim fabric	+		+	++	+
	knitted fabric	++		🟨	+	🟨
viscose fibers and polyacrylonitrile	woven fabric	++	🟨	+	+	+
	denim fabric					
	knitted fabric			🟨		🟨
polyester	woven fabric	🟨	++	+	🟥	+
	denim fabric					
	knitted fabric	+		🟨		🟨
blends of cotton and synthetic fibers	woven fabric	++	+	+	+	+
	denim fabric					
	knitted fabric			🟨		🟨
regenerated fibers	woven fabric	+	+	🟨	++	🟨
	denim fabric					
	knitted fabric	++		🟥	+	🟥

Heinz E. *The Rieter Manual of Spinning.* Winterthur : Rieter Machine Works Ltd., 2014.

Basic principle of rotor yarn production

Tab. 2 An example of recommendation of navel selection application



100% Co	KS-R4 K4-ASG	K4-R4 K8/36	Spirit-A K4	Spirit-K K4-ASG	Spirit-A K4-A	Spirit-K K4-ASG
	K4-A K3-A		Spirit-S KSS-A		Spirit-S KSS-A	
Blends	Spirit-R K8	Spirit-K K4-ASG	Spirit-A K4-A	Spirit-K K4-ASG	Spirit-A K4-A	Spirit-K K4-ASG
	K4-A K3-A		Spirit-G KG-A		Spirit-G KSS-A	
100% MMF	Spirit-P K4-A	K4-ASG	Spirit-A K4-A	K4-ASG	Spirit-A Spirit-P	K4-ASG
	KG-A K3-A		KG-A K3-A		Spirit-G KG-A	

OE – Spinning: Navel Selection. Dornbirn: Bröll Textile Systems, 2011.

Sonntag E., Bolze J. Design of Navel and its Influence on Yarn Structure. Melliand Textilberichte *Fibres and Textiles*. 84 (3), 2003.

Selected quality indicators of rotor yarns

- ✓ Standard quality indicators of fiber quality for rotor yarns: fiber characteristics (Uster ®HVI, Uster ®Afis Pro).

- ✓ Standardly determined qualitative indicators of rotor yarn quality: yarn unevenness *CV*, number of faults, yarn hairiness index *H*, summation criteria of yarn hairiness S_{12}, S_3, relative strength *F*, yarn elongation ε, eventually number of break during production and the need of yarn cleaning thanks to information of sensors from production (Uster® Tester 5, Uster ® Zweigle, Uster ® Tensorapid, Uster ® Tensojet, Uster ® Statistics, e.g. Uster / Rieter quality sensors during yarn production).

- ✓ Other characteristics describing the structure of rotor yarns: yarn packing density μ, the way of fibers distribution in the yarn cross - section, parameters of the surface structure of the yarn – wrap fibers (belt fibers).

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www.uster.com.
Křemenáková, D. Rubnerová J. IS 22-103-01/01 Yarn packing density. Direct method and method Secant. FT TUL 2002.
Drašarová J. IS 22-105-01/01 Belt fibers in open-end spun yarn. FT TUL 2002.
Vyšanská M. IS 22-105-01/02 Wrapper fibers in a rotor yarn, modified version. FT TUL 2009.

Selected quality indicators of rotor yarns

- ✓ Wrapper fiber (belt) is defined as one or more fibers wrapped around approximately perpendicular to the yarn axis. The individual belt lie tightly beside each other and partially bind up the yarn.

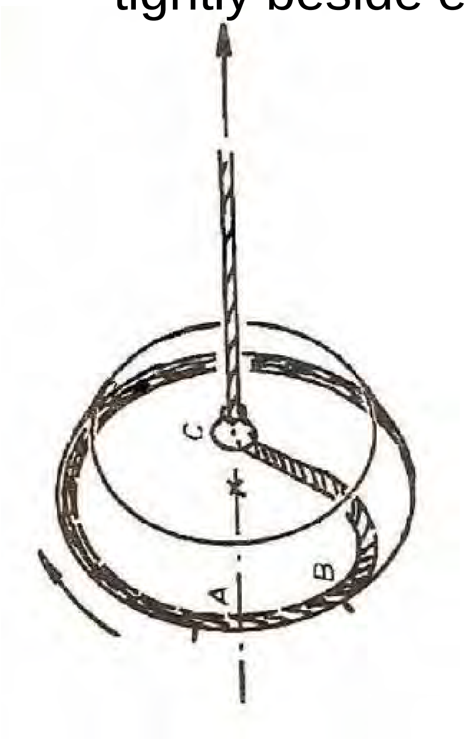


Fig. 5 rotor yarn formation
A-B ribbon of fibers on the rotor surface ,
B-C free end of rotor formed yarn

Neckář B. *Příze. Tvorba struktura vlastnosti,* SNTL 1990, ISBN: 80-03-00213-3 (only in Czech).
Drašarová J. IS 22-105-01/01 Belt fibers in open end spun yarn. FT TUL 2002.
Vyšanská M. IS 22-105-01/02 Wrapper fibers in a rotor yarn, modified version. FT TUL 2009.

Selected quality indicators of rotor yarns

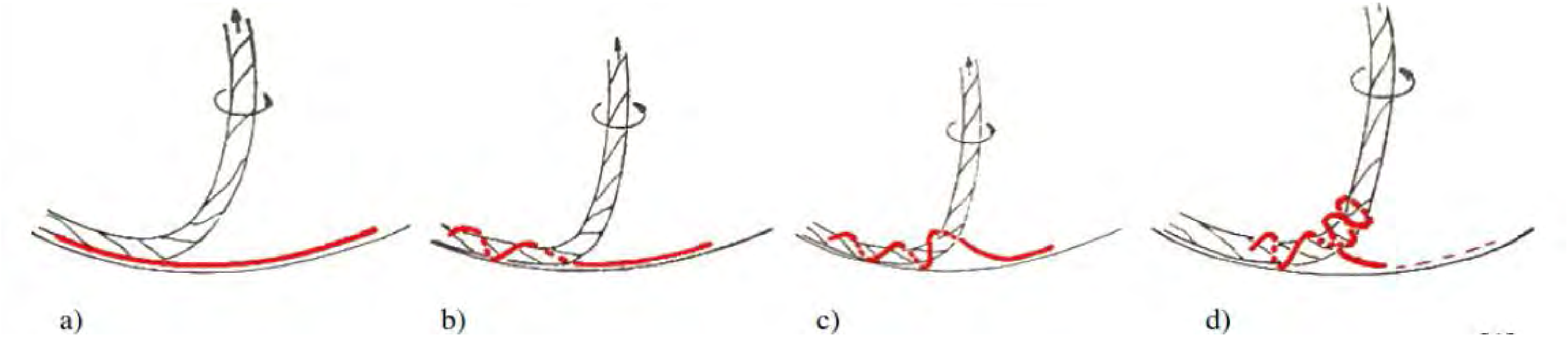


Fig. 6 Formation of wrapper fiber (belt fibers) in the rotor

Neckář B. *Příze. Tvorba struktura vlastnosti,* SNTL 1990, ISBN: 80-03-00213-3 (only in Czech).
Drašarová J. IS 22-105-01/01 Belt fibers in open end spun yarn. FT TUL 2002.
Vyšanská M. IS 22-105-01/02 Wrapper fibers in a rotor yarn, modified version. FT TUL 2009.

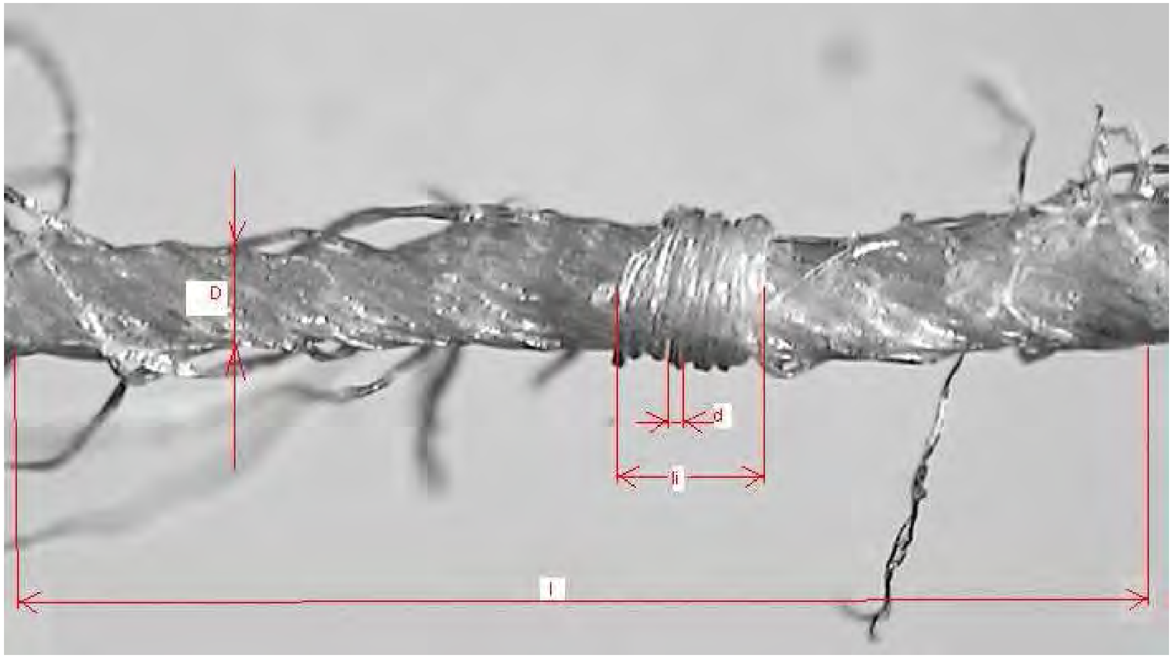
Selected quality indicators of rotor yarns

- ✓ The twisting torque is in the direction for inserting Z-twist into the fibre ribbon, and as a fibre slides down the rotor wall into the rotor groove to become a bridging fibre, its leading end will be caught by the twist insertion point (Fig. 6a).
- ✓ This causes the length landing on the peripheral twist extent to become wrapped in the S-twist direction around the yarn (Fig. 6b).
- ✓ When this short, twist length is peeled from the rotor groove, the bridging fibre length becomes folded, and its trailing end is lifted from the gap and the tail end of the ribbon to form a bridge fiber (Figs. 6c and d).
- ✓ When the yarn length reaches the doffing tube, the reverse twisting (S-twisting) of the false twist removes Z-twist not only from the yarn core but also from what was the trailing length of the wrapper fibres. However, the leading length of the wrapper fibre undergoes further S-twisting and binds tighter onto the yarn.

Neckář B. *Příze. Tvorba struktura vlastnosti,* SNTL 1990, ISBN: 80-03-00213-3 (only in Czech).
Drašarová J. IS 22-105-01/01 Belt fibers in open end spun yarn. FT TUL 2002.
Vyšanská M. IS 22-105-01/02 Wrapper fibers in a rotor yarn, modified version. FT TUL 2009.
Koc E., Lawrence C. K. Mechanisms of wrapper fibre formation in rotor spinning: *An experimental approach. The Journal of The Textile Institute 97(6)*, 2005.

Selected quality indicators of rotor yarns

- Internal standard – version 01 evaluates: number of wrapper fibers (belt fibers) n on tested length L and the cover factor of wrapper fibers (belt fibers) CF_B, where the l_i is length of wrapper fiber (belt fiber), see the equation and figure.



$$CF_B = \frac{\sum_{i=1}^{n} l_i}{L} 10^2$$

Neckář B. *Příze. Tvorba struktura vlastnosti,* SNTL 1990, ISBN: 80-03-00213-3 (only in Czech).
Drašarová J. IS 22-105-01/01 Belt fibers in open end spun yarn. FT TUL 2002.
Vyšanská M. IS 22-105-01/02 Wrapper fibers in a rotor yarn, modified version. FT TUL 2009.

Selected quality indicators of rotor yarns

- ✓ Topology of wrapper fibers: assessment of the type of wraps and its classification.

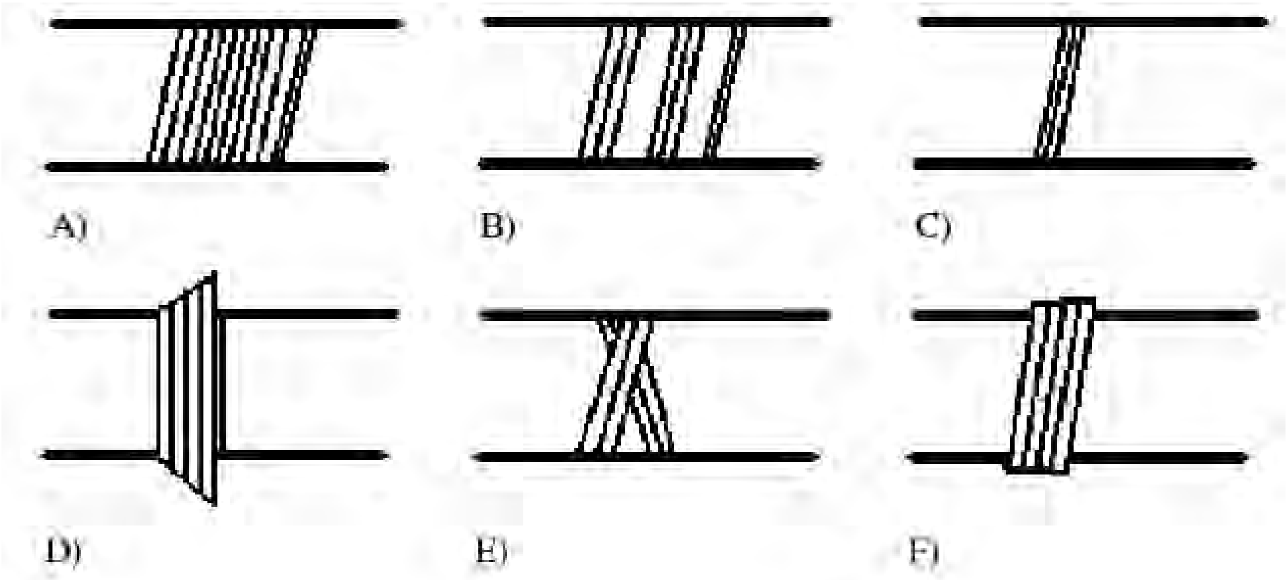


Fig. 9 Types of belt fibers

Roudbari B. Y.; Eskandarnejad S: Effect of Some Navels on Properties of Cotton/Nylon66 Blend (1:1) Rotor Spun Yarn and Wrapper Formation: A Comparison between Rotor and Ring Spun Yarn, *Journal of Textiles*, 2013.
Koc E., Lawrence C. A. Type Ch. Wrapper fibres in open-end rotor spun yarns: yarn properties and wrapper fibres. *Fibres & Textiles in Eastern Europe*, 2 (50), 2005.
Sengupta A. K., Dutta B., Radhakrishnaiah P. Studies on fiber belts in rotor spun yarn. *Textile Research Journal 50(4)*, 1980.
Lawrence C. A.; Finikopulos E. Factors effecting changes in the structure and properties of open-end rotor yarns. *Indian Journal of Fibre and Textile Research*, 17(12), 1992.
Sonntag E., Bolze J. Design of Navel and its Influence on Yarn Structure. Melliand Textilberichte *Fibres and Textiles*. 84 (3), 2003.
Klosová M. Belts distribution and classification; influence of yarn fineness and twist factor. FT TUL. 1999. (In Czech)

Factors influencing the quality of rotor yarns

- ✓ **purpose of use of yarn,**
- ✓ **fiber properties** (type, length, fineness, diameter and cross-sectional shape, flexural and torsional stiffness, tensile strength and elongation, coefficient of friction; compression),
- ✓ **geometric parameters of the yarn** (count, twist, or mixed proportion),
- ✓ **production technology** (method of setting the production technology, which is related to the degree of fiber arrangement in the yarn and the use of selected components – rotor diameter, its surface, type of rotor grove, navel, … .
- ✓ The obtained results, describing the quality of the yarn, may be influenced by the type of used instrument, the measurement methodology, the procedure for data evaluation, the test conditions (humidity, speed, number of measurements) and the sampling method.

Carl A Lawrence *Advances in Yarn Spinning Technology* pp. 261–273, Woodhead Publishing, Oxford 2010 ISBN 978-1-84569-444-9.

Klein W. *The Technology of Short Staple Spinning - Manual of Textile Technology.* The Textile Institute, England 1993.

Discussion and conclusions

- ✓ Long fibers tend to form more concentrated wrapper fibers. The type of fibers with a longer length predominates in the wrapper fibers.
- ✓ Coarse yarns have significantly more wrapper fibers than finer ones. The frequency of wraps increases with increasing twist coefficient.
- ✓ The length of the wrapper fibers and the distance between them depends on the rotor diameter. As the rotor diameter increases, the number of wrapper fibers and the distance between them increases too.
- ✓ The occurrence of wrapper fibers can affect the yarn diameter, yarn unevenness, hairiness and its mechanical properties, when the wrapper fibers are formed densely and perpendicularly to the yarn axis wound the yarn.

Koc E., Lawrence C. A. Type Ch. Wrapper fibres in open-end rotor spun yarns: yarn properties and wrapper fibres. *Fibres & Textiles in Eastern Europe*, 2 (50), 2005.

Hunter, L. The production and Properties of Staple-Fibre Yarns Made by Recently Developed Techniques, *Textil Progress*, 10 1/2, The Textile Institute, Manchester, 1978.

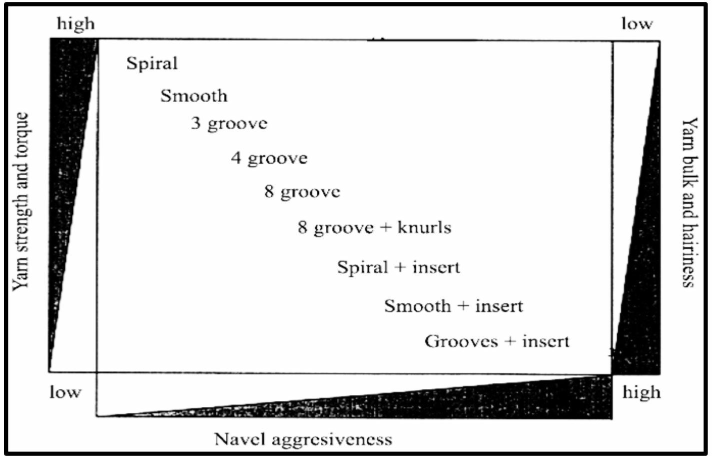
Lunenschloss, P. R.-Kampen, W.: How Fibre Length and Coefficient of Fibre Fiction Affect the Formation of Wrappers, Melliand Textilberichte 9 Englist edition, 1978.

Ibrahim, A. K. A. H. Abrasion Resistance of Open-End Spun Yarns, MPhil Thesis, Leeds, 1985.

Nová L. Structure of rotor spun yarn, BP FT TUL 2006 (Only in Czech).

Discussion and conclusions

- ✓ Navel type: By using a smooth, steel navel, yarns can be produced with the best yarn unevenness and the low number of faults.
- ✓ The spiral navel reduces the surface friction between the navel and the formed yarn and provides higher strength, smoothness and a more closed yarn surface structure compared to other navels.



Sonntag E., Bolze J. Design of a navel and its influence on yarn structure. *Dornbirn: Bröll Textile Systems 3*, 2003.

Coruh E., Celik N. Influence of nozzle type on yarn quality in open end spinning. *Fibers & Textiles in Eastern Europe*, 21, 2 (98), 2013.

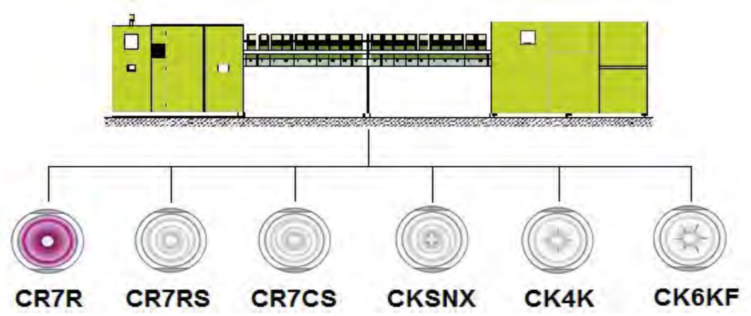
Kaplan S., Araz Ceyhun, Göktepe Ö. A multi-criteria decision aid approach on navel selection problem for rotor spinning. *Textile Research Journal*, 76 (12), 2006.

Guo B., Tao Xiaoming and Lo T. A mechanical model of yarn twist blockage in rotor spinning. *Textile Research Journal*, 70 (1), 2000.

Xu B. G., Tao X. M. Integrated approach to dynamic analysis of yarn twist distribution in rotor spinning. Part I. Steady State. *Textile Research Journal*, 73 (1), 2003.

Balasubramanian N. Rotor Spinning: Effect of rotor, navel parameters, winding tension. *Bombay Textile Research Association* 2013.

Discussion and conclusions – example of results



Technological settings

- ✓ Yarn: 100% CO 29,5 tex am 65 ktex$^{2/3}$m^{-1} a 80 ktex$^{2/3}$m^{-1}
- ✓ Navels: smooth (CR7R), sharp spiral (CR7RS), smooth spiral (CR7CS), smooth spiral with eddy insert in nozzle (CKSNX), 4 notches (CK4K), 6 notches and small nozzle radius (CK6KF)
- ✓ Rotor spinning machine BT 923, rotor speed 100 000 rpm, opening roller speed 9000 rpm, delivery speed of yarn for knitting - 120 mmin^{-1}, delivery speed of yarn for weaving 150 mmin^{-1}.

Richter M., Krupincová G., Boněk K. Evaluation of used nozzle type on yarn quality in open end spinning. *21th International conference Structure and structural mechanics STRUTEX 2016*, FT TUL, Liberec Czech Republic, 2016. ISBN: 978-80-7494-269-3.

Richter M. Evaluation of the draw off nozzle influence on quality of OE yarns. DP FT TUL 2016 (Only in Czech).

Discussion and conclusions – example of results

Assumptions

- ✓ The parameters of the used ceramic navels are more or less comparable in terms of their geometry. It can be expected that yarns spun by using of smooth navel CR7R and both spiral navels (CR7RS, CR7CS) will have similar quality due to similar arrangement of fibers in yarn.
- ✓ Higher diversity of fibers arrangement mainly in surface area caused by used type of navel can be expected if the four and six notches navels will be used (CK4K, CK6KF).
- ✓ Differences in the geometry of navels: Only the six notched navel CK6KF have a slightly lower wrap angle. The spiral navel has only a point contact with the formed yarn, what caused a lower frictional resistance during twisting. The spiral shape of navel supports the torsional effect and allow easier yarn forming by twisting.

Sonntag E., Bolze J. Design of a navel and its influence on yarn structure. *Dornbirn: Bröll Textile Systems*, 3 2003.

Coruh E., Celik N. Influence of nozzle type on yarn quality in open end spinning. Fibers & Textiles in Eastern Europe, 21, 2 (98), 2013.

Kaplan S., Araz Ceyhun, Göktepe Ö. A multi-criteria decision aid approach on navel selection problem for rotor spinning. Textile Research Journal, 76 (12), 2006.

Tyagi K., Choudhary A. K. and Varshney R. K. Contribution of draw-off nozzle profile to certain characteristics of acrylic-cotton rotor-spun yarns. Indian Journal of Fibre & Textile Research, 21 (12), 1996.

Kaplan S., Araz Ceyhun, Göktepe Ö. (2006) A multi-criteria decision aid approach on navel selection problem for rotor spinning. *Textile Research Journal*, 76 (12), 896 - 904.

Discussion and conclusions – example of results

Assumptions

- ✓ The high frequency vibration caused by number and geometry of notches on navel surface (CK4K, CK6KF) can lead to changes in yarn structure on the surface area. Changes in fiber arrangement will probably cause the diversity in yarn unevenness, number of faults and yarn hairiness. The level of mechanical parameters can remain similar with yarn produced by using smooth navel CR7R. The CKSNX is spiral navel with insert and therefore the combination of both phenomena (geometry of spiral and number of used notches) is combined.
- ✓ The higher twist coefficient leads to more compact yarn structure and can reduced yarn unevenness, number of faults, yarn hairiness and variability of yarn quality indicators. The range of twist coefficient applied in this study is possible in extreme case used for both end applications of yarn and therefore the expected diversity among verified yarn characteristics is relatively small.

Sonntag E., Bolze J. Design of a navel and its influence on yarn structure. *Dornbirn: Bröll Textile Systems*, 3 2003.

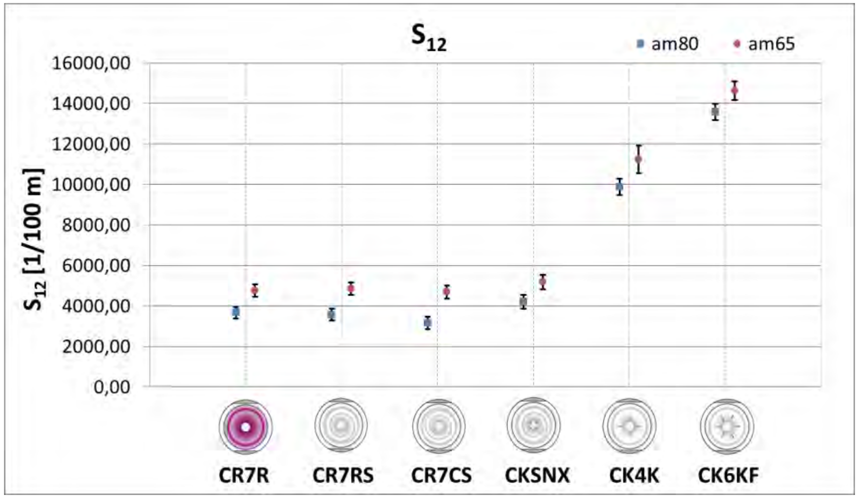
Coruh E., Celik N. Influence of nozzle type on yarn quality in open end spinning. Fibers & Textiles in Eastern Europe, 21, 2 (98), 2013.

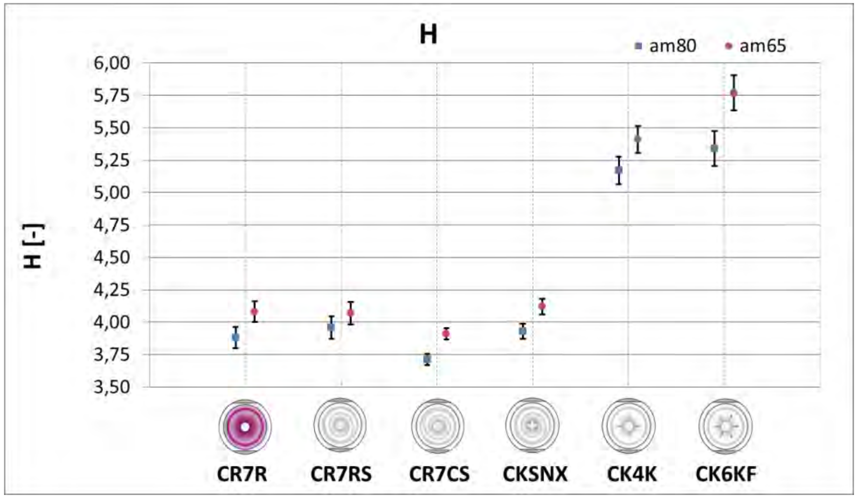
Kaplan S., Araz Ceyhun, Göktepe Ö. A multi-criteria decision aid approach on navel selection problem for rotor spinning. Textile Research Journal, 76 (12), 2006.

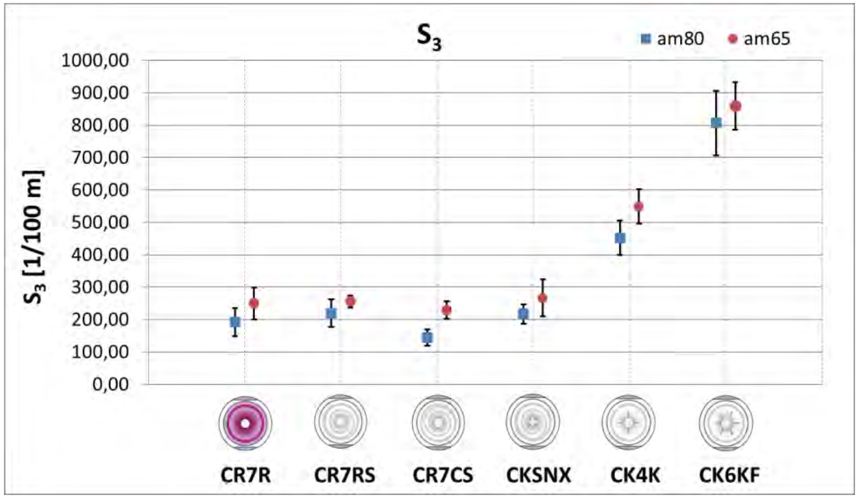
Tyagi K., Choudhary A. K. and Varshney R. K. Contribution of draw-off nozzle profile to certain characteristics of acrylic-cotton rotor-spun yarns. Indian Journal of Fibre & Textile Research, 21 (12), 1996.

Kaplan S., Araz Ceyhun, Göktepe Ö. (2006) A multi-criteria decision aid approach on navel selection problem for rotor spinning. *Textile Research Journal*, 76 (12), 896 - 904.

Discussion and conclusions – example of results





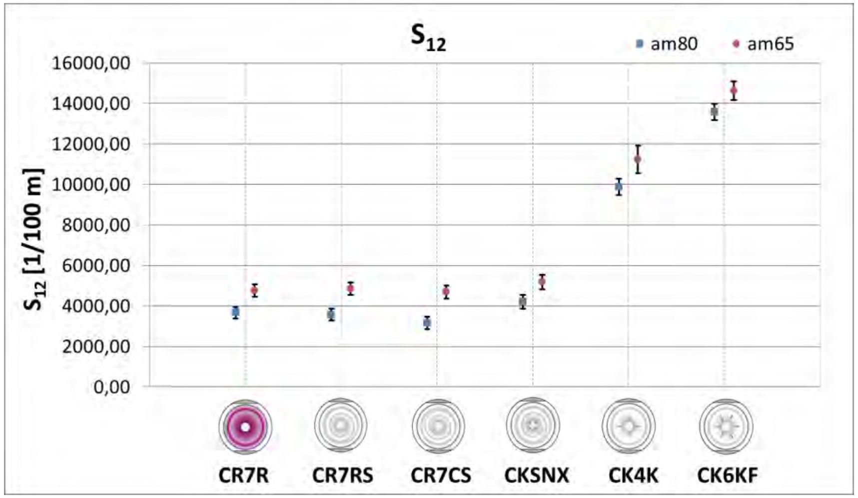


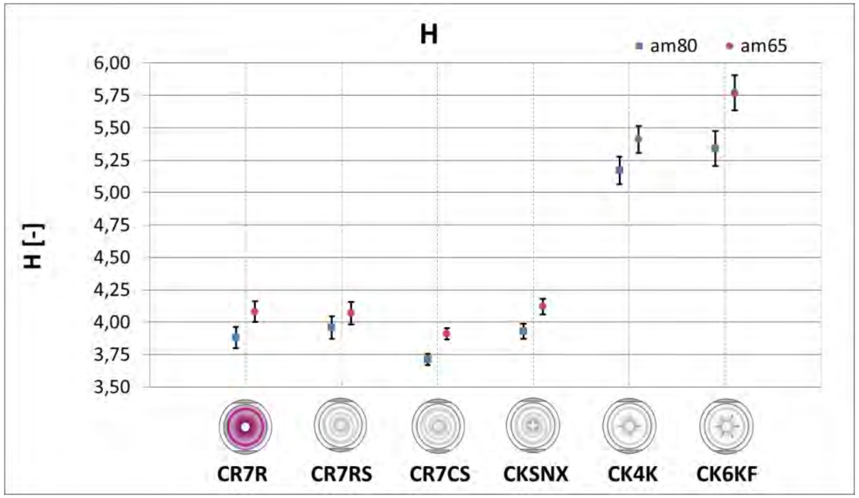
Similar trend for both type of yarns.

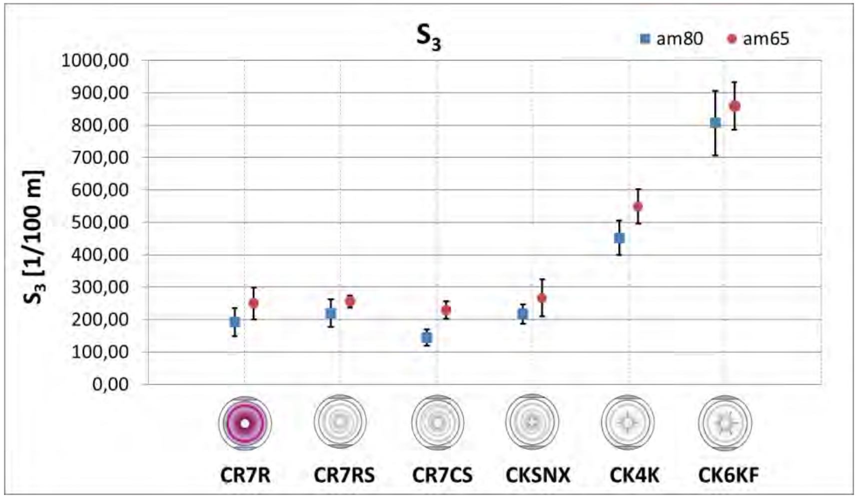
Yarns spun by using navels with notches have significantly higher hairiness.

ANOVA – both influencing factors (twist coefficient, type of navels) are significant

Discussion and conclusions – example of results





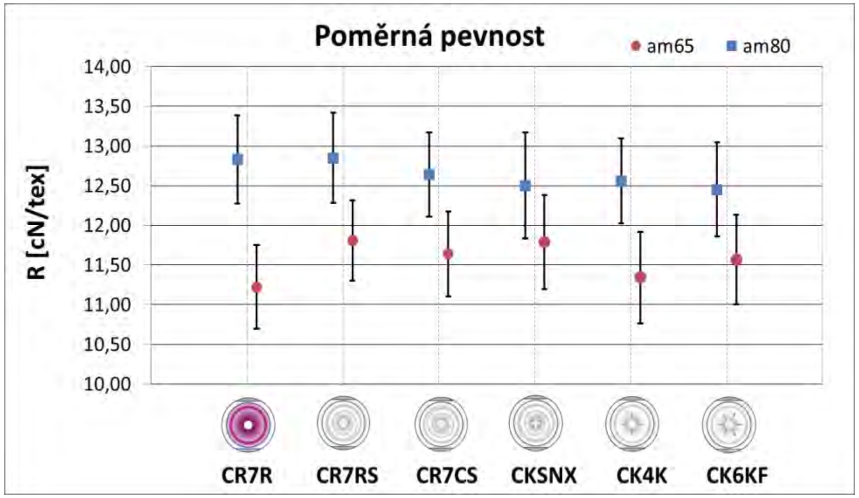


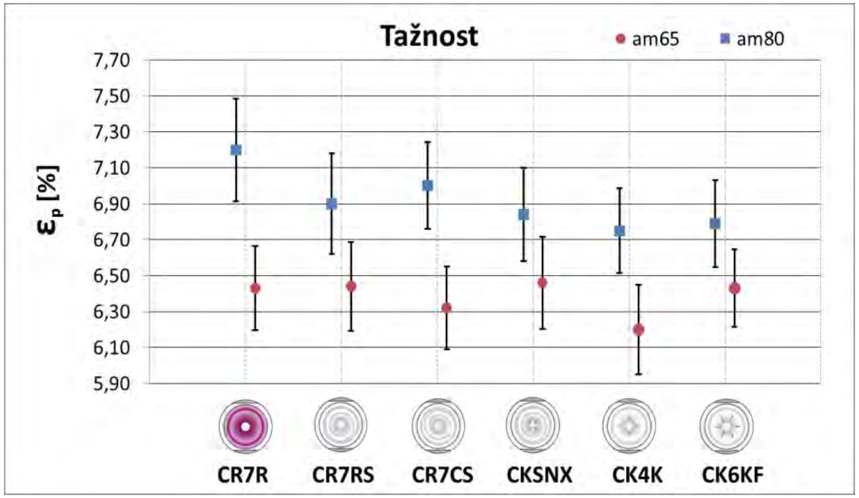
Similar trend for both type of yarns.

Yarns spun by using navels with notches have significantly higher hairiness.

ANOVA – both influencing factors (twist coefficient, type of navels) are significant.

Discussion and conclusions – example of results





Similar trend for both type of yarns.

ANOVA – only twist coefficient is significant influencing factor.

Discussion and conclusions – example of results

Technological settings

- ✓ Yarns: 100% CO 29,5 tex am 80 ktex$^{2/3}$m^{-1}
- ✓ Navel: smooth (CR7R), sharp spiral (CR7RS), 6 notches and small nozzle radius (CK6KF)
- ✓ Rotor spinning machine BT 923, rotor speed 100 000 rpm, opening roller speed 9000 rpm, delivery speed of yarn for knitting - 120 mmin^{-1}, delivery speed of yarn for weaving 150 mmin^{-1}.

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results

- ✓ Evaluation in accordance with IS 22-105-01/02; Topology of wrapper fibers and classification, definition of own criteria - bulkiness.

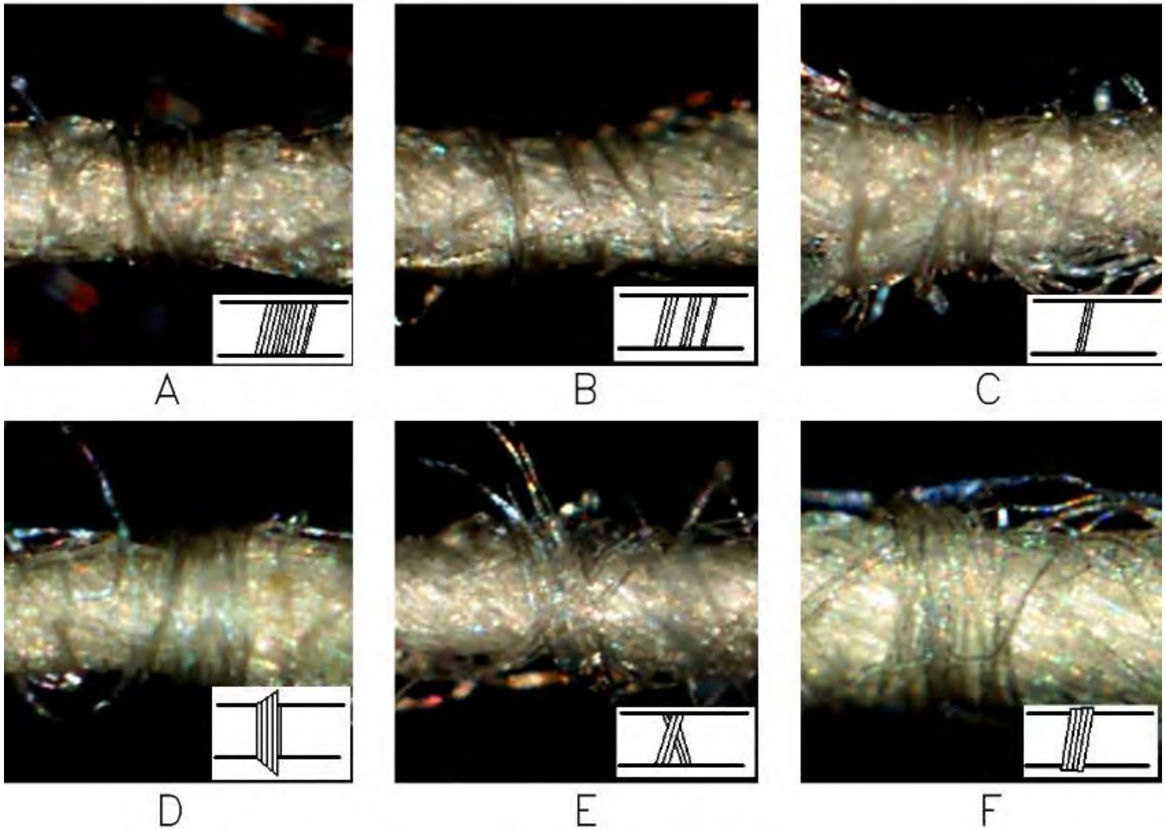


Fig. 10 type of wrapper fibers (belt fibers)

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results

Assumption

- ✓ The type of navel can affect the length of the wrapper fibers and the cover factor of yarn by the wrapper fibers.
- ✓ It can be expected that yarns made of the same material, the same sliver, with the same yarn count and twist coefficient will show minimal differences in the the wrapper fibers characteristics (length, occurrence frequency, distance between their centres).
- ✓ Used type of navel influence mainly the arrangement of fiber on yarn surface and may also be reflected in the wrapper fibers topology and their occurrence frequency.
- ✓ Yarns spun with a smooth and spiral navel should have a smooth and ordered structure on yarn surface. On the other hand, the notches navel could caused greater differences in the character and topology of the wrapper fibers on yarn surface (higher yarn bulkiness and loosening of the surface layers).

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

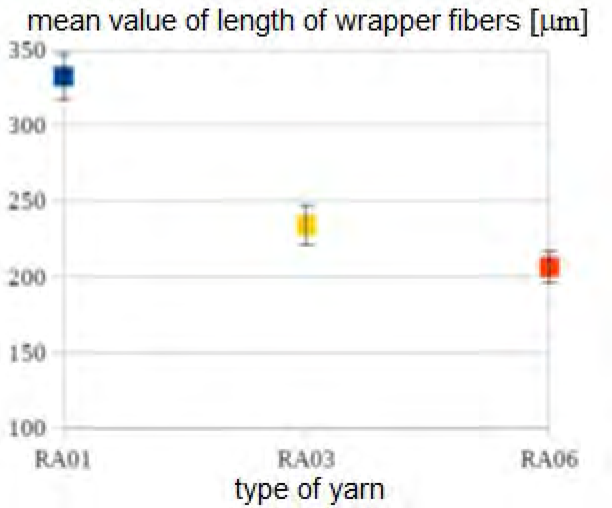
Kaplan S., Göktepe Ö. Investigation into Navel Selection for Rotor Spinning Machine Using Cotton Waste. *Fibers & Textiles in Eastern Europe*. 14, 3 (57), 2006.

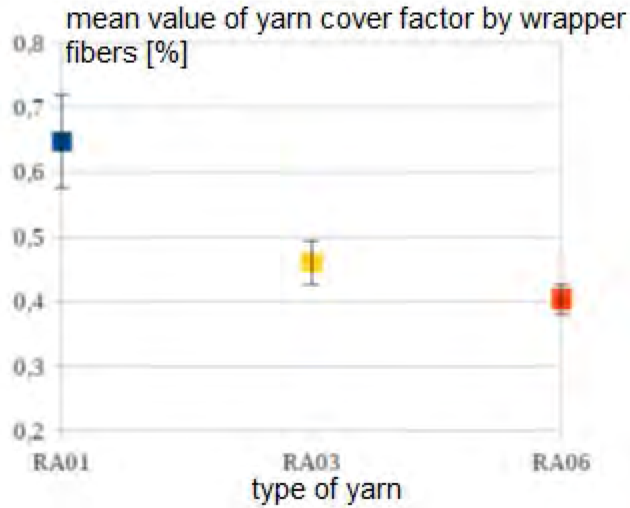
Lawrence C. A., Finokopulos E. Factors effecting changes in the structure and properties of openend rotor yarns. 1992.

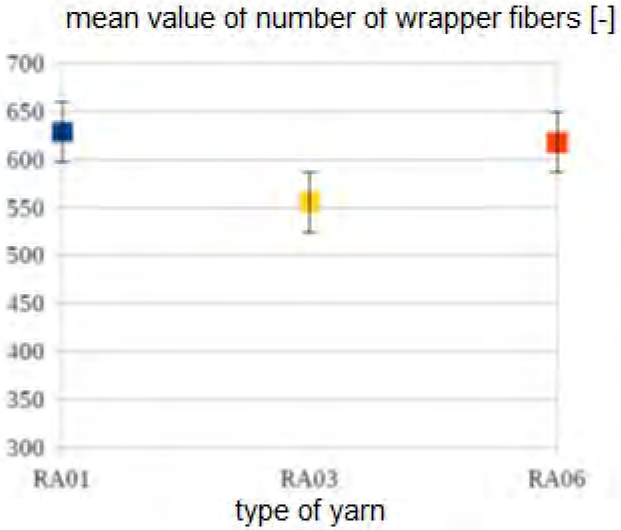
Sonntag E., Bolze J. Design of Navel and its Influence on Yarn Structure. Melliand Textilberichte *Fibres and Textiles*. 84 (3), 2003.

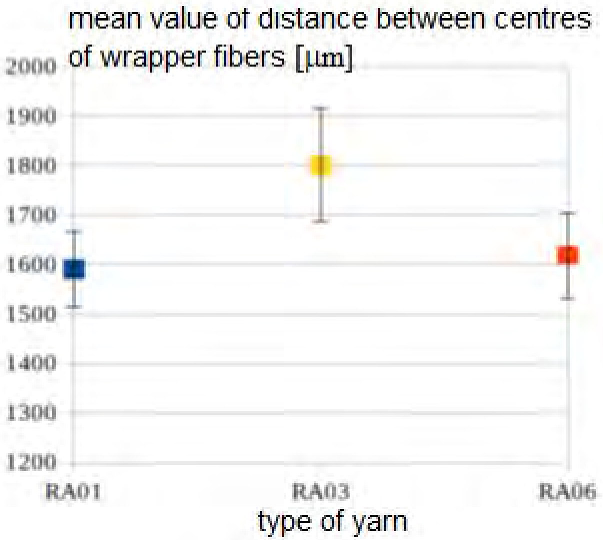
Çoruh E., Çelik N. Influence of nozzle type on yarn quality in openend rotor spinning. *Fibres & Textiles in Eastern Europe*, 2013.

Discussion and conclusions – example of results


mean value of length of wrapper fibers [µm]

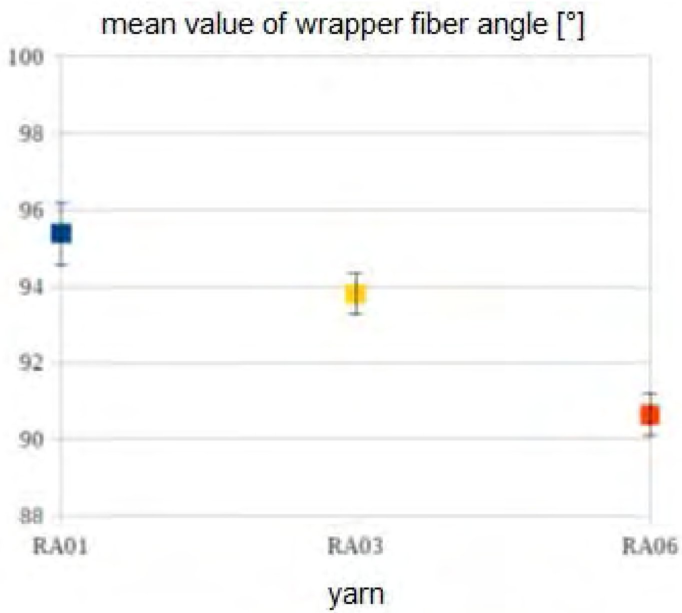

mean value of yarn cover factor by wrapper fibers [%]

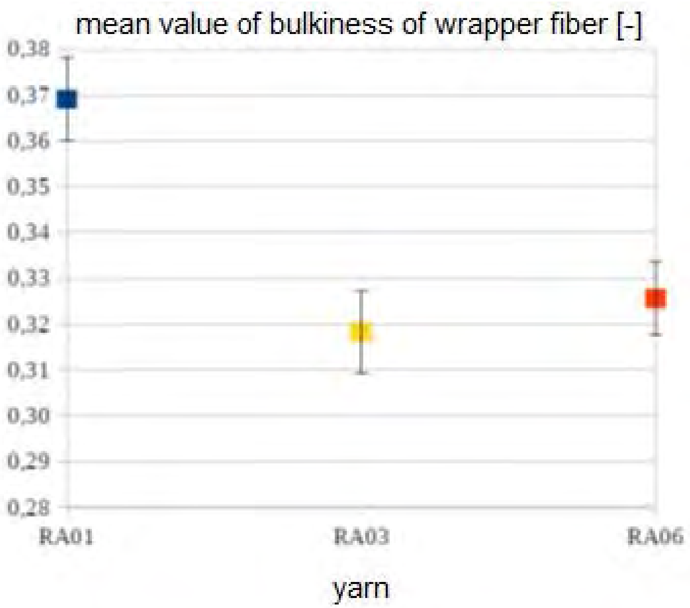

mean value of number of wrapper fibers [-]


mean value of distance between centres of wrapper fibers [µm]

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results


mean value of wrapper fiber angle [°]


mean value of bulkiness of wrapper fiber [-]

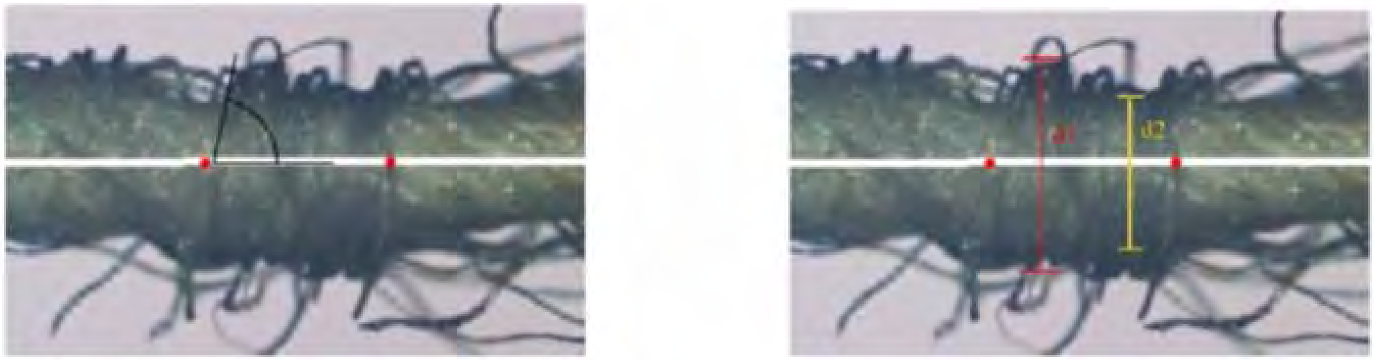
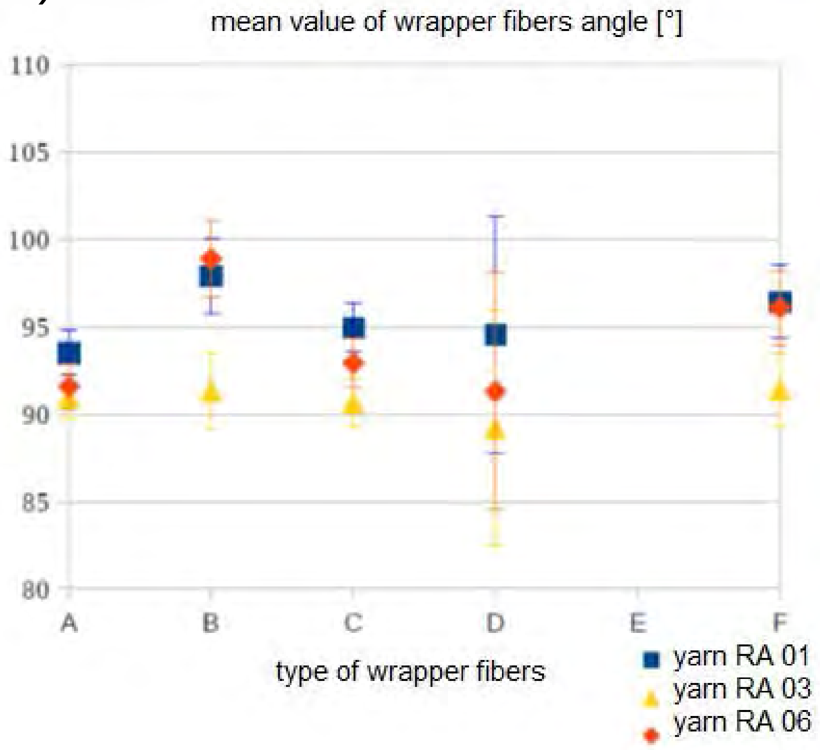


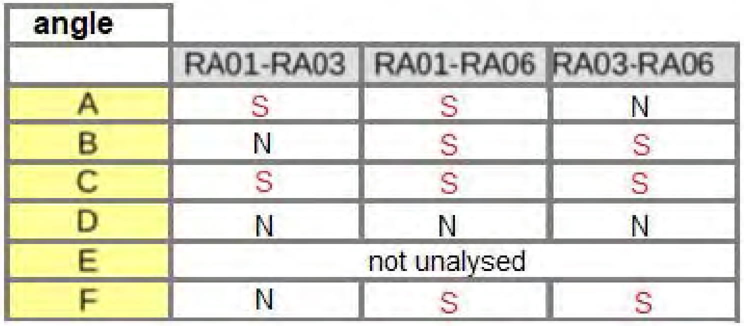
Fig. 11 Schema of evaluation of wrapper characteristics

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results

ANOVA analysis was used to verify whether the angle of wrapper fibers category differs significantly or not. (Whether wrapper fibers type A for RA01-RA03 yarns has the same angle, whether wrapper fibers type A for RA01 - RA06 yarn has the same angle, …)





angle			
	RA01-RA03	RA01-RA06	RA03-RA06
A	S	S	N
B	N	S	S
C	S	S	S
D	N	N	N
E	not unalysed		
F	N	S	S

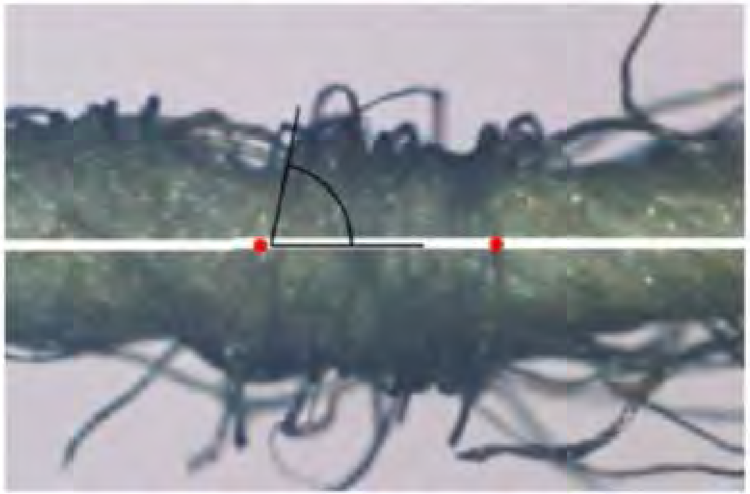
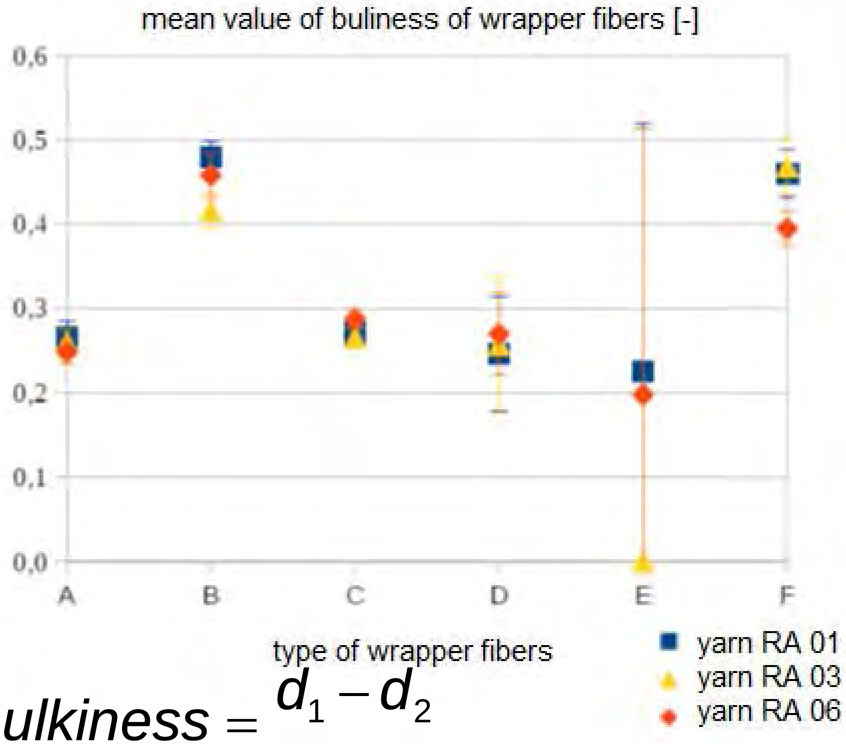


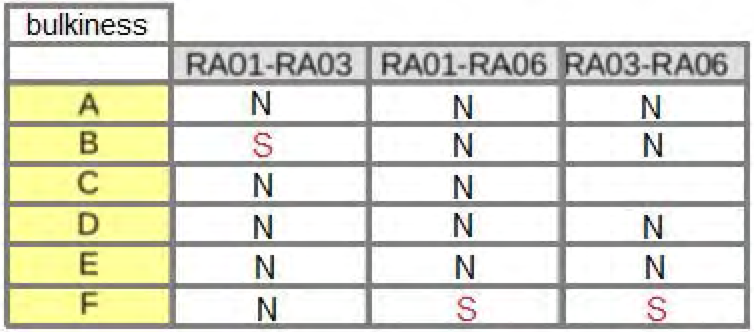
Fig. 12 Schema of evaluation of wrapper characteristics

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results

ANOVA analysis was used to verify whether the bulkiness of wrapper fibers differs significantly or not. (Whether wrapper fibers type A for RA01-RA03 yarns has the same bulkiness, whether wrapper fibers type A for RA01 - RA06 yarn has the same bulkiness, …)





bulkiness			
	RA01-RA03	RA01-RA06	RA03-RA06
A	N	N	N
B	S	N	N
C	N	N	
D	N	N	N
E	N	N	N
F	N	S	S

$$bulkiness = \frac{d_1 - d_2}{d_2}$$

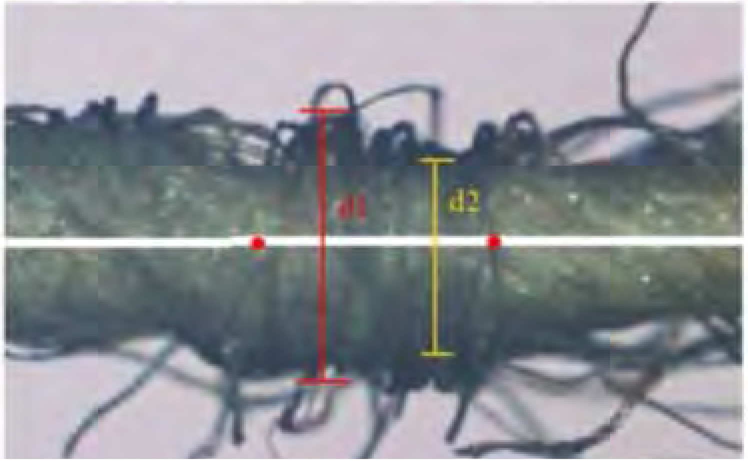
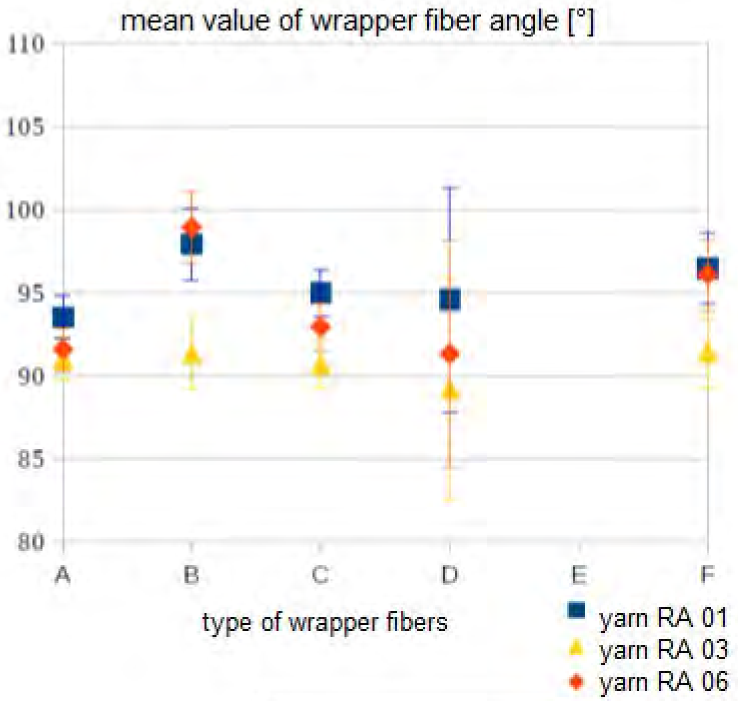


Fig. 13 Schema of evaluation of wrapper characteristics

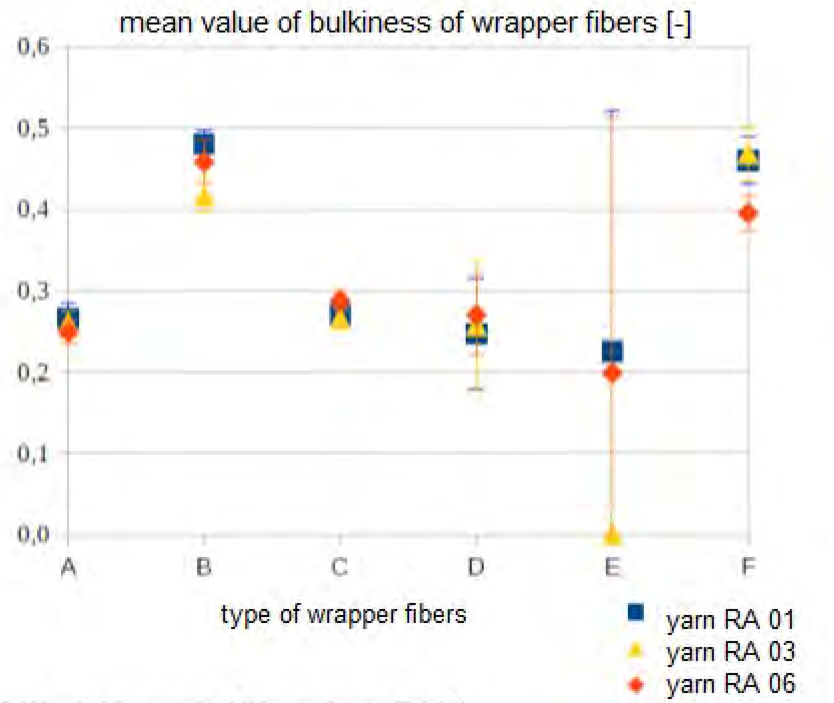
Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results

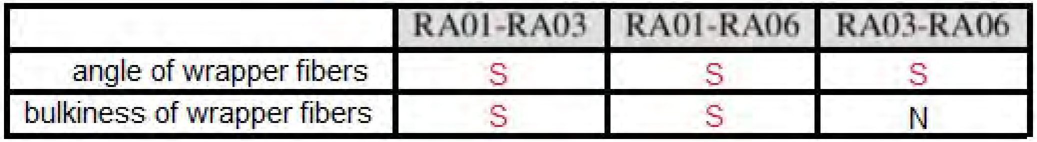
ANOVA analysis was used to verify whether the bulkiness of wrapper fibers differs significantly or not. (Whether wrapper fibers type A for RA01-RA03 yarns has the same bulkiness, whether wrapper fibers type A for RA01 - RA06 yarn has the same bulkiness, …)



mean value of wrapper fiber angle [°]



mean value of bulkiness of wrapper fibers [-]



	RA01-RA03	RA01-RA06	RA03-RA06
angle of wrapper fibers	S	S	S
bulkiness of wrapper fibers	S	S	N

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Discussion and conclusions – example of results

- ✓ The yarn diameter, yarn unevenness and yarn hairiness increase significantly with increasing aggressiveness of navel.
- ✓ The type of used navel affects the character of the rotor yarns and their surface structure.
- ✓ The analysed yarns show statistically different values of the wrapper fibers length and the cover factor CF_B of yarn by wrapper fibers for 5 cm length.
- ✓ The number of wrapper fibers for individual types of yarns spun with various navel does not differ significantly and can be considered comparable.
- ✓ The bulkiness and angle of wrapper fibers also differ significantly with respect to the used type of navel.

Mudráková J. Analysis of the surface structure of OE-rotor spun yarns depending on the type of draw off nozzle. DP, FT TUL 2018 (Only in Czech).

Questions for knowledge verification and repetition

- What is a wrapper fiber, how does it form and what characterizes it?
- How can the character / quality / structure of the rotor yarn be influenced?
- How can the character of the surface structure of rotor yarns be evaluated and what qualitative indicators are used for it?
- Is it possible to assess the topology of wrapper fibers? If so, in what way (advantages / disadvantages)?
- What have to be taken into account if we want to compare the quality of staple yarns (data from different laboratories / from different evaluators / various qualitative indicators)?

Thank you for your attention…

CHARAKTER EFEKTNÍCH A KOMPOZITNÍCH PŘÍZÍ I a II/ CHARACTER OF FANCY AND COMPOSED YARNS I & II

Ing. Gabriela Krupincová, Ph.D. / Katedra technologií a struktur

Aims and motivation

Motivation:

- ✓ Fancy yarn, sometimes called "novelty yarn", offers very interesting application possibilities for various types of final products due to different structure and quality parameters. This type of yarn usually offers a visual or other synergistic effect. The production of these types of yarns is realized via modified technologies used for production of standard yarns or thanks to completely innovative production processes.
- ✓ Yarns that use a non-visual synergistic effect (e.g. elastic structures, conductive yarns,…) are called composite or hybrid yarns. These are manufactured on standard machines with modified parts or variable production settings. It can be also produced on the same technological units as "fancy yarn" or thanks to innovative production processes only by using a combination of different types of materials.
- ✓ The aim is to map the current state and for selected types of yarns to check the possibilities of describing their structure and properties using image analysis. The partial information related to previous experiments for selected types of yarns is presented.

Aims and motivation

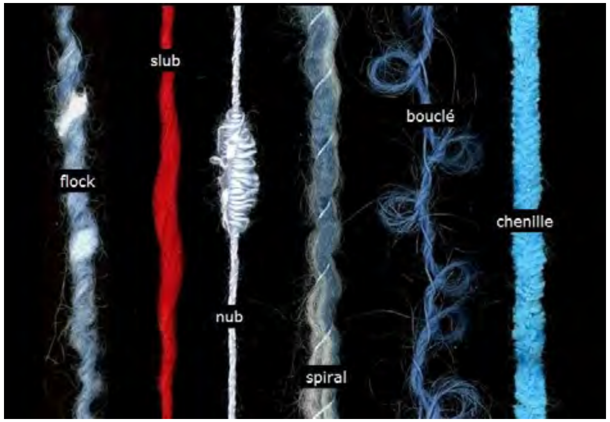
Character of fancy and composite yarns:

- ✓ Understanding the basic processes of yarn creation by individual technologies enables innovations leading to the production of other types of yarns for specific applications (fancy and composite yarns).
- ✓ Understanding of spinning process limitations related to the innovation of production technology intended for standard yarns makes it easier to describe the qualitative indicators of fancy and composite yarns and to find their limits.
- ✓ It allows to compile recommendations related to machine setup and the use of different types of parts.
- ✓ The research process provides feedback and verify the quality of the yarn and the production equipment itself.

Overview of the current state

- ✓ Selected types of fancy and composite yarns - terminology, structure
- ✓ Selected technological procedures for the production of fancy and composite yarns
- ✓ Selected qualitative indicators of these yarns - practical examples

Fancy yarn



- ✓ There are many types of yarns and possibilities of their production. The terminology differs with regard to corporate culture or is linked to the method of their production. They are usually called as "fancy yarn" or "novelty yarn".
- ✓ They are manufactured via modified standard technologies or on special machines.
- ✓ Characteristic for this type of yarn is mainly the visual synergistic effect (type of material, color, deliberate unevenness of the structure,…).
- ✓ They can be made of pure staple fibers or in combination with multifilament / monofilament. In some cases, two-stages production is necessary to ensure the effect of the so-called "binder yarn" - the cross thread securing the effect on a fancy yarn.

Iqbal S., Pramanik P. Fancy yarns: Slub and multicount. *The Indian Textile Journal* 5, 2009.
Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Goswami B. C., Martindale J. G., Scardino F. L. *Textile Yarns*. John Wiley and Sons, Inc. 1977.

Fancy yarn

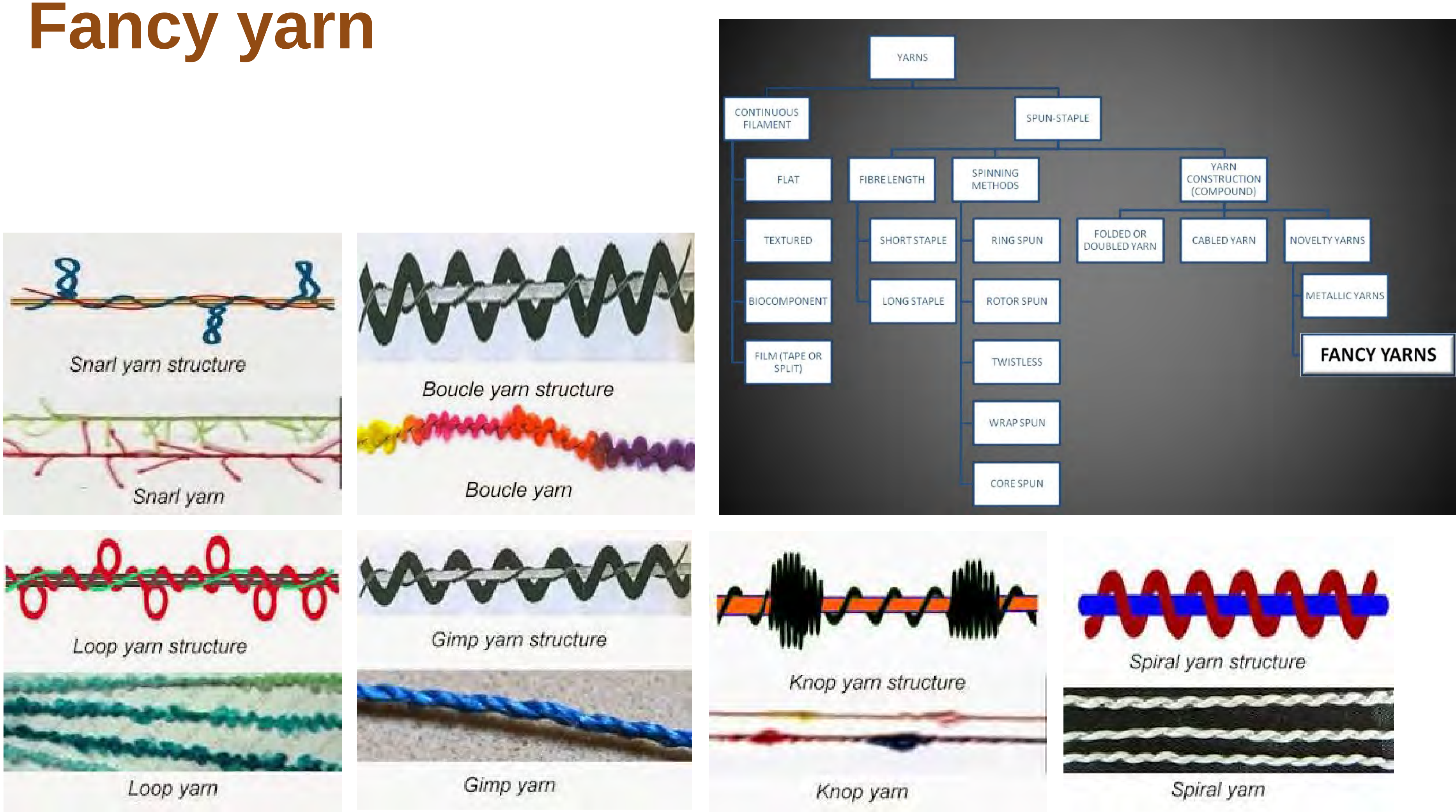


Fig 1 Examples of fancy yarn

Iqbal S., Pramanik P. Fancy yarns: Slub and multicount. *The Indian Textile Journal* 5, 2009.
Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Slub yarns - selected types of fancy and hybrid yarns

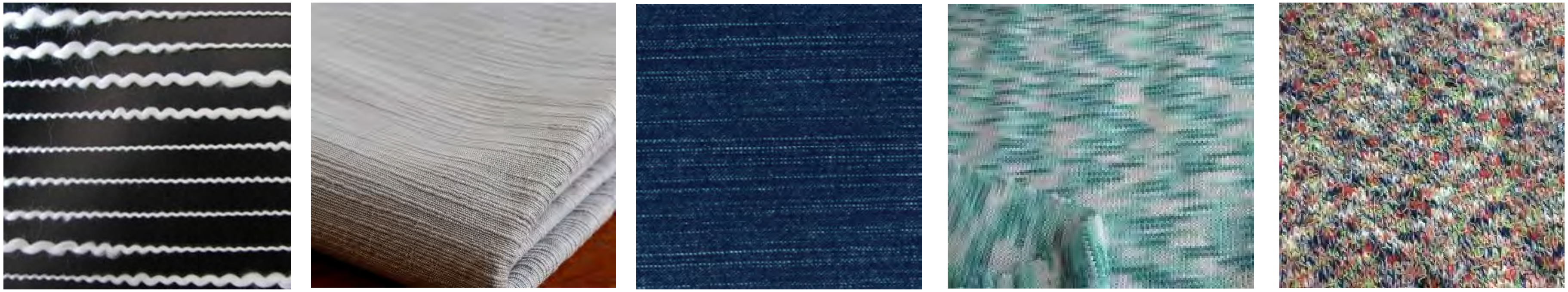


Fig. 2 Slub yarns - woven and knitted fabrics

Slub yarns: yarn spun intentionally to achieve an irregular shape in terms of length and diameter. It is possible to produce them by ring spinning technology by the speed regulation of rollers in drafting zone or rotor spinning by the regulation of opening roller speed with combination of take up speed.

Applications: decorative fabrics, curtains, home textiles, clothing - denim goods, knitted goods - sweaters, T-shirts, linen.

Iqbal S., Pramanik P. Fancy yarns: Slub and multicount. *The Indian Textile Journal* 5, 2009.
Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.

Slub yarns - selected types of fancy and hybrid yarns

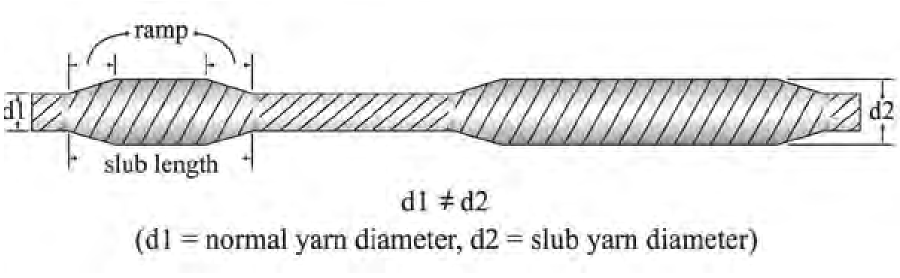


Fig. 3 Standard „slub yarn“

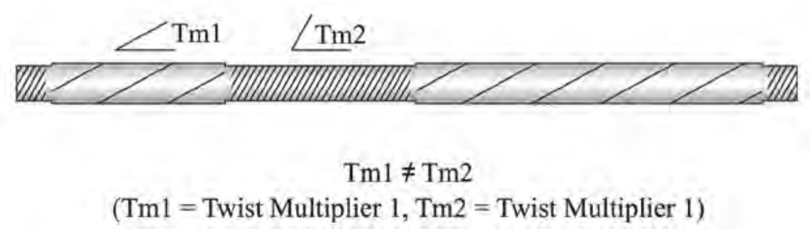


Fig. 4 „Multitwist slub yarn“

Standard slub yarn is the well known and commonly used fancy yarn in the market. The slub length varies between 3 cm to 10 cm. Generally slub length should not be less than the length of stable fibers. Slub yarns are produced by varying the yarn diameter (mass) with constant spindle speed. This is produced by changing drafts continuously at pre programmed intervals.

Multitwist slub yarn is a fancy yarn having a no change in mass. Draft is kept constant and with different twist multiplier and the yarn twist varies. The multi twist yarn length varies between 10 to 50 cm. Small or large twist changes in the yarn will affect the dyeing properties and this produces the dark and light shades in denim fabrics.

Slub yarn - selected types of fancy and hybrid yarns

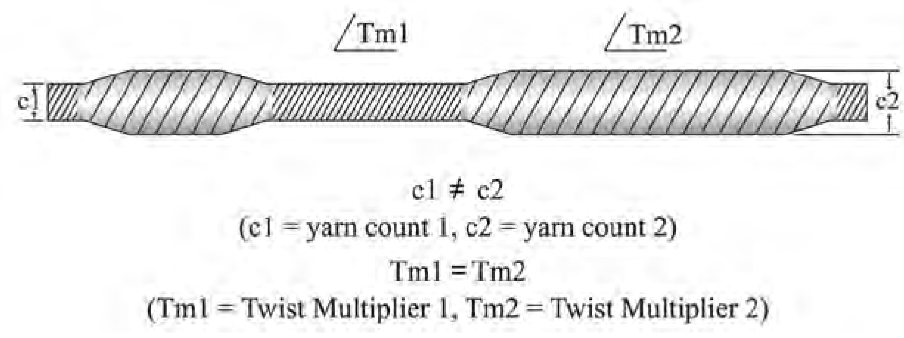


Fig. 5 Multicount slub yarn

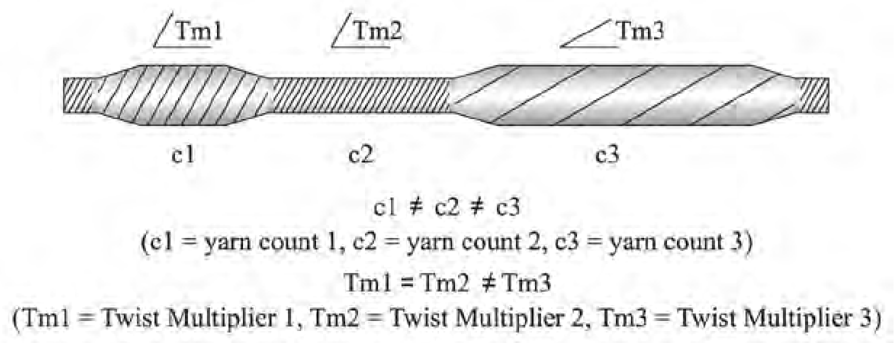


Fig. 6 Multiefekt slub yarn

A multi count yarn is a fancy yarn having a different yarn count with various length. The multi count yarn length varies between 10 to 50 cm. This is achieved by changing the yarn diameter (mass) by applying different draft with corresponding variable front roller speed related to different yarn count. The twist for corresponding yarn count will change but the twist multiplier will be kept constant for different yarn count.

Multi-effect yarn is a slub yarn with multi-count and multi twist in yarn.
This is achieved by variable twist factor combined with variable yarn diameter .

Slub yarns - selected production technologies

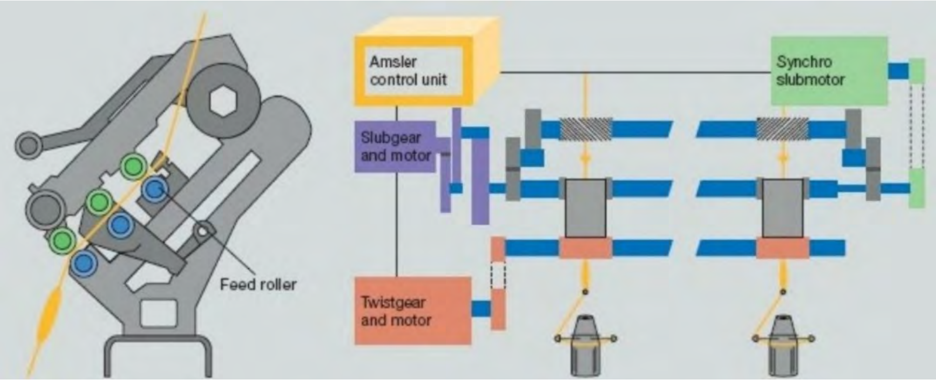


Fig. 7 Principal of slub yarn production - AMSLER

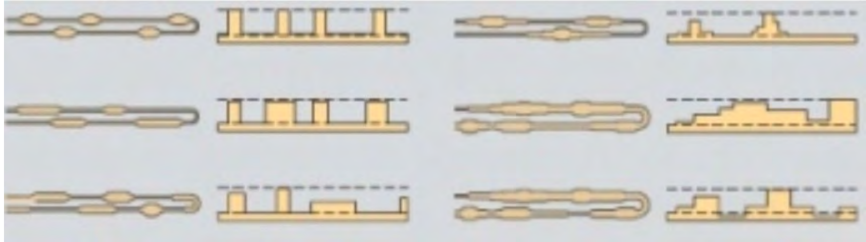


Fig. 8 Slub yarns AMSLER
(type of effect, way of regulation)

Manufacturers of standard ring spinning machines with the extension for slub yarn production: Marzoli - Italy, Ginger - Germany, Toyota - Japan, etc.

Manufacturers of attachment for slub yarn production: Amsler - Germany, Jiangxin CF Tex Tech Co., Ltd. - China, Kaipo - Italy, Pinter - Spain, Fansitex's slub-and-generators - Gwalior, India, etc.

www.amsler.com,
www.mantisa.com

Slub yarns - selected production technologies

Fig. Injection slub yarn production principle - Skaatindia

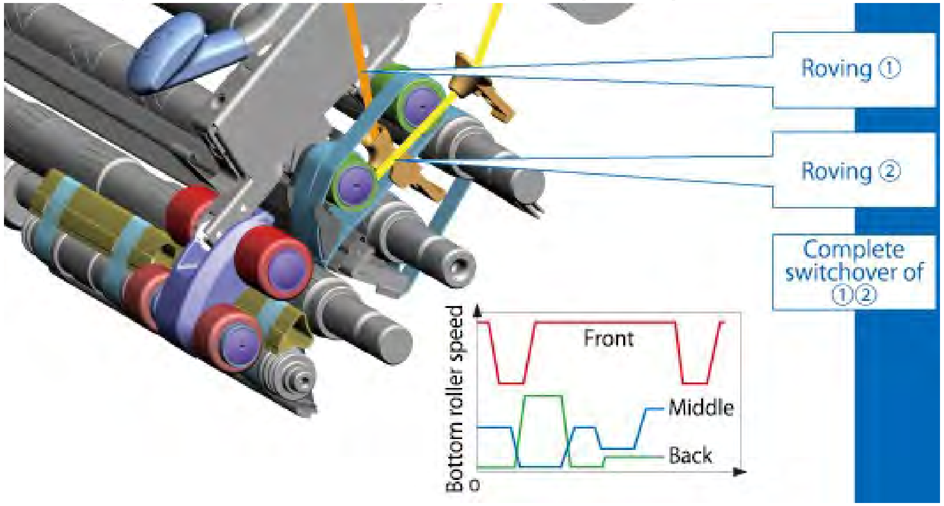


Fig. 10 Principal of slub yarn production - Toyoda Ring spinning frame RX 300

http://skaatindia.com/injslub.htm
http://textile-machinery.toyota-industries.com

Slub yarns - selected qualitative characteristics

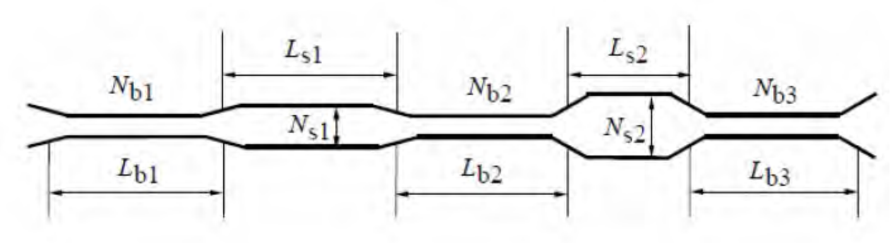


Fig. 11 N_{bi} / N_{si} base yarn parts/ slubs, L_{bi}/ L_{si} base length/ slub length

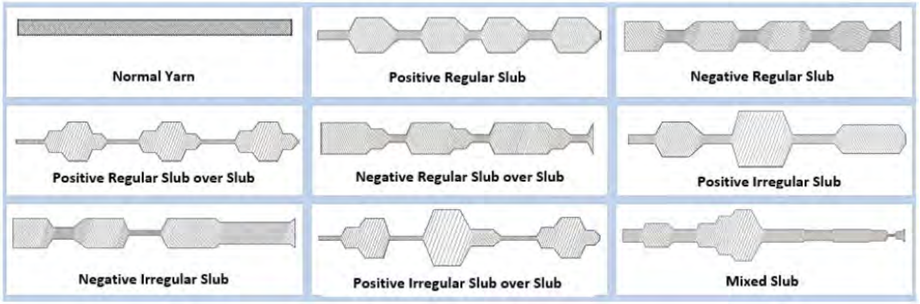


Fig. 12 Slub yarns - Filcom Mantisa

Qualitative characteristics:

- ✓ number of base yarn parts (slub distance), number of slubs,
- ✓ base yarn length / slubs length,
- ✓ diameter of base part/ diameter of slubs,
- ✓ slub distance,
- ✓ randomness of the intended slub effect (periodical / non periodical occurrence of base structure or slubs),
- ✓ mixing quality,

Mathematical model described the character of slub ring spun yarn see in …

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www.mantisa.com

Ma Ch. Q., yhou B. M. Liu Z., Hu CH. S. Theoretical profile of ring spun slub yarn and its experimental validation. *Fibers and Textile in Eastern Europe* 21 1(97), 2013.

Slub yarns - selected qualitative

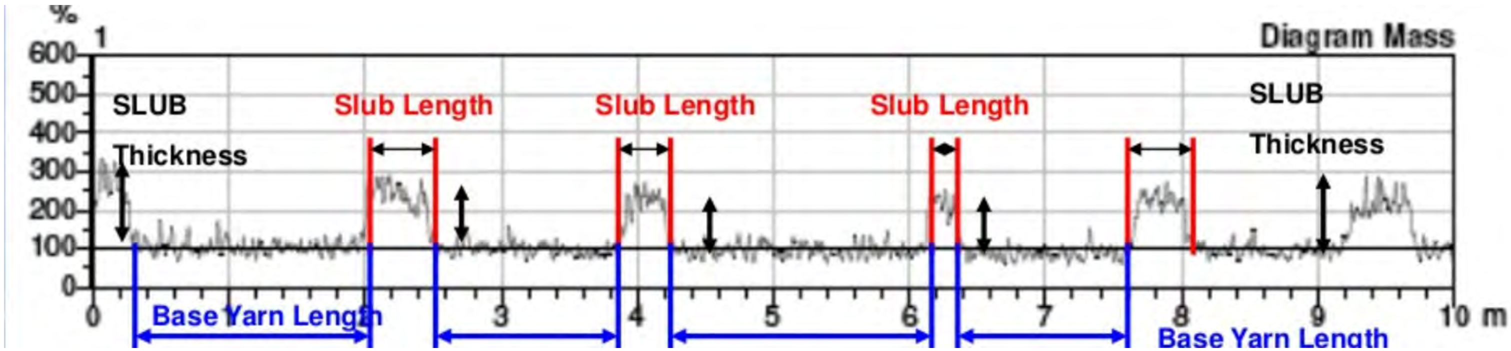


Fig. 13 Slub yarns AMSLER – Uster Tester 5 (usually 1000 m, 400 mmin^{-1}, recommended 50 mmin^{-1})

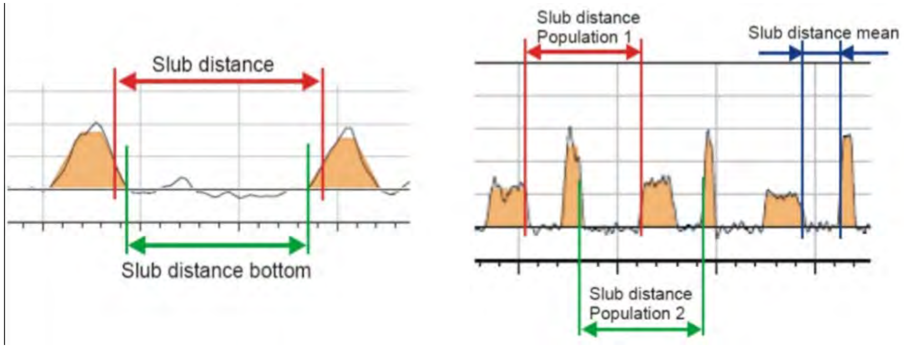


Fig. 14 Slub yarns – characteristics (it is defined on a hell or half high of trapezoid)

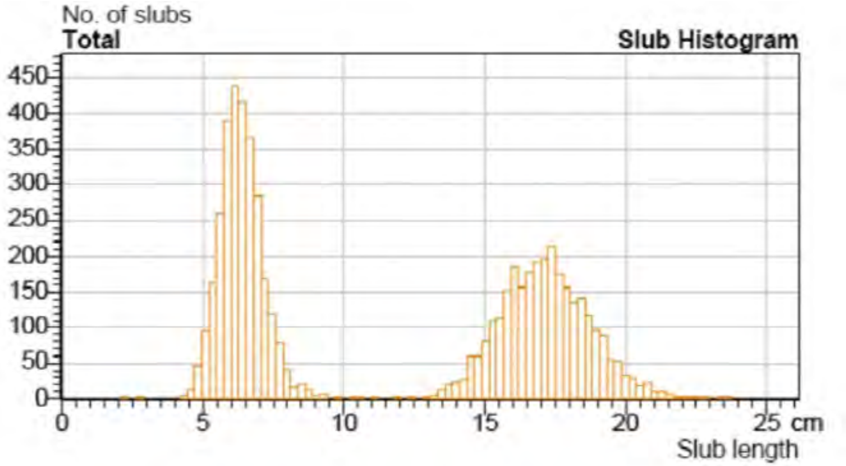
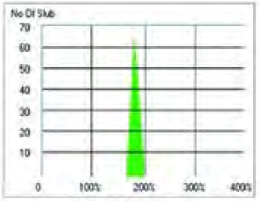


Fig. 15 Slub yarns AMSLER – Uster Tester 5 (two populations, population A 4 cm – 8 cm a B 11 cm – 23 cm)

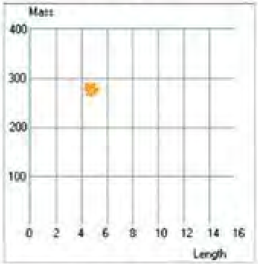
www.amsler.com,
www.uster.com

Slub yarns - selected qualitative characteristics

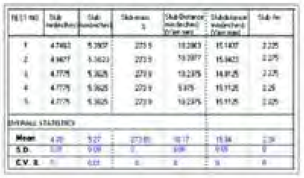
Fig. 16 Slub yarn tester SKAAT



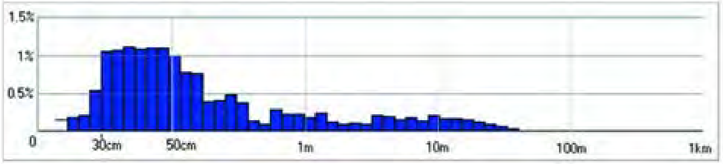
Histogram



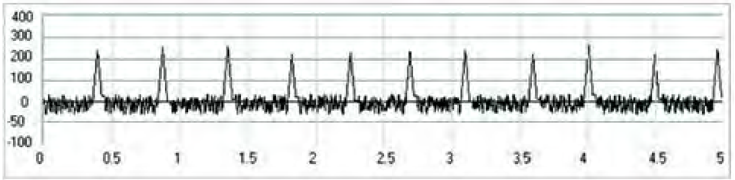
Scatter Diagram



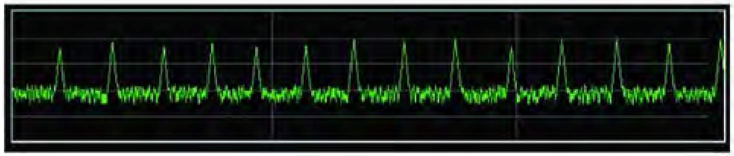
Result



Spectogram



Mass diagram



Graph

Evaluated parameters of slub yarn:

slub mass, slub length, yarn length / slub interval, slubs / meter, slubs CV%, mass diagram and scatter diagram, 3D spectrogram, sequential mass diagram

http://skaatindia.com/injslub.htm

Slub yarns - selected qualitative characteristics

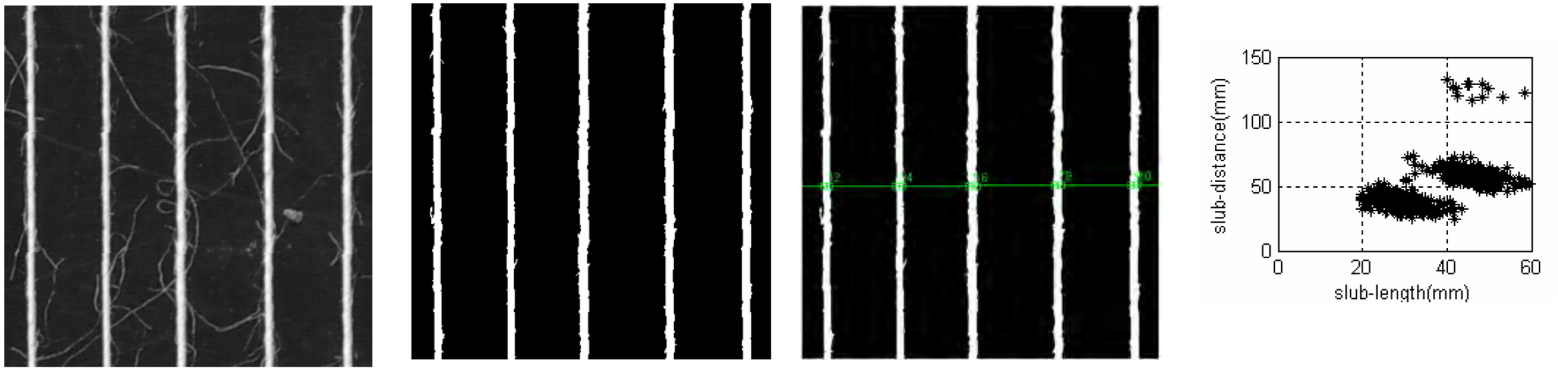


Fig. 17 Image analysis – subjective and objective ways of evaluations

1. Scanning of longitudinal views of slub yarns, 2. thresholding, binarization, opening of image, 3. removing of small objects (removing of hairs), 4. finding the contour using an edge detector, 5. processing of images using the cluster technique and a description of the base and slub structure of yarn.

Pan R., Gao W., Liu J., Wang H. Recognition the parameters of slub-yarn based on image analysis. *Journal of Engineered Fibers and Fabrics* 6(1), 2011.

Liu J., Xie Z., Gao W., Jiang H. Automatic determination of slub yarn geometrical parameters based on an amended similarity-based clustering method. *Textile Research Journal* 80(11), 2010.

Liu J., Li Z., Lu Y., Jiang H. Visualization and determination of the geometrical parameters of slub yarn. *Fibers and Textile in Eastern Europe* 18, 1(78), 2010.

Ilhan I., Babaarslan O. Vuruskan D. Effect of descriptive parameters of slub yarn on strength and elongation properties. *Fibres and Textiles in Eastern Europe* 20 3(92), 2012.

Baghernezhad S., Ghane M., Moei M. Strain monitoring in voven fabrics with locally induced mass irregularities using an image based method. *Fibres and Textiles in Eastern Europe* 24 2(116), 2016.

Discussion and conclusions – example of results 1

Based on previous experience and research, it is possible to say:

- ✓ Slub yarn produced by ring spinning technology

The length, distance, character of the base yarn structure (yarn count, yarn diameter, number of fibers in the cross-section, number of twist) have a significant effect on the strength and elongation of the slub yarn.

In the case where the length or the frequency of slubs are higher, higher variability can be expected in terms of the uniformity of the distributed twist, which leads to a reduction in the strength of the slub yarn.

- ✓ Slub yarn produced by rotor spinning technology

The length of the slub is significantly affected by the rotor diameter, the yarn count of the base yarn structure and the regulating possibility of the feed and opening roller.

The length of the slub is always higher than the perimeter of the rotor; the proportion of yarn count between the slub and the base yarn structure is related to the final length of the slub. The higher the proportion, the longer the slub.

Pan R., Gao W., Liu J., Wang H. Recognition the parameters of slub-yarn based on image analysis. *Journal of Engineered Fibers and Fabrics* 6(1), 2011.

Wang J., Huang X. Parameters of rotor spun slub yarn. *Textile Research Journal* 72(1) 2002.

Chenille yarns - selected types of fancy and hybrid yarns

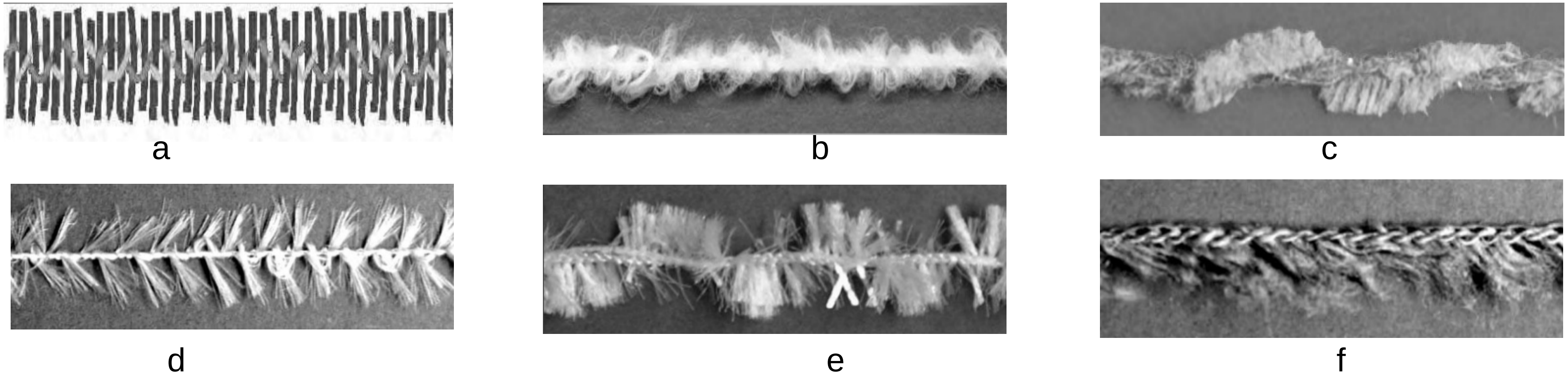


Fig. 18 Chenille yarns (basic structure, airjet textured chenille yarn, spiral chenille yarn, sparse chenille yarn, tricot chenille yarn, feather yarn)

Chenille yarn: The chenille yarn has a specific structure. It is manufactured by placing short piles between two core yarns placed in helix. The edges of these piles then stand at right angles to the yarn's core, giving chenille both its softness and its characteristic look.

Applications: home and decorative fabrics, upholstery fabrics, knitted and woven clothing fabrics. Usually produced from CO, PAN, VS, POP with a count range 0,2 Ne - 12 Ne.

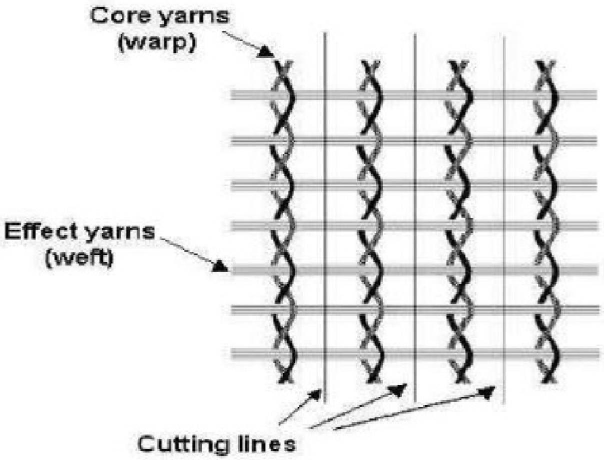
Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.

Chenille yarns - selected production technologies

Production methods:

Weaving - the method of weaving corresponds to the production of leno fabric, in which weft threads creates the pile effect of chenille yarn (piles) at the end of a process. The fabric is cut and the chenille yarn is wound on bobbin. It is not widely used at the moment.

Flocking - the base core yarn is coated with adhesive and the piles are sett using an electrostatic field. This type of production is efficient, but the yarns have a low resistance to abrasion.



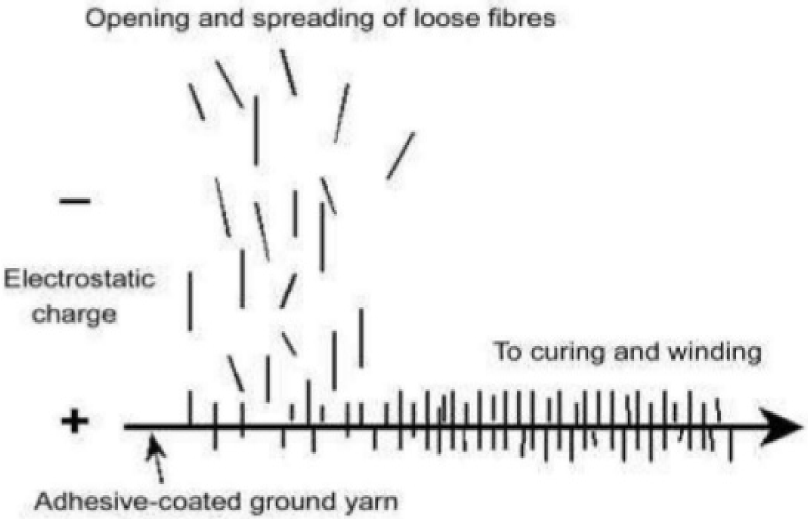


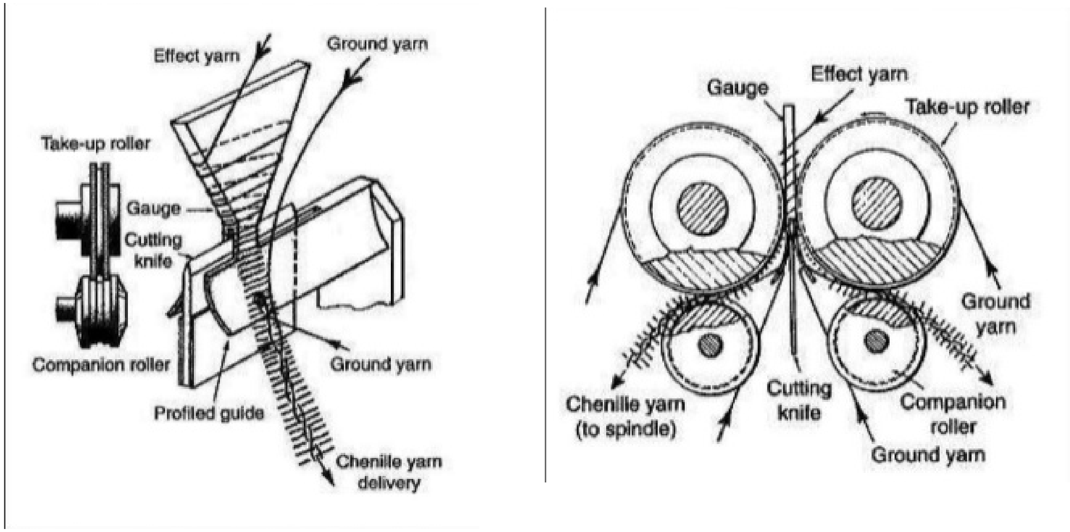
Fig. 19 Schema of chenille yarn production by flocking weaving and process

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.

Chenille yarns - selected production technologies

Production methods:

Special equipment for the production of chenille yarn – effect yarn is wound on a triangularly shaped part, after which it gradually slides to the cutting knife. The width at the bottom defines the length of the effective hair segments (piles). Core yarns with a defined pretension are guided from both sides. Thanks to the guide rollers, effective hair segments are placed and fix in a structure of chenille yarn by twisting of core yarns.



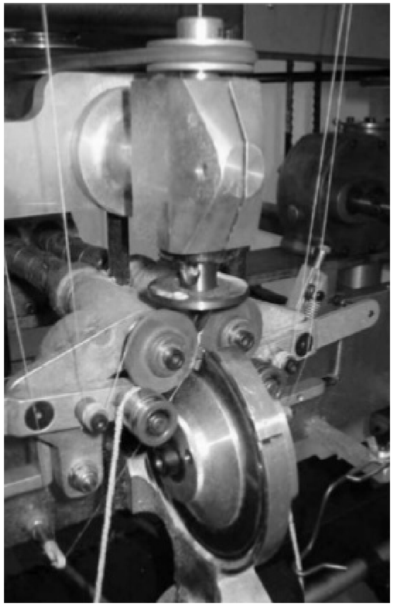
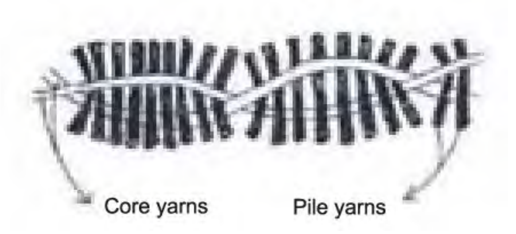


Fig. 20 Schema of chenille yarn process (side view, front view and the machine)

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.

Chenille yarns - selected qualitative characteristics



Factors influencing quality:

- ✓ the type of material used for effective hair segments (piles) and core yarns,
- ✓ fineness of effective hair segments (piles) and core yarns,
- ✓ length of effective hair segments (piles),
- ✓ twist (defined by spindle speed and take up speed),
- ✓ technological settings (spindle speed, winding speed, winding speed of effect yarn, % of shortening - similar to shortening due to twisting and insertion of effect segments)…

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.

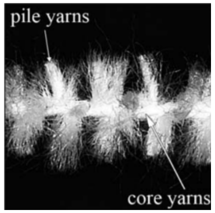
Cerven E., K. Özdemir Ö. A study of the basic parameters describing the structure of chenille yarns. *Fibers and Textiles in Eastern Europe* 14, 2(56), 2006.

Hristian L., Ostafe M. M., Manea L. R., Leon A. L. The study about the improvement of the quality for the fabrics made of chenille yarn. *ModTech Conference – Modern Technologies in Industrial Engineering IV*, IOP Publishing. *Material Science Engineering* 145, 2016.

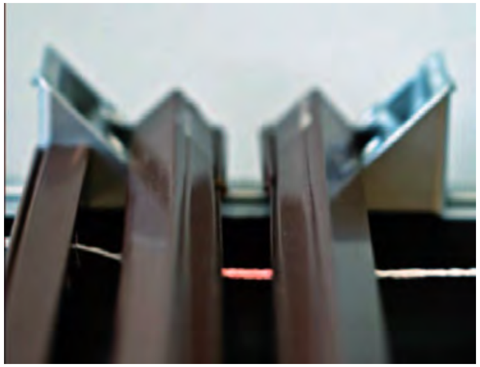
Nergis B. U. Performance of chenille yarns with elastane. *Fibers and Textiles in Eastern Europe 14, 3(57), 2006.*

Cerven E., K. Özdemir Ö. Effect of chenille yarn parameters on yarn shrinkage behavior. Textile Research Journal 75(3), 2005.

Chenille yarns - selected qualitative characteristics



Structural defect indicator - the length of effective hair segments of chenille yarns can be monitored using image analysis and EWMA control charts.



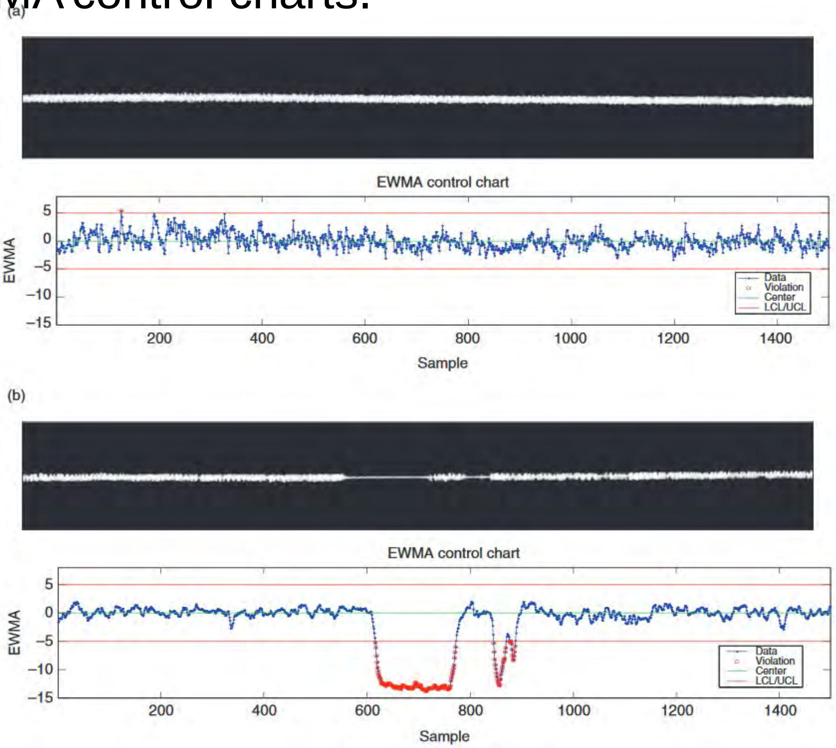


Fig. 21 Laboratory setting for monitoring chenille yarn defects, scanning of chenille yarn, example of longitudinal chenille yarn with control charts

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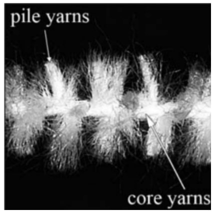
Tunák M., Bajzík V., Testik M. C. Monitoring chenille yarn defects using image processing with control charts. *Textile Research Journal* 81(13), 2011.

Süle I., Süle C. Investigation of the production properties of fancy yarns using image processing method. IEEE Xplore 2015.

Süle I. The determination of the twist level of the chenille yarn using novel image processing methods: Extracting of axial grey-level characteristic and multi-step gradient based thresholding. Digital Signal Processing 29, 2014.

Chenille yarns - selected qualitative characteristics



Chenille yarn quality assessment is evaluated by the analysis of the character of the inserted effect hair segments in chenille yarn. This procedure can be used to assess abrasion resistance via analyzing longitudinal views of the chenille yarn before and after abrasion strokes. The abrasion resistance is also tested on final fabrics, not only from chenille yarn itself.

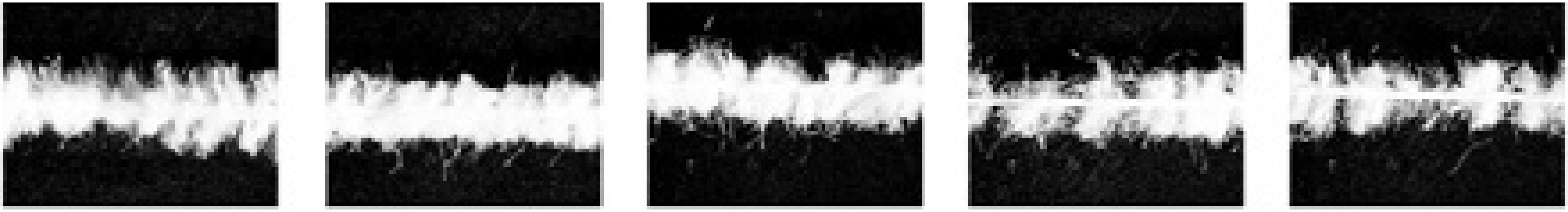


Fig. 22 Chenille yarn 19,5 tex 20 µm WO, 1,5 den PES before and after 50, 75, 100 a 150 abrasion cycles

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Ceven E. K. Özdemir Ö. Influence of chenille yarn manufacturing parameters on yarn and upholstery fabric abrasion resistance. *Textile Research Journal* 74(6), 2004.

Ceven E. K. Özdemir Ö. Evaluation of chenille yarn abrasion behavior with abrasion tests and image analysis. *Textile Research Journal* 76(4) 2006.

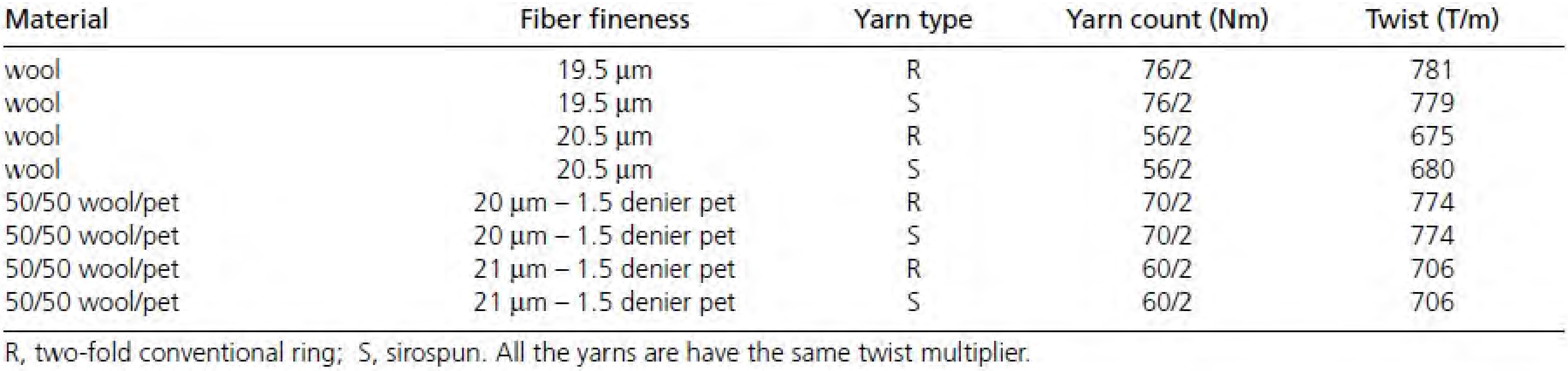
Ulku S., Ortlek H. G., Omeroglu S. The effect of chenille yarn properties on the abrasion resistance of upholstery fabrics. *Fibers and Textiles in Eastern Europe* 11 3(42), 2003.

Kavusturan Y., Ceven E. K. Özdemir Ö. Effect of chenille yarns produced with selected comfort properties of knitted fabrics *Fibers and Textiles in Eastern Europe* 18 1(78), 2010.

Discussion and conclusions – example of results 2

Experimental material:

Chenille yarns 2,8 Ne were produced from two type of piles 100% WO and 50/50 WO/PES by ring and siro spinning technologies, the core yarn were made up from 100% CO yarn with yarn count 34/1 Ne and twist 790 m^{-1}, the length of piles were 1,2 mm. The single faced knitting samples realized on flat knitting machine with E7.



Material	Fiber fineness	Yarn type	Yarn count (Nm)	Twist (T/m)
wool	19.5 µm	R	76/2	781
wool	19.5 µm	S	76/2	779
wool	20.5 µm	R	56/2	675
wool	20.5 µm	S	56/2	680
50/50 wool/pet	20 µm – 1.5 denier pet	R	70/2	774
50/50 wool/pet	20 µm – 1.5 denier pet	S	70/2	774
50/50 wool/pet	21 µm – 1.5 denier pet	R	60/2	706
50/50 wool/pet	21 µm – 1.5 denier pet	S	60/2	706

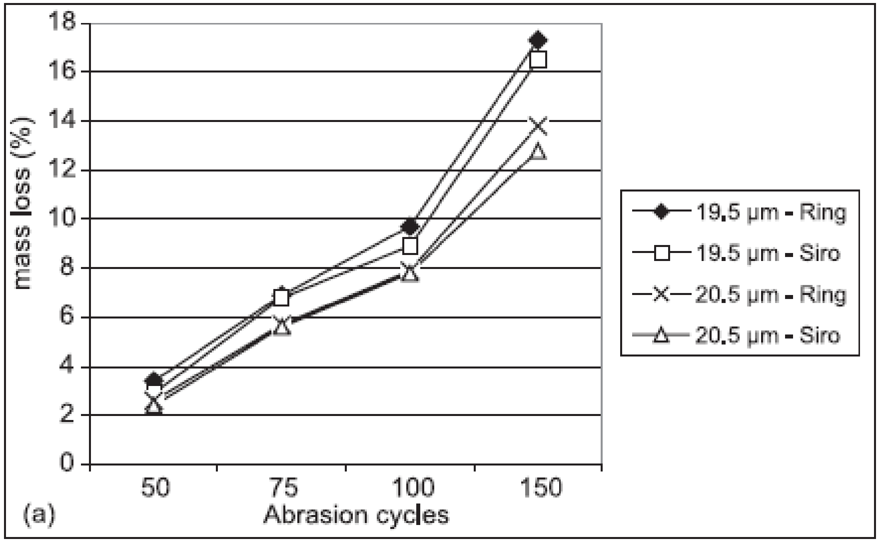
R, two-fold conventional ring; S, sirospun. All the yarns are have the same twist multiplier.

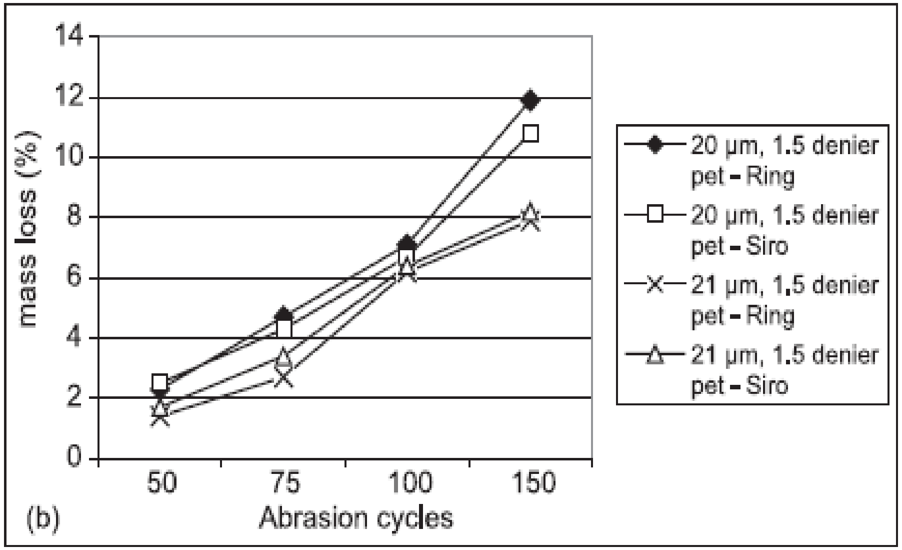
Ceven E. K. Özdemir Ö. Evaluation of chenille yarn abrasion behavior with abrasion tests and imag analysis. *Textile Research Journal* 76(4) 2006.

Discussion and conclusions – example of results 2

Results:

- ✓ ANOVA verifies, that the fiber material and yarn count of piles significantly influenced the knitting fabric abrasion resistance. The addition of PES fiber improves resistance to frictional forces. Coarse fibers show better stability in the abrasion process.
- ✓ The lower weight loss of knitted fabric shows the knitted fabric made of chenille yarns with coarser piles and chenille yarns processed by Sirospun technology.





Ceven E. K. Özdemir Ö. Evaluation of chenille yarn abrasion behavior with abrasion tests and imag analysis. *Textile Research Journal* 76(4) 2006.

Discussion and conclusions – example of results 2

Experimental material:

The chenille yarns were produced using Ne 20/1 count, two core and one pile yarn (Z 650 m^{-1}). The twist levels of chenille yarn were 800 m^{-1}, 850 m^{-1}, 900 m^{-1} and pile lengths were 0,7 mm, 0,8 mm and 1,0 mm. Upholstery fabrics, which are double-cloth structure, were produced with three different constructions on a rapier weaving machine fitted with a jacquard (21 den 100 % PES warp treads, 10 Ne other weft treads, D_o = 66 cm^{-1}, D_u = 21 cm^{-1}).

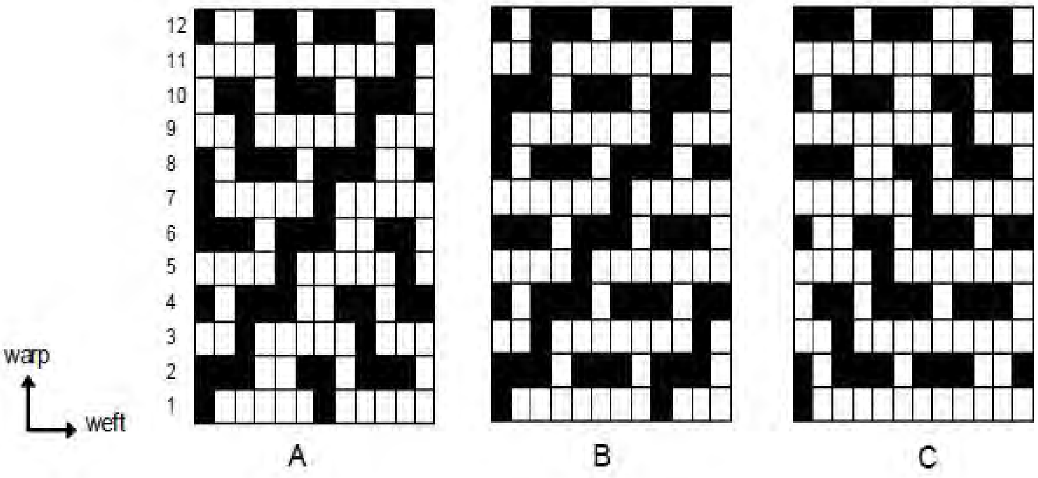


Fig. 23 construction of double- cloth structure upholstery fabrics with chenille yarns

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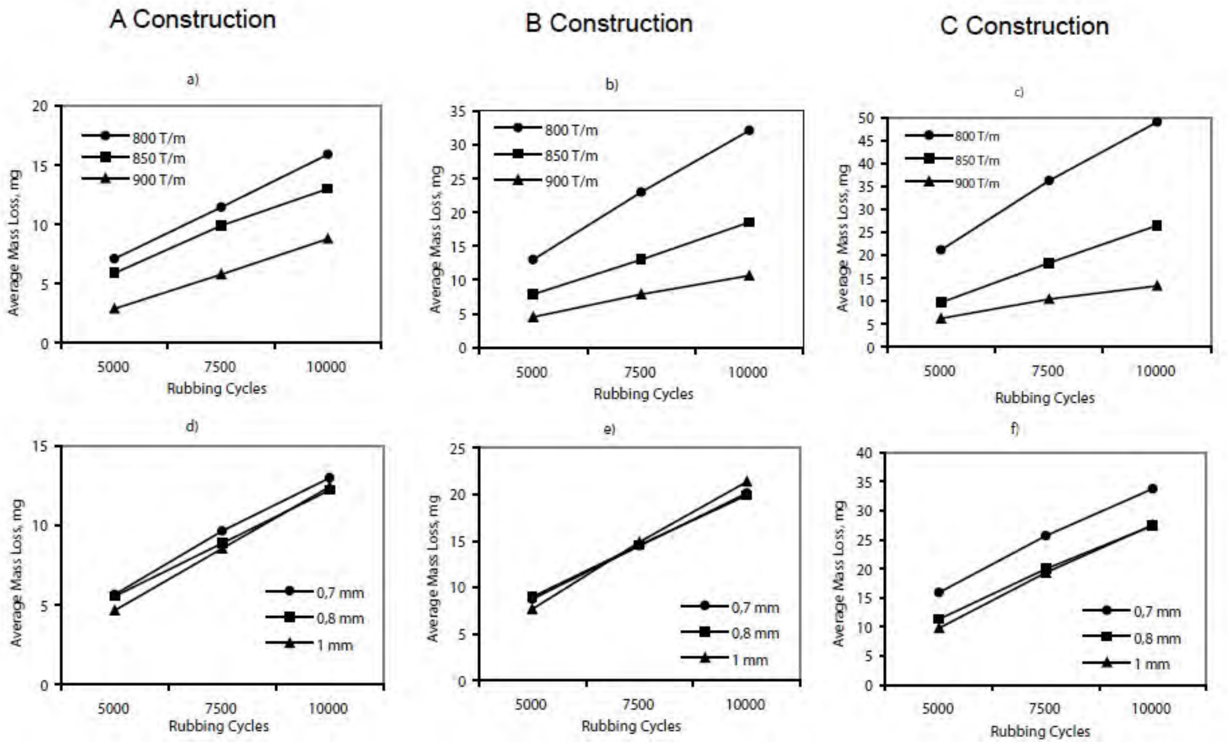
Ulku S., Ortlek H. G., Omeroglu S. The effect of chenille yarn properties on the abrasion restistance of uphostery fabrics. Fibers and Textile in Eastern Europe 11, 3(42), 2003.

Discussion and conclusions – example of results 2

Results:

The analysis of the obtained results confirmed that the twists level of chenille yarns and the used fabric construction parameters influence significantly the weight loss due to abrasion. The higher twists of chenille yarn guarantee better stability of piles in chenille yarn and leads to higher abrasion resistance of the fabric.

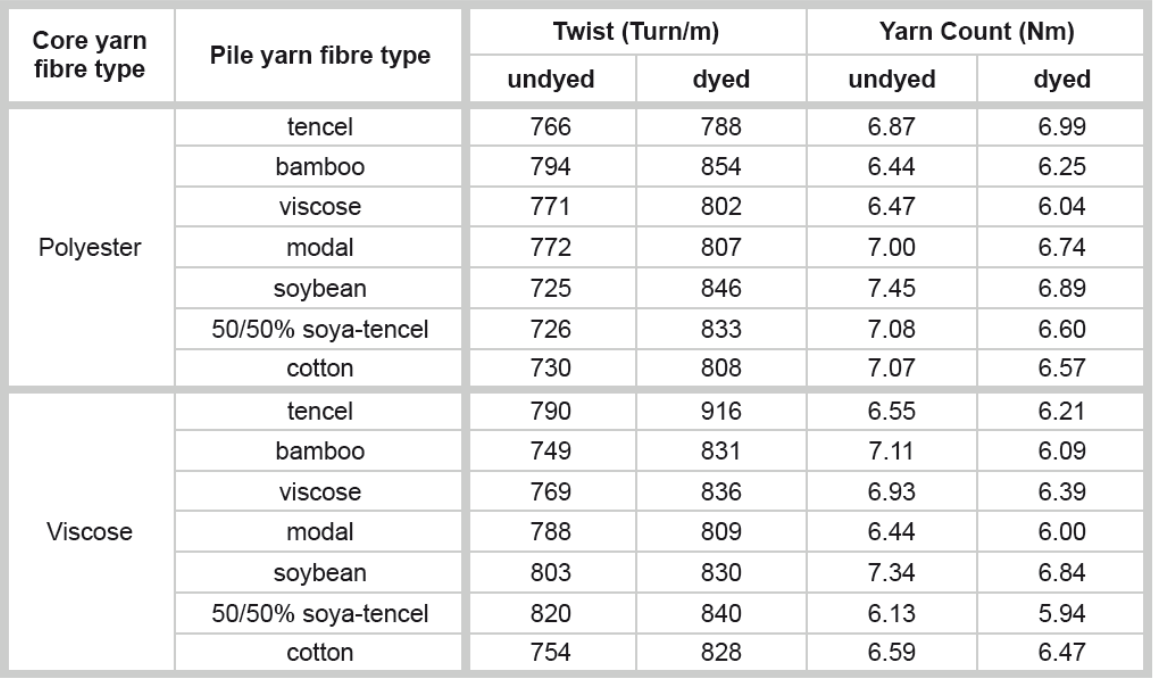


Ulku S., Ortlek H. G., Omeroglu S. The effect of chenille yarn properties on the abrasion restistance of uphostery fabrics. Fibers and Textile in Eastern Europe 11, 3(42), 2003.

Discussion and conclusions – example of results 3

Experimental material:

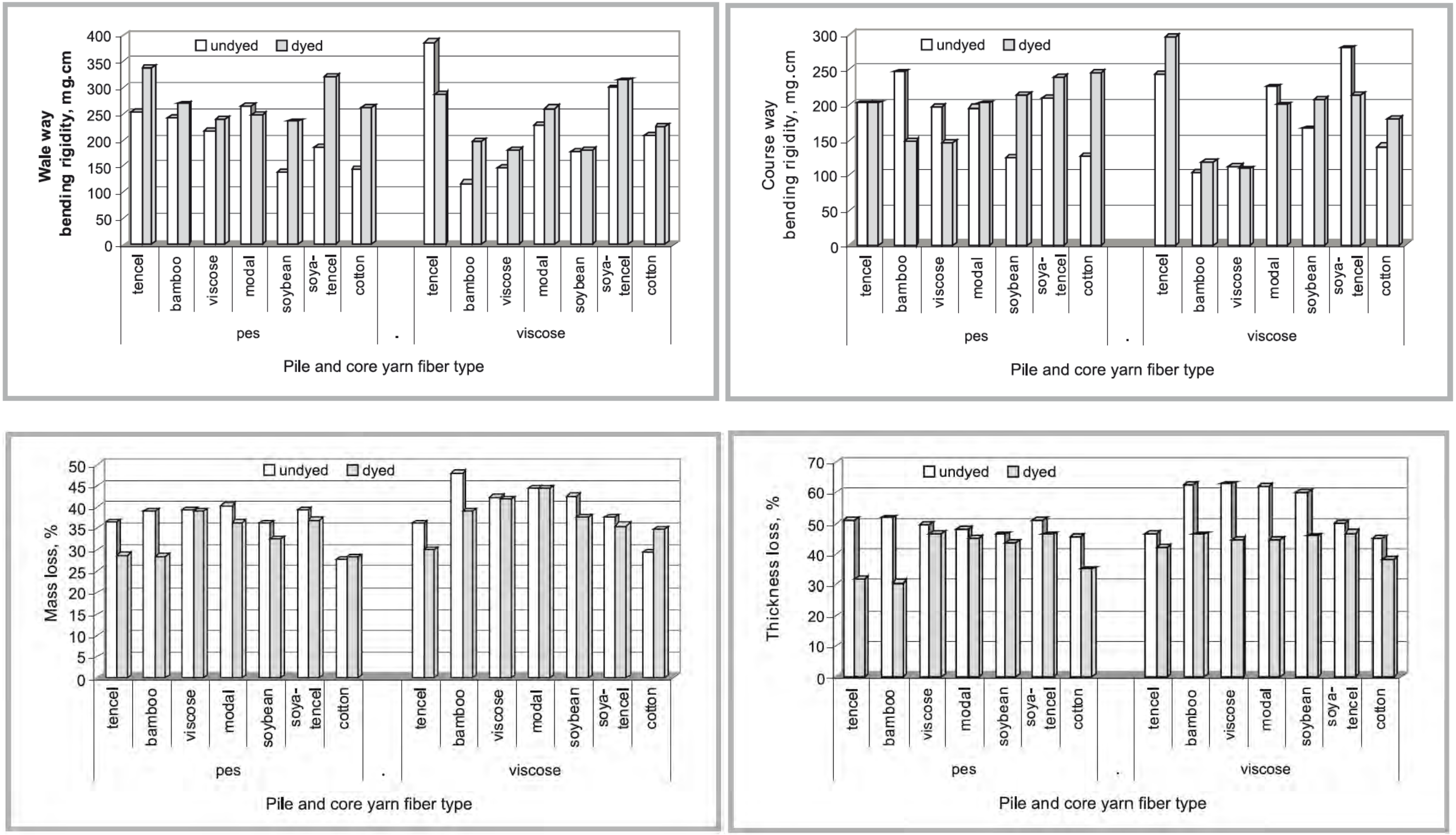
14 kinds of chenille yarn with a yarn count 150 tex spun from core yarn of 20 tex with piles length 1 mm and twists 800 m^{-1} were dyed. Single faced knitted fabric from gray and dyed chenille yarns were produced on flat knitting machine Shima Seiki 7E.



Core yarn fibre type	**Pile yarn fibre type**	**Twist (Turn/m)**		**Yarn Count (Nm)**	
		undyed	**dyed**	**undyed**	**dyed**
Polyester	tencel	766	788	6.87	6.99
	bamboo	794	854	6.44	6.25
	viscose	771	802	6.47	6.04
	modal	772	807	7.00	6.74
	soybean	725	846	7.45	6.89
	50/50% soya-tencel	726	833	7.08	6.60
	cotton	730	808	7.07	6.57
Viscose	tencel	790	916	6.55	6.21
	bamboo	749	831	7.11	6.09
	viscose	769	836	6.93	6.39
	modal	788	809	6.44	6.00
	soybean	803	830	7.34	6.84
	50/50% soya-tencel	820	840	6.13	5.94
	cotton	754	828	6.59	6.47

Kavusturan Y., Ceven E. K. Özdemir Ö. Effect of chenille yarns produced with selected comfort properties of knitted fabrics. *Fibers and Textiles in Eastern Europe* 18 1(78), 2010.

Discussion and conclusions – example of



Kavusturan Y., Ceven E. K. Özdemir Ö. Effect of chenille yarns produced with selected comfort properties of knitted fabrics. *Fibers and Textiles in Eastern Europe* 18 1(78), 2010.

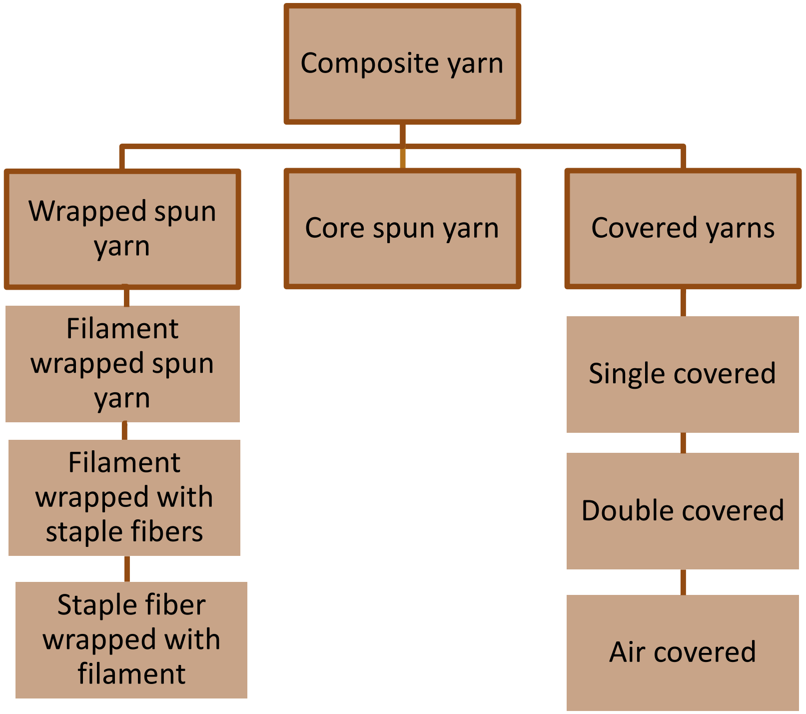
Discussion and conclusions – example of results 3

Results:

- ✓ ANOVA verified that fiber material used for piles and core yarn significantly influence the weight loss due to abrasion and also the thickness of knitted fabric. The knitted fabric made of 100% PES fibers guarantee higher stability but it is not usually used for knitted fabric production.
- ✓ When viscose (tencel, bamboo) or cotton yarns are used as piles, the weight loss of the chenille knitted fabric due to abrasion is lower.
- ✓ Knitted fabric made of gray chenille yarns shows a higher abrasion than knitted fabrics made of dyed chenille yarns.
- ✓ ANOVA also confirmed that gray and dyed chenille yarns processed into knitted fabric do not show statistically significant differences in the flexural rigidity of knitted fabrics in both main directions. Chenille yarns containing viscose (tencel) piles show a relatively high flexural rigidity.

Kavusturan Y., Ceven E. K. Özdemir Ö. Effect of chenille yarns produced with selected comfort properties of knitted fabrics. *Fibers and Textiles in Eastern Europe* 18 1(78), 2010.

Composite yarns - selected types of fancy and hybrid yarns



- Composite yarn
  - Wrapped spun yarn
    - Filament wrapped spun yarn
    - Filament wrapped with staple fibers
    - Staple fiber wrapped with filament
  - Core spun yarn
  - Covered yarns
    - Single covered
    - Double covered
    - Air covered

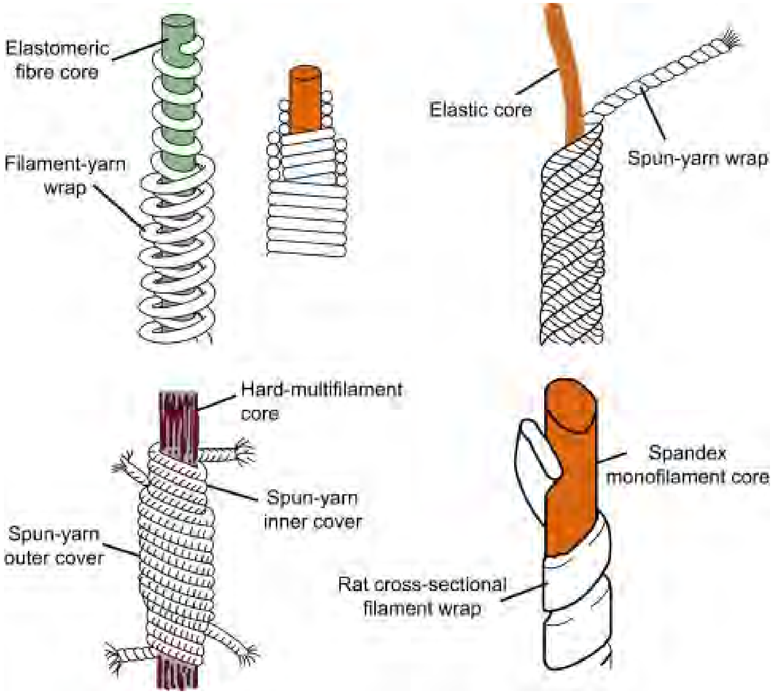


Fig. 24 Examples of composite yarn structures

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Lord P. R. Handbook of yarn production. Woodhead Publishing India Limited 2003.

Composite yarns - selected types of fancy and hybrid yarns

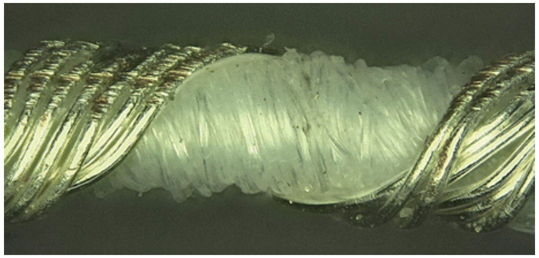
Composite yarn: In general, a composite yarn composed of two or more components. The yarn can have various constructions, e.g. one component can be formed of arranged staple fibers without twisting and the other component is formed by staple yarn/ yarns or multifilament / multifilaments.

Wrapped yarn is a composite structure comprising a core of twisted or twist-less fibers (sliver/ roving/ monofilament or multifilament) bound by a staple yarn or continuous filament. Market offer wrapped yarn with count range 15 tex – 1500 tex made of natural or synthetic fibers.

Core yarn has a core/ sheath structure. The core may consist of a special yarn, a multifilament with small protective twist, a bundle of parallel twist-less filaments or an elastic component. The sheath consists of one or more staple yarns, other multifilaments or elastic material. Some technologies allow the production of multiple types of composite yarns.

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Wrapped yarns - selected production technologies



Methods of wrapped yarn production:

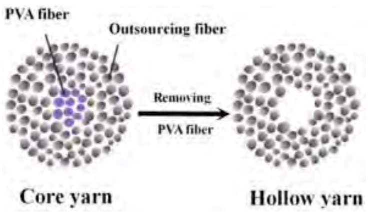
using a hollow spindle, modified ring spinning technology, rotor spinning Rotona, using modified wool carded technology, (also technology Selfil, Repco, Parafil).

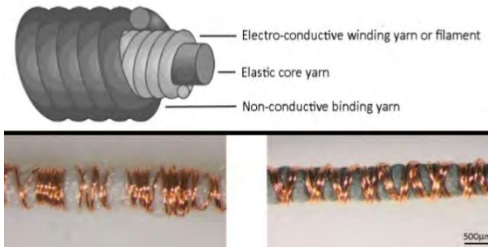
Application:

production of clothing and technical textiles with regard to the type of effect that is achieved, e.g. high-strength and durable yarns for workwear and jeans, elastic yarns to ensure the shape of knitwear - socks, sportswear, conductive yarn, household textile, terry cloths. It is also possible to produce auxetic yarns using a hollow spindle.

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Core yarns - selected production technologies





Methods of core yarn production:

modified ring spinning technology, modified rotor spinning, friction spinning, modified Air Jet technology and Core-twin spinning technology.

Applications:

sportswear and underwear, sewing threads, technical textiles for various applications, including reinforcements for composites. A special yarn designed for terry cloths with a specific hand. Polyvinyl alcohol multifilament is used as the core, which dissolves after washing. The structure of the yarn is called core hollow yarn, now is replaced by "air rich yarn", where the various fibers (base and solvable) are blended in slivers. Special yarn used for the realization of conductive paths in textiles, where the core or sheath is formed by a conductive component.

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Lord P. R. Handbook of yarn production. Woodhead Publishing India Limited 2003.
Schwarz A., Kazani I., Cuny L., Hertleer C., Ghekiere F., De Clercq G., De Mey ., Van Langenhove L., Electro-conductive and elastic hybrid yarns – The effects of stretching, cyclic straining and washing on theier electro-conductive properties. *Materials and Design* 32, 2011.

Wrapped yarns - selected production technologies

Methods of production of wrapped yarn using hollow spindle technology:

The technology is based on previous partial solutions (German patent 601, 637 from 1932; British patent 572, 244 from 1943, Czechoslovak patent 124508 from 1956), which were comprehensively modified by the team of George Mitov in the 70s of the 20th century (PRENOMIT ON-1 device , OF-1, PE-3, PR-3). The aim was to replace the two phases production of fancy yarns by means of a modified ring spinning with a hollow spindle.

It is used for the production of fancy yarns as well as of wrapped yarns, when the phase of staple yarn production is discarded and the core of parallel arranged fibers is formed from a sliver or roving.

Selected equipment manufacturers: Leesona, Sussen, Gemmill and Dunsmore, Saurer Alma.

Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Lord P. R. Handbook of yarn production, Woodhead Publishing India Publishing Limited 2003.

Chen J., Du Z. Structural design and performance characterization of stable helical auxetic yarns based on the hollow spindle covering system. *The Textile Research Journal* 90(3-4), 2019.

Wrapped yarns - selected production technologies

Methods of wrapped yarn production by using wool technology of a roving production on a carding machine with a hollow spindle:

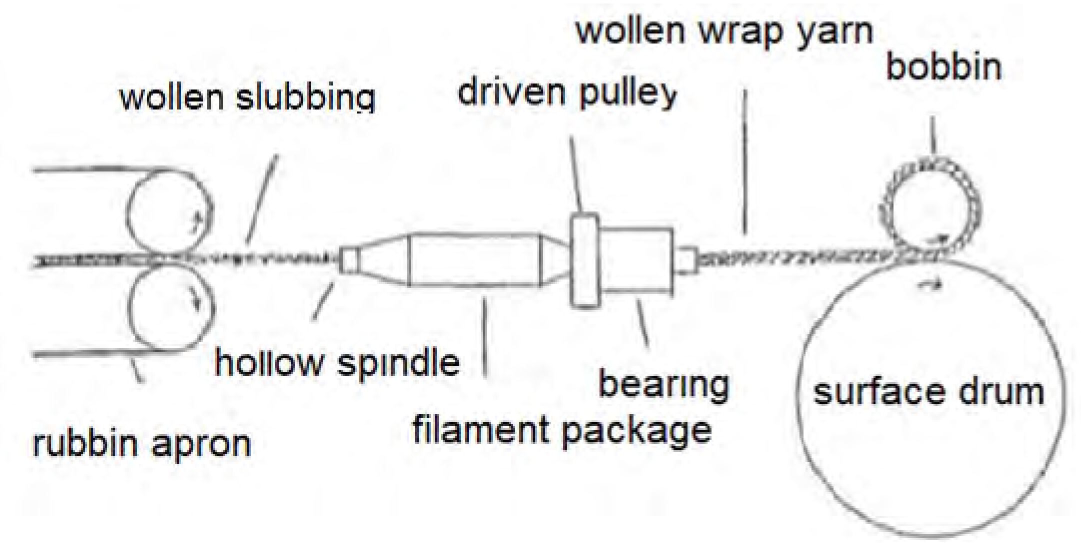
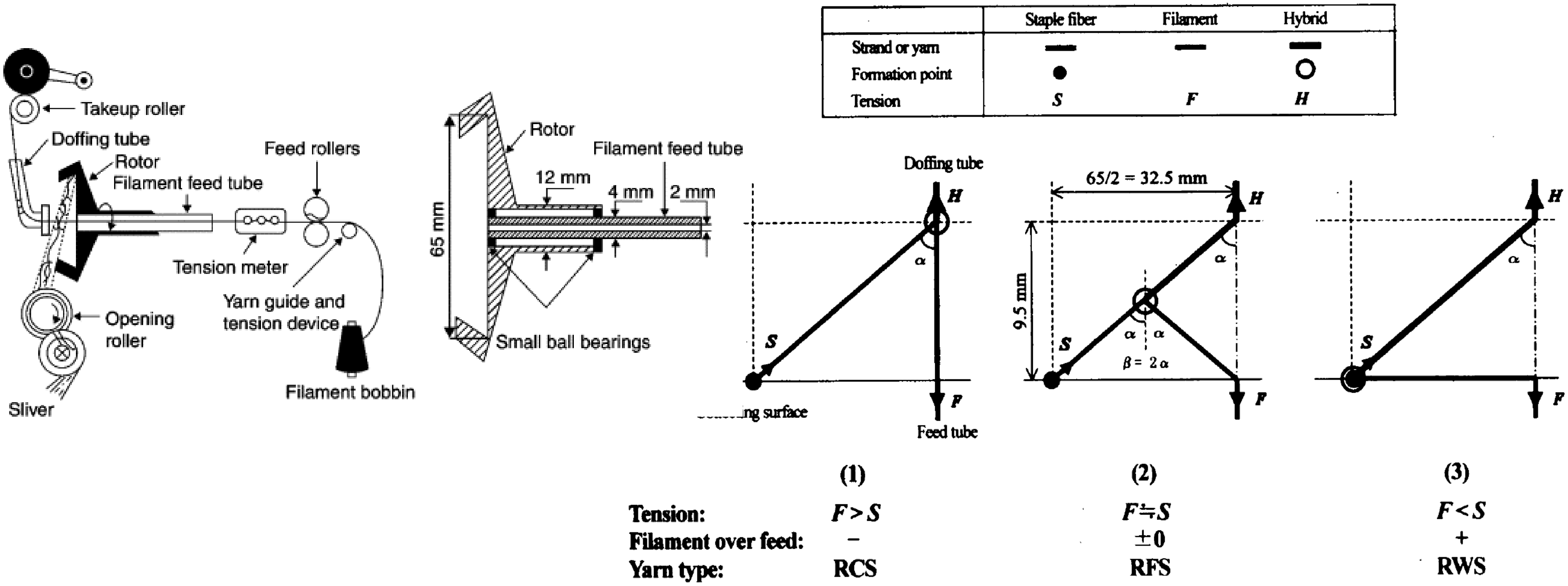


Fig. 26 Principle of wrapped yarn production by using modified woolen technology (directly on condenser of woolen carding machine during forming of roving)

Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.

Wrapped yarns - selected production technologies

Methods of wrapped yarn production by using by modified rotor spinning technology:



	Staple fiber	Filament	Hybrid
Strand or yarn	▬	▬	▬
Formation point	●		○
Tension	*S*	*F*	*H*

	(1)	(2)	(3)
Tension:	$F > S$	$F \fallingdotseq S$	$F < S$
Filament over feed:	–	±0	+
Yarn type:	RCS	RFS	RWS

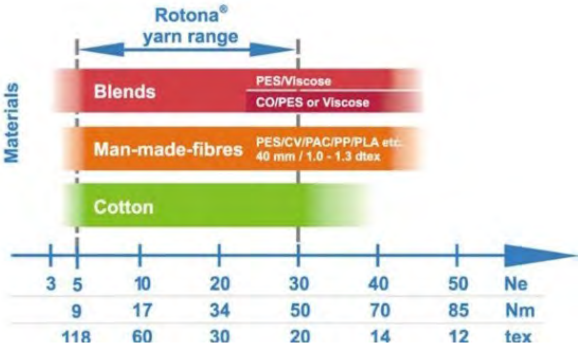
Fig. 27 Principal of wrapped yarn production by using modified rotor spinning technology and the schema of „yarn forming point“ for various type of yarn (H hybrid yarn, F multifilament, S staple fibers), The Czech patent Rotona (wrapped yarn) it is possible to use also for production of core yarn.

Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.

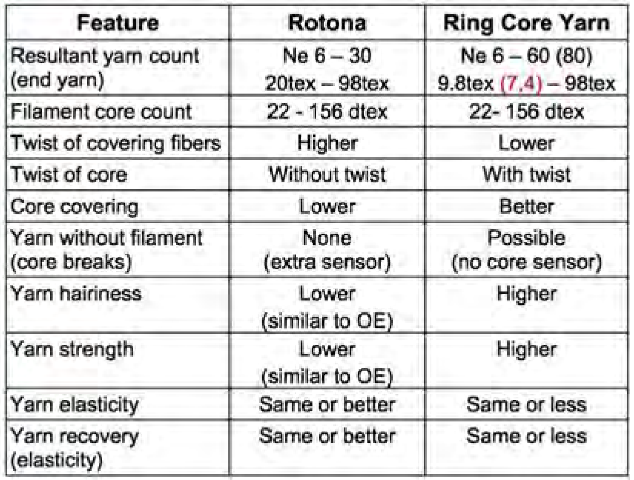
Matsumoto Y., Saito H., Sakaguchi A., Toriumi K., Nishimatsu T., Shimizu Y., Shirai H. Combination Effects of open end rotor spun hybrid yarn. *Textile Research Journal* 74(8), 2004.

Matsumoto Y., Fushimi S., Saito H. Sakaguchi A., Toriumi K, Nishimathu T., Shimizu Y., Shirai H. Twisting mechanisms of open end rotor spun hybrid yarns. *Textile Research Journal* 72(8), 2002.

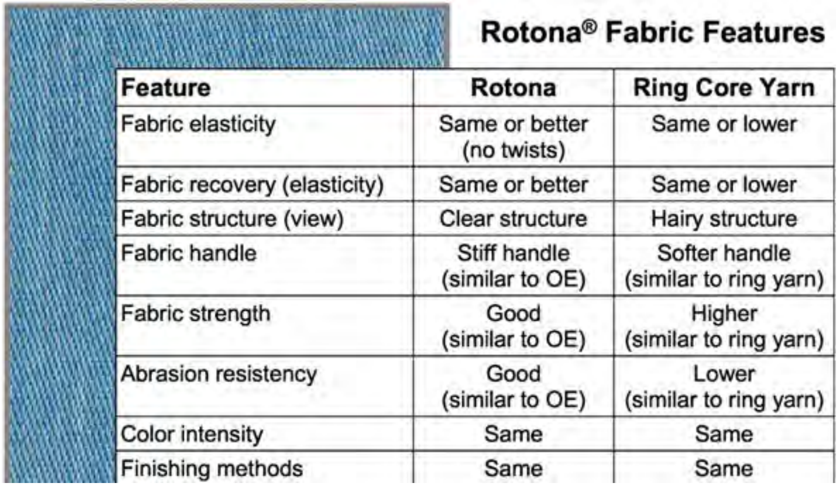
Wrapped yarns - selected production technologies



Methods of wrapped yarn production by using modified rotor spinning technology:



Feature	Rotona	Ring Core Yarn
Resultant yarn count (end yarn)	Ne 6 – 30 20tex – 98tex	Ne 6 – 60 (80) 9.8tex (7.4) – 98tex
Filament core count	22 - 156 dtex	22- 156 dtex
Twist of covering fibers	Higher	Lower
Twist of core	Without twist	With twist
Core covering	Lower	Better
Yarn without filament (core breaks)	None (extra sensor)	Possible (no core sensor)
Yarn hairiness	Lower (similar to OE)	Higher
Yarn strength	Lower (similar to OE)	Higher
Yarn elasticity	Same or better	Same or less
Yarn recovery (elasticity)	Same or better	Same or less



Rotona® Fabric Features

Feature	Rotona	Ring Core Yarn
Fabric elasticity	Same or better (no twists)	Same or lower
Fabric recovery (elasticity)	Same or better	Same or lower
Fabric structure (view)	Clear structure	Hairy structure
Fabric handle	Stiff handle (similar to OE)	Softer handle (similar to ring yarn)
Fabric strength	Good (similar to OE)	Higher (similar to ring yarn)
Abrasion resistency	Good (similar to OE)	Lower (similar to ring yarn)
Color intensity	Same	Same
Finishing methods	Same	Same

Fig. 28 Rotona Rieter BT 904, production of elastic wrapped yarn

Applications:

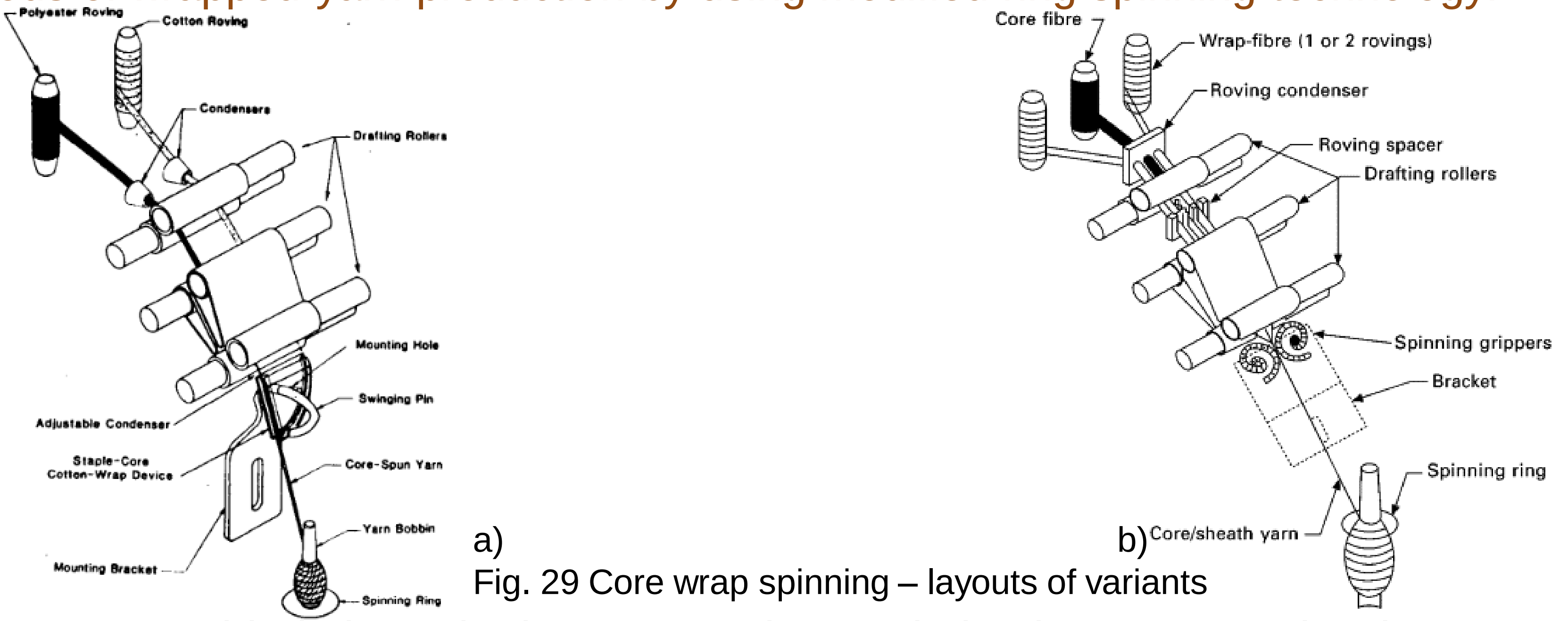
Elastic ROTONA is preferably used in the production of elastic underwear, sanitary textiles, sports elastic knitted fabrics, elastic upholstery materials, and clothing for leisure. The production machine can also be used for the production of special industrial yarns containing glass, mineral fibers, metal wires, aramid fibers, etc.

www.rieter.com

IS 22-106-01/01 Determination of core covering of wrapped yarns. Research Centre Textile, FT TUL 2004.

Wrapped yarns - selected production technologies

Methods of wrapped yarn production by using modified ring spinning technology:



a) b)

Fig. 29 Core wrap spinning – layouts of variants

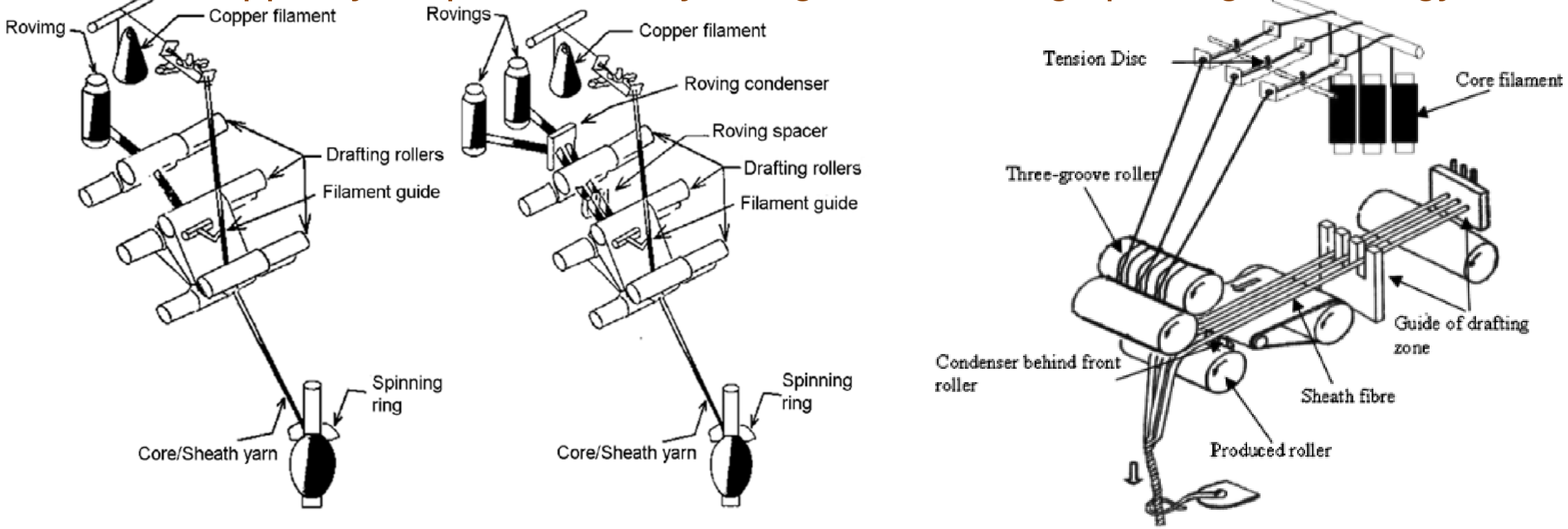
Rovings are guided through the compacting and drafting zone and subsequently guided into guide channels. A ribbon of drawn fibers is wrapped around the core. The geometry of the shaped channel of variant a) ensures that there is no propagation of the twist between the core and cover rovings. The aim is to draw the wrapping ribbon and flatten it if possible to effectively cover the yarn core.

Alagirusamy R., Das A. *Technical Textile Yarn*. Woodhead Publishing 2010.

Sawhney A. P. S., Robert K. Q., Ruppenicker G. F. Device for producing staple core/cotton wrap ring spun yarn. *Textile Research Journal* 59(8), 1989.

Core yarns - selected production technologies

Methods of wrapped yarn production by using modified ring spinning technology:



a) Modified ring spinning technology for core yarn, b) siro-spun technology for core and wrapped yarn, c) TSMM technology for core and wrapped yarn

Fig. 30 Principals of core yarn production by using modified ring spinning technology

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Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.

Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.

Lord P. R. Handbook of yarn production. Woodhead Publishing India Limited 2003.

Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Morarah M. H., Najar s. S., Etrati S. M. Mechanical properties of copper/cotton core-spun yarns produced by siro and ring spinning methods. *Indian Journal of Fibre and Textile Research* 44(12), 2019.

Kurban M., Babaarslan O, Cagatay I. H. Textile for advance apliction – Chapter 5, Hybrid yarn composites for construction. INTECHOPEN 2017.

Covered yarns - selected production technologies

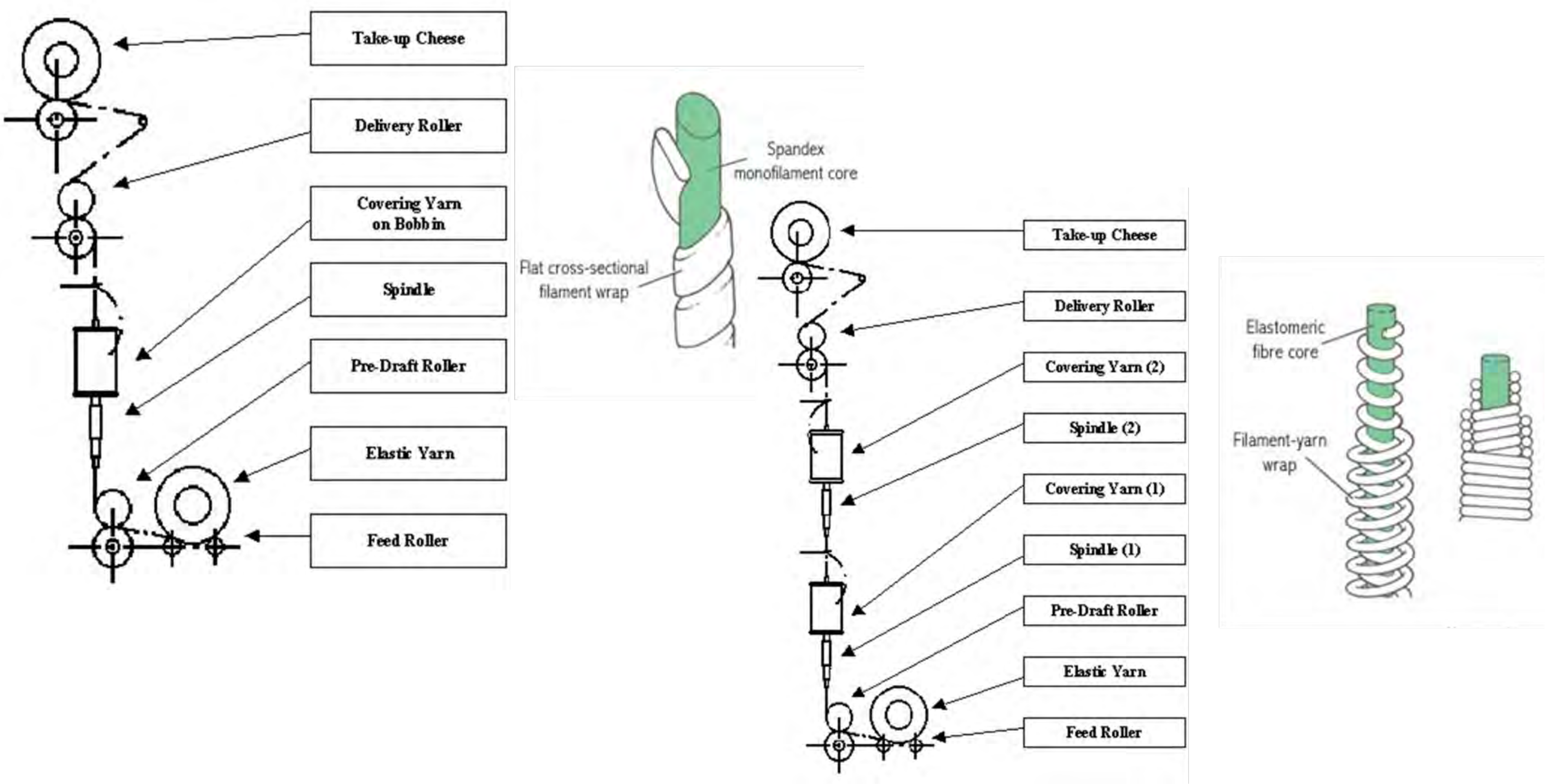
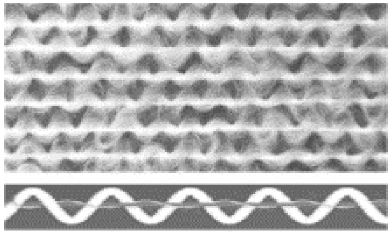
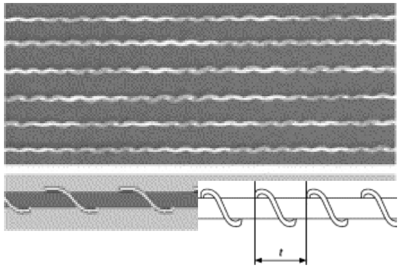


Fig. 31 Principles of coved yarn production

Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.
Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Lord P. R. Handbook of yarn production. Woodhead Publishing India Limited 2003.

Wrapped yarns - selected qualitative characteristics





Factors influencing yarn quality:

- ✓ The type and quality of the fibrous material significantly affects the mechanical properties of the yarn. In the case where the staple fiber sliver / roving is wrapped with a monofilament / multifilament / staple yarn, the load carrier component is a wrapping component. The cohesion of the wrapped component (sliver / roving) is mainly influenced by the material composition, the length of the fibers and their surface properties, especially the friction and the bending rigidity.
- ✓ Hollow spindle technology: Technological setting, especially the level of the twist of the wrapped component (see Fig. parameter *t* - height of the wrap / angle of wrapped structure, distance of the last pair of rollers in the drafting zone from the hollow spindle) affects the overall character of yarn (bending rigidity, cohesion, mechanical properties, …).

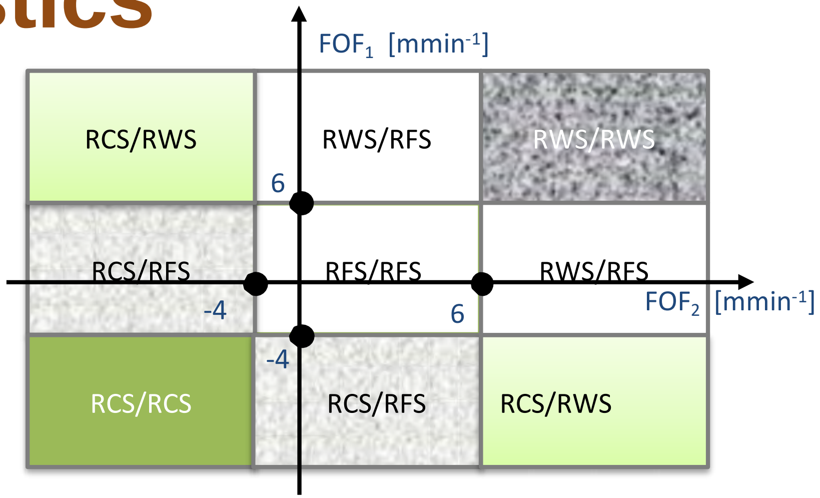
Gong R. H., Wright R. M. *Fancy yarns, Their manufacture and application*, Woodhead Publishing 2002.

Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.

Subramaniam V., Mohamed P. A. Wrap spining technology – A critical review of yarn properties. *Indian Journal of Fibre and Textile Research* 17(12), 1992.

Chen J., Du Z. Structure design and performance characterization of stable helical auxetic yarns based on the hollow-spindle covering system. Textile Research Journal 90(3-4), 2020.

Wrapped yarns - selected qualitative characteristics



Factors influencing yarn quality:

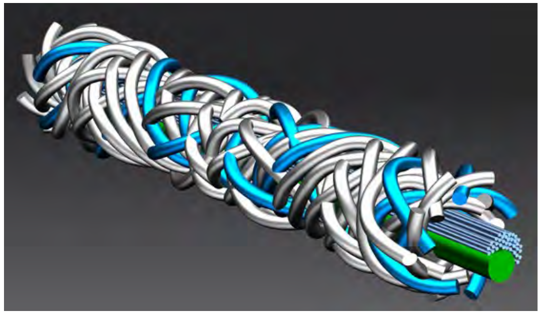
- ✓ Modified rotor spinning technology: production of rotor core spun yarn RCS, rotor folded spun yarn RFS and rotor wrapped yarn RWS yarns is given by the chosen combination of multifilament feed speed and take-off speed (FOF1, FOF2 [mmin-1]). The position of yarn forming point, where the new yarn is formed in the rotor affects the resulting yarn structure. The staple fiber core can be fully wrapped by multifilament, the yarn has the characteristic structure of a wrapped yarn, or the multifilament core is completely wrapped with staple fibers (see the diagram in Fig. 27).

Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.

Matsumoto Y., Saito H., Sakaguchi A., Toriumi K., Nishimatsu T., Shimizu Y., Shirai H. Combination Effects of opend end rotoro spun hybrid yarn. *Textile Research Journal* 74(8), 2004.

Matsumoto Y., Fushimi S., Saito H. Sakaguchi A., Toriumi K, Nishimathu T., Shimizu Y., Shirai H. Twisting mechanisms of open end rotor spun hybrid yarns. *Textile Research Journal* 72(8), 2002.

Core yarns - selected qualitative characteristics



Factors influencing yarn quality:

- ✓ Technological setting in terms of core / cover proportion (sewing threads usually 2:1), number of rovings at input, core pretension if it is a multifilament or elastic material (for ordinary core yarns 5% - 10%, for core yarns using textured multifilament 50% - 400%), elongation in case that staple fibers are used for yarn formation, twist level.

Selected qualitative indicators:

- ✓ Diameter of core yarn, angle of wrapped structure (height of the wrap or helix angle), distance between individual wraps, core covering and other standard quality characteristics (yarn unevenness, hairiness, IPI, mechanical properties, abrasion resistance, method of distribution of individual components in cross section and other specific properties such as conductivity, degree of shielding of electric radiation, fatigue in cyclic loading, …)

Lawrence C. A. *Advances in yarn spinning technology*, Woodhead Publishing Limited 2010.
Lawrence C. A. *Fundamentals of Spun yarn technology*, CRC Press 2003.
Lord P. R. Handbook of yarn production. Woodhead Publishing India Limited 2003.

Wrapped yarns - selected qualitative characteristics

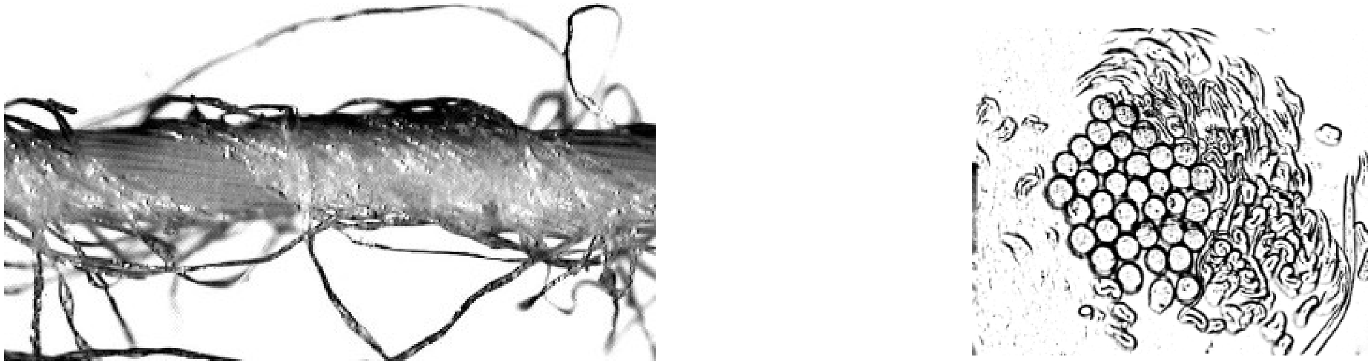


Fig. 32 Rotona 100 % PES core, cover 100 % CO, covering ability of cover is 96%

Presumptions for the yarn structure model:

✓ The core is composed of parallel cylindrical fibers (multifilament with very low twist or twist-less in this case),

✓ A flat ribbon of a given width is wrapped around the core in the shape of a helix. The thickness and profile of the ribbon are neglected for simplicity.

✓ The ribbon wraps the core regularly, the number of wraps per unit length is defined by twist Z [m^{-1}], the axis of the ribbon forms a helix on a cylinder of diameter D_h [m^{-1}], .

✓ The core covering is important from the point of view of subsequent processing.

IS 22-106-01/01 Determination of core covering of wrapped yarns. Research Centre Textile, FT TUL 2004.

Wrapped yarns - selected qualitative characteristics

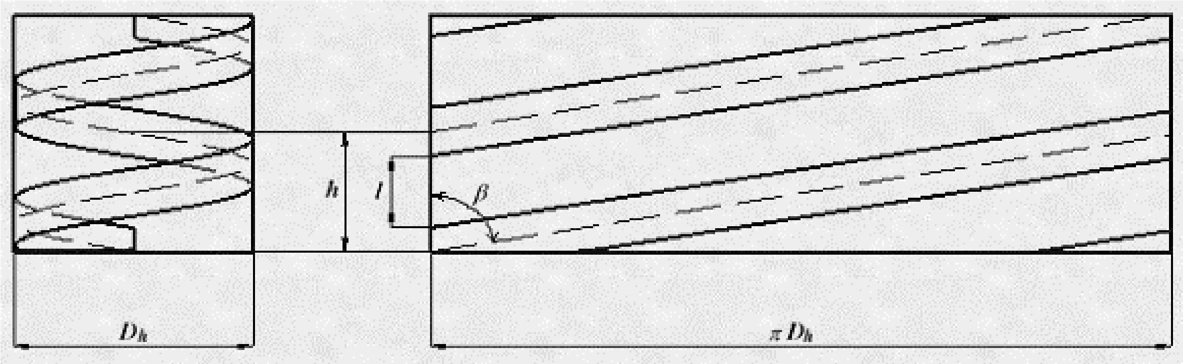


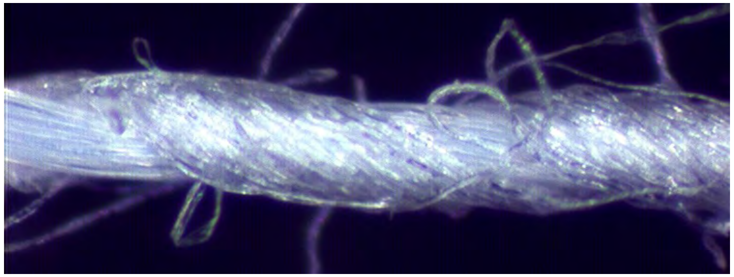
Fig. 33 Model of wrapped yarn structure

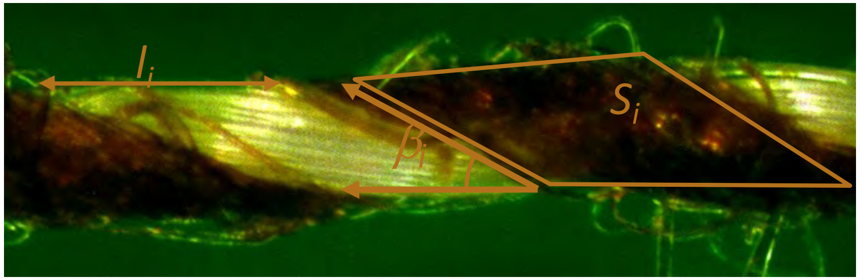
Model:

- ✓ Helix angle of the wrapped material β, high of wrap $h = 1/Z$, length of uncovered part of yarn in direction of yarn axis l. When the cylinder is unrolled at the height of one wrap, a rectangle with an area $\pi D_h h$ is formed (one side of the rectangle is the height of helix angle h and the other the circumference of the cylinder πD_h).
- ✓ The core covering ability of wrapped yarn can be defined as a portion of area covered by the wrapping ribbon and the whole area of rectangular of the area.

IS 22-106-01/01 Determination of core covering of wrapped yarns. Research Centre Textile, FT TUL 2004.

Wrapped yarns - selected qualitative characteristics





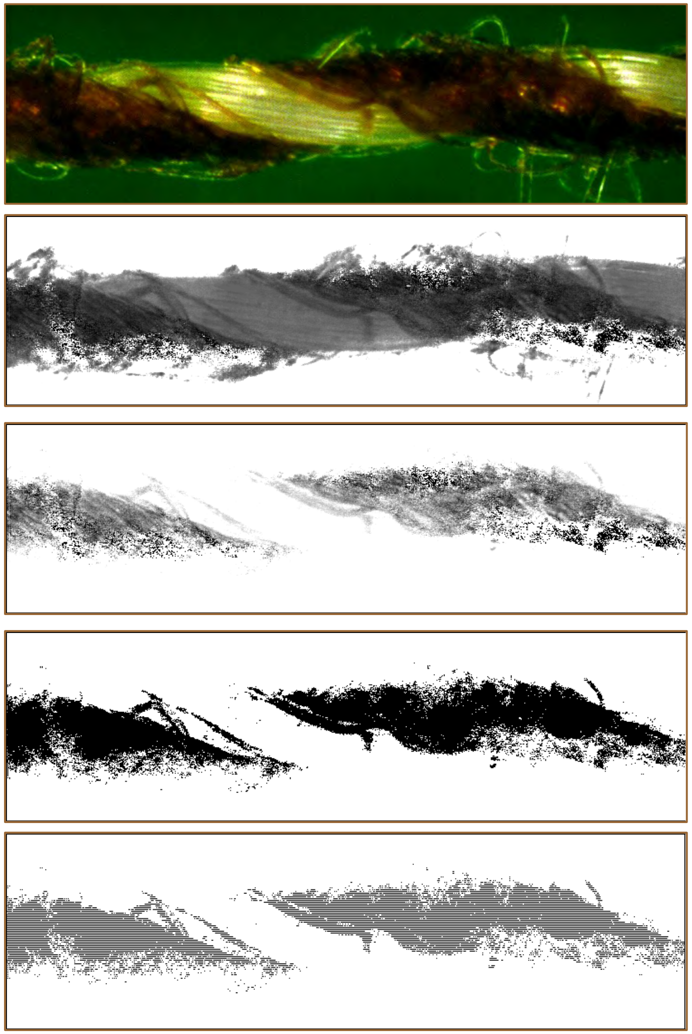
Methodologies for determining the structural parameters of wrapped yarn:

- ✓ Method A: The lengths of the covered and exposed sections are measured subjectively in the direction of the yarn axis. In addition, it is possible to measure the angles of helix of the wraps. Usually the predominant angle of the surface fibers in wrapping ribbon to the yarn axis is evaluated. In some cases, it is necessary to intuitively estimate these parameters based on the operator's experience.
- ✓ Method B: is based on automatic program-controlled image processing. Prior to automatic evaluation, samples must be scanned with a suitable background and if necessary the partial fibers are dyed. (In this case, the yarn sample was dyed in iodine solution and scanned on a blue background. It appears to be the most effective when the core is made of synthetic fibers and cover consists from cotton fibers.)

IS 22-106-01/01 Determination of core covering of wrapped yarns. Research Centre Textile, FT TUL 2004.

Wrapped yarns - selected qualitative characteristics

Procedure B:



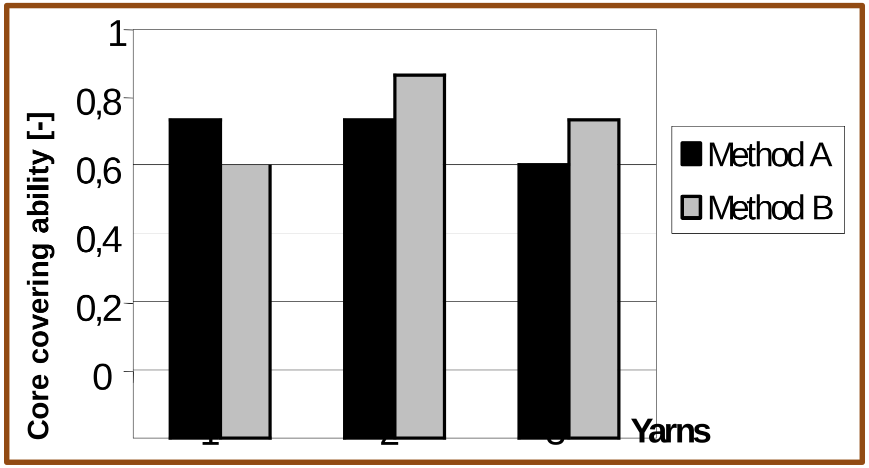
- ✓ sample preparation, setting of optical system and camera;
- ✓ selection of object features (maximum ferret, minimum ferret, angle, length, coordinates of centers of gravity, orientation, …)
- ✓ capturing the required number of images of wrapped yarn;
- ✓ image processing (segmentation), image thresholding and conversion to binary form; application of morphological operations under image;
- ✓ outputs saving – matrix of results.
- ✓ calculation of core covering ability of wrapped yarn. (It can be also calculated as the maximum of portion of the coved length of the measured section to the sum measured length).

IS 22-106-01/01 Determination of core covering of wrapped yarns. Research Centre Textile, FT TUL 2004.

Discussion and conclusion – examples of results 4

Experimental material:

3 samples of wrapped yarns spun by open end spinning technology with a yarn count 33 tex made off PES/CO (multifilament fineness 7,5 tex). Yarns were spun from the same sliver quality under the same technological setting on the same spinning frame only the twist coefficient differs: 70 ktex$^{2/3}$m^{-1}, 75 ktex$^{2/3}$m^{-1} a 80 ktex$^{2/3}$m^{-1}.



	Method A		Method B	
sample	distribution	median	distribution	median
Yarn 1	Normal	0,828	Gumbel	0,809
Yarn 2	Normal	0,830	Gumbel	0,867
Yarn 3	Normal	0,804	Gumbel	0,843

Poulová A. *The Structure and Properties of Wrapped Rotor Yarn*, DP FT TUL, 2002 (Only in Czech).

Discussion and conclusion – examples of results 4

Results:

- ✓ The empirical distribution of data in the case of method B is not normal. For these reasons, only the median values were compared. It can be said that the values of cover ability are approximately comparable. The various probability distribution may be given by the different sensitivity of the methods possibly caused by the surface hairiness of the yarn. When using method A, the operator measures the length of the sections so that it does not include the occurrence of single fibers that cover the core of the yarn and change the shape of the ribbon helix. Method B includes these fibers into account.
- ✓ The core covering ability of yarn defined by the model assumes a regular ribbon wound on a cylinder, but the real ribbon is irregular. Using method B, it would be possible to identify a real covered area. The potential irregularities on the edge of an image should be solved e.g. by a combination of lower and upper lighting exposure. Similarly, to determine the helix angle of the ribbon, the method of data sorting and removing of noise from the images needs to done.
- ✓ There are only very small differences between the core covering ability of yarn with various level of the twist coefficient .

Poulová A. *The Structure and Properties of Wrapped Rotor Yarn*, DP FT TUL, 2002 (Only in Czech).

Composite yarns - selected qualitative characteristics

Mixing quality:

- ✓ Assessment of radial packing density of yarn including the radial packing density for each components.
- ✓ Evaluation of mixing quality by using criterion *IBI* (index of blended irregularity) and fiber configuration (aggregation/ segregation) *Z*.

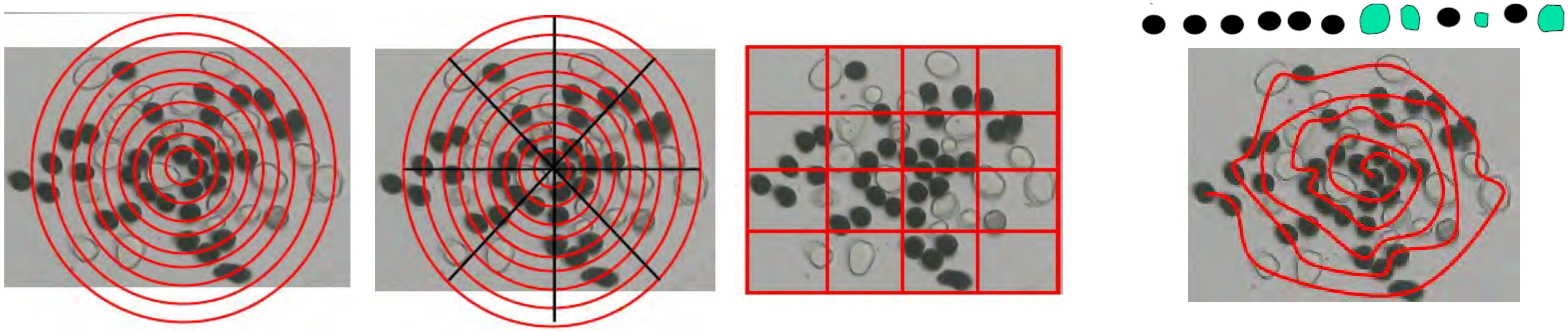


Fig. 34 a), b) c) Different types of nets for assessing the mixing quality by *IBI* and d) configuration of fibers *Z*

IS 12-108-01/01 Definitions. Geometrical properties of staple yarns. Research Centre Textile, FT TUL 2002.

IS 22-103-01/01 Yarn packing density. Direct method and Secant method. Research Centre Textile, FT TUL 2002.

IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report Research Centre Textile, FT TUL 2003 (Only in Czech).

Composite yarns - selected qualitative characteristics

$$d_e = \sqrt{4t / \pi\rho} \qquad \mu_i = S_i / Sc_i$$

Procedure:

- ✓ selection and sample preparation for analysis;
- ✓ preparation, scanning and processing of recommended number of images of yarn cross-sections;
- ✓ Secant method: marking the center of gravity of all fibers subjectively and all components [x_i, y_i], data are saved for all yarn cross section and processed in external program.

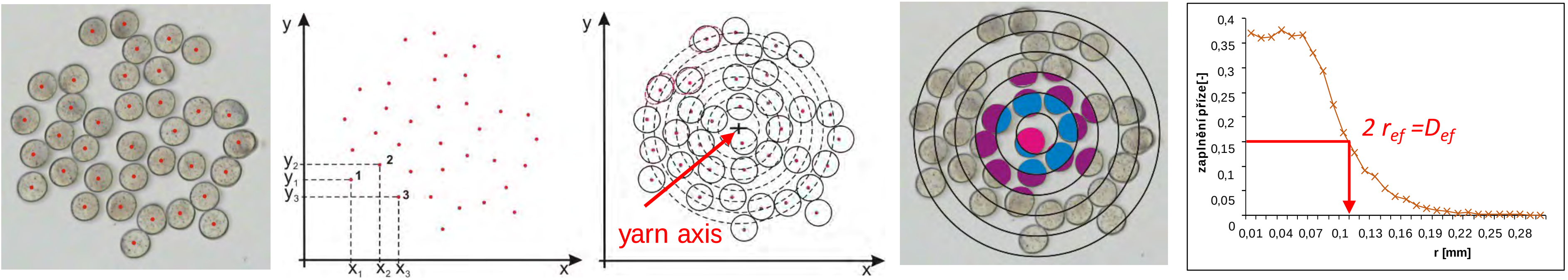


Fig. 35 Yarn cross-section processing procedure

IS 12-108-01/01 Definitions. Geometrical properties of staple yarns. Research Centre Textile, FT TUL 2002.
IS 22-103-01/01 Yarn packing density. Direct method and Secant method. Research Centre Textile, FT TUL 2002.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Composite yarns - selected qualitative characteristics

$$\mu_{ef} = S_{ef} / Sc_{ef}$$

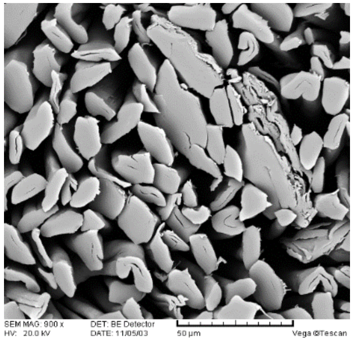
Procedure:

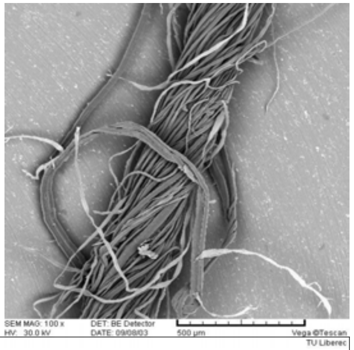
- ✓ Yarn axis position is the median of x and y coordinates of all fibers in given yarn cross-section. Reconstruction of fiber areas s_i based its fineness t and mass density ρ and their integration into the system of radial rings with h distance in all yarn cross-sections and images.
- ✓ Correction of fiber inclination due to twist in respect to its distance from yarn axis. Fibers placed closer to the yarn surface are more inclined by the twist.
- ✓ Calculation of partial radial packing density μ_i in all yarn radial cross-sections for all images as a portion of areas of all fiber segments S_i and the area of cross-sectional annular rings S_{ci}.
- ✓ Determination of effective yarn diameter D_{ef} and effective packing density μ_{ef} for all yarn cross-sections and images for the level of $\mu=0,15$.
- ✓ In the case of two component yarn is data processing realized partly separately and partly as a complex data…

IS 12-108-01/01 Definitions. Geometrical properties of staple yarns. Research Centre Textile, FT TUL 2002.
IS 22-103-01/01 Yarn packing density. Direct method and Secant method. Research Centre Textile, FT TUL 2002.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

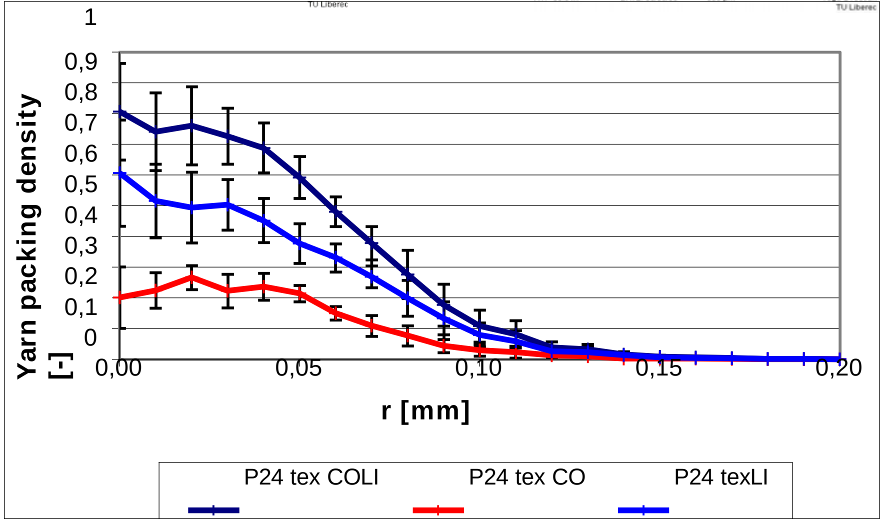
Composite yarns - selected qualitative characteristics

Example of results:





yarn count [tex]	24
yarn twist [m^{-1}]	968 (956; 981)
number of fibers in yarn cross-section [-] cotton linen whole	53 (47; 60) 60 (54; 66) 113 (104; 124)
nominal mass portion cotton/ linen [%]	45/55
experimental mass portion [%] cotton linen	40 (37; 43) 60 (57;63)
yarn effective diameter [mm]	0,22
yarn effective packing density [-]	0,40



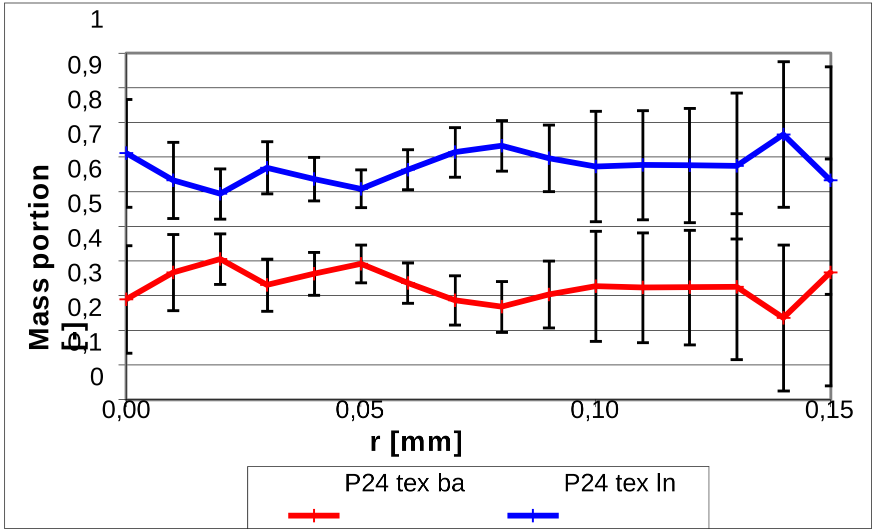


Fig. 36 Example for ring spun yarn 45 CO/ 55 LI 24 tex (higher amount of cottonized flax)

IS 12-108-01/01 Definitions. Geometrical properties of staple yarns. Research Centre Textile, FT TUL 2002.
IS 22-103-01/01 Yarn packing density. Direct method and Secant method. Research Centre Textile, FT TUL 2002.
IS 46-108-01/01 Recommended procedure for preparation of samples. Soft and hard sections (slices). Research Centre Textile, FT TUL 2002.

Composite yarns - selected qualitative characteristics

Mixing quality of subcomponents:

- ✓ The mixing uniformity in the radial and axial directions of two or more components yarns can be observed. It is possible to evaluate the uniformity of the fiber distribution in given area of given yarn cross-section or among yarn cross-sections.
- ✓ The nearest neighbor of all fibers are used as a criterion for assessment of yarn mixing uniformity. It is possible to arrange the fiber in given yarn cross-section in a row sequence or to divide the yarn cross-section into a net of cells of a certain shape. Furthermore, it is necessary to determine the boundary variants of the arrangement of fibers and define with regard to the analyzed yarn which arrangement corresponds to the required mixing quality (blended yarn, core or wrapped yarn).

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Composite yarns - selected qualitative characteristics

Index of blended irregularity *IBI*:

- ✓ The cross-section of the yarn is divided into a suitable net and the mixing uniformity is examined with respect to changes in the number of fibers of components in the individual cells. You can choose a rectangular net, radial rings or pie segments net.

- ✓ Obviously, each network configuration is only able to evaluate certain types of fiber arrangements. Examining of local behavior in cells is a common way to evaluate the variability of random fields. The problem is that due to the non-constant yarn packing density, the local changes in the number of fibers cannot be directly investigated. All that remains is to analyze local and global changes in the frequency of components defined by their probabilities respectively their relative frequencies.

- ✓ Lets number of fiber of *i*-th cell is N_i. Number of fibers of first component is N_{1i} and number of fibers of second component is N_{2i}. Local estimation of relative occurrence of first and second component fibers are α_{1i}, α_{2i}.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Composite yarns - selected qualitative characteristics

Index of blended irregularity *IBI*:

- ✓ The global probability estimations are usually dependent on the accepted assumption of a probability model for a random arrangement of fibers (see e.g. Cox model). In this case, the relative frequency of components α_1 and α_2 for yarn cross-section can be used a global estimation of fiber occurrence probability. The comparison of local and global probability estimations for both components can advantageously be performed on the basis of the χ^2 test .

- ✓ Thanks to mathematical adjustments and the fact that it is valid $N_{1i} + N_{2i} = N_i$ and $\alpha_1 + \alpha_2 = 1$ we can get the expression of χ^2 in a form:

$$\chi^2 = \sum_{i=1}^{m} \frac{\alpha_1 \left(N_{1i} - \alpha_1 N_i\right)^2 + \alpha_2 \left(N_{2i} - \alpha_2 N_i\right)^2}{\alpha_1 \alpha_2 N_i} = \sum_{i=1}^{m} \frac{\left(N_{1i} - \alpha_1 N_i\right)^2}{\alpha_1 \alpha_2 N_i}$$

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.

Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics

Index of blended irregularity *IBI*:

- ✓ When the hypothesis of a random arrangement of fibers in the yarn cross-section is valid, the χ^2 statistic has distribution with $v = m$-2 degrees of freedom. To analyze the mixing quality based on the division of the cross section into m cells, the so-called IBI blending irregularity index was designed, which can be adjusted for sufficiently large data sessions to the form.

$$IBI = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\frac{\left(N_{1i} - \alpha_1 N_i\right)^2}{\alpha_1\alpha_2 N_i}} = \frac{\chi^2}{v}$$

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.

Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics

Configuration *Z*:

- ✓ The term expresses a unique configuration of fibers from yarn cross-section in a row according to the selected criterion (e.g., "nearest neighbor"). Configurations are gradually formed from all fibers in yarn cross-section, it is possible to describe the configuration of the nearest area. For created configurations, the occurrence of the number of sequences of certain lengths is tested, and it is also possible to test the occurrence of bundles with different numbers of fiber of individual components.

- ✓ A sequence is set of the same fiber type. Sequence length is the number of fibers in a given set. It can be easily shown that it is valid $S_1 = S_2$ for the total number of sequences (the number of sequences of all lengths), where S_1 is the total number of fiber sequences of component 1, S_2 is the total number of fiber sequences of component 2 and S is the total number of sequences of all fibers.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.

Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics

Configuration *Z*:

- ✓ There are two extreme configurations of components: the fibers of each component form only one sequence – the limit aggregation, the individual fibers of the components alternate regularly – the limit segregation.

- ✓ In many cases, the total number of sequences of all lengths for a given configuration can be easily determined. The derivation of the distribution of the total number of sequences is based on the same assumptions as the distribution of sequence lengths (constant probability of occurrence of a given fiber is equal to the relative frequency portion of individual components, independence of individual elements in sequences). The distribution of the total number of sequences was described by Mood. It has been shown that the distribution of the total number of sequences is close to the normal distribution for sufficiently long configurations.

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.

Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics

Configuration *Z*:

✓ The marginal distribution of the number of sequences of the 1st component is called the Ising-Stevens.

$$P\left(\Sigma_1 = S_1\right) = \binom{N_1 - 1}{S_1 - 1}\binom{N_2 - 1}{N_2 + 1 - S_1}\Big/\binom{N}{N_1}$$

✓ For the mean values E(S_1), E(S_2) and the variants D(S_1), D(S_2) are valid:

$$E\left(S_1\right) = \left(N_1 + 1\right)N_2 / N; E\left(S_2\right) = \left(N_2 + 1\right)N_1 / N$$

$$D\left(S_1\right) = N_1\left(N_1 + 1\right)N_2\left(N_2 - 1\right) / N^2\left(N - 1\right); D\left(S_2\right) = N_2\left(N_2 + 1\right)N_1\left(N_1 - 1\right) / N^2\left(N - 1\right)$$

✓ To determine the mean and variance of the total number of sequences, it is possible to use the relationships for the mean and variance of two random (correlated) quantities.

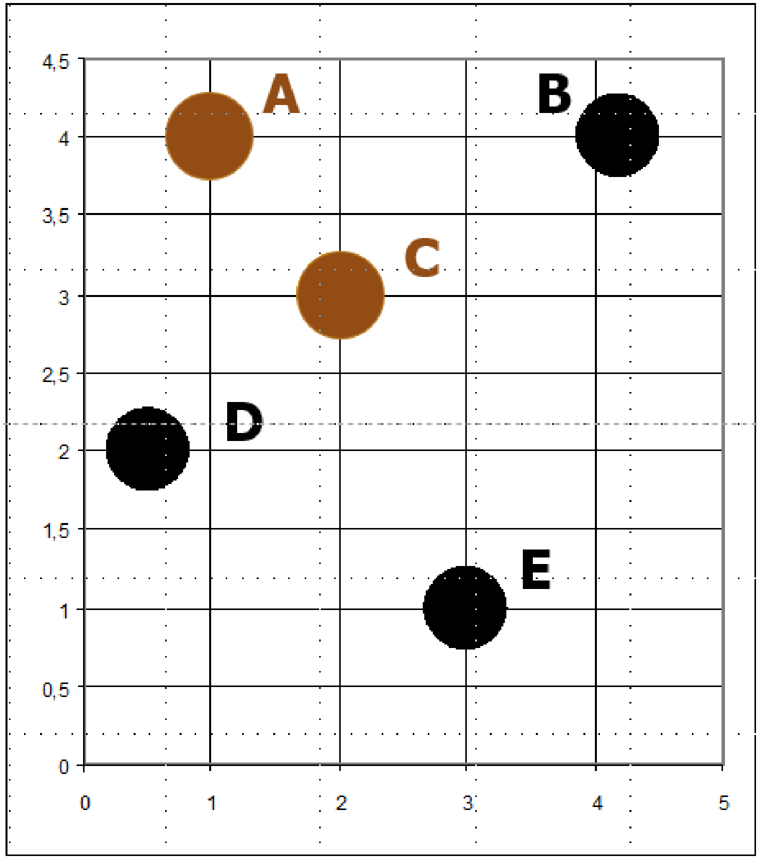
$$E\left(S\right) = 1 + \frac{2N_1N_2}{N} \qquad D\left(S\right) = 2N_1N_2\left(2N_1N_2 - N\right) / N^2\left(N - 1\right)$$

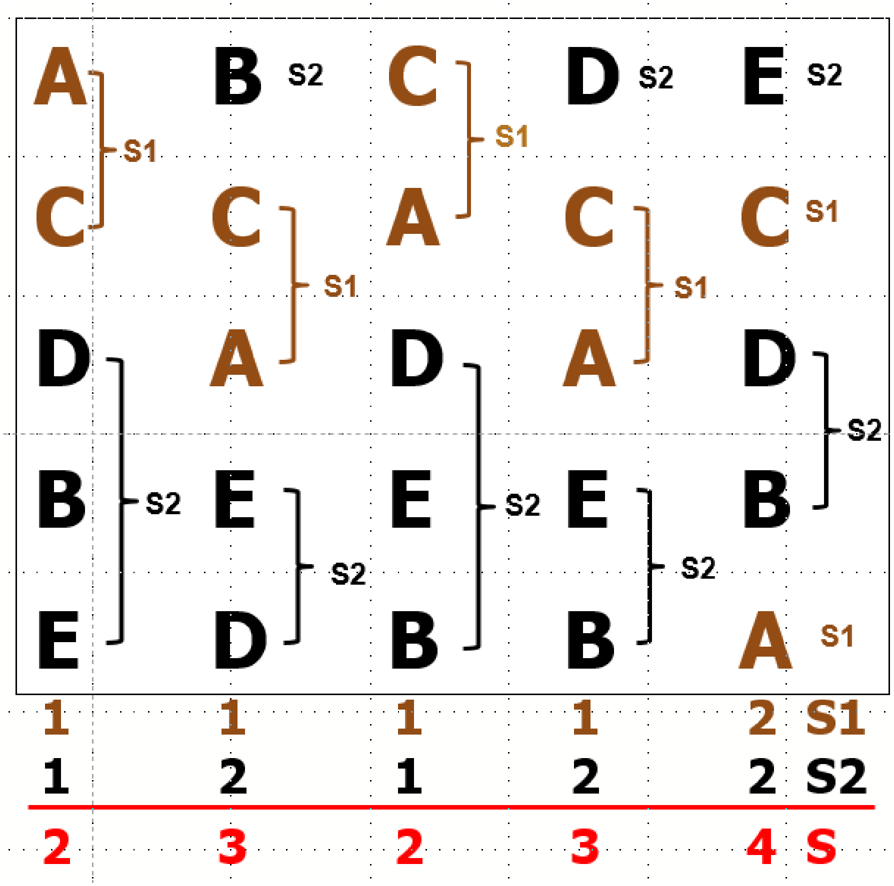
Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.

Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics





Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report. Research Centre Textile, FT TUL 2003 (Only in Czech).
Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.
Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics

Configuration *Z*:

- ✓ For a sufficiently high *N*, the distribution of the total number of sequences *S* can be approximated by a normal distribution with parameters *E*(*S*), *D*(*S*). The total number of sequences can then be converted to a standardized random variable *Z* with distribution *N*(0;1), where 0.5 is a correction for continuity that can be neglected without loss of accuracy in practical calculations.

- ✓ Using *Z*, it is easy to test the randomness of the total number of sequences in a configuration or to assess the statistical behaviour of different types of configurations. The values of *Z* can be determined for all possible configurations generated by the nearest neighbour method.

$$Z = \frac{S - E\left(S\right) \pm 0{,}5}{\sqrt{D\left(S\right)}}$$

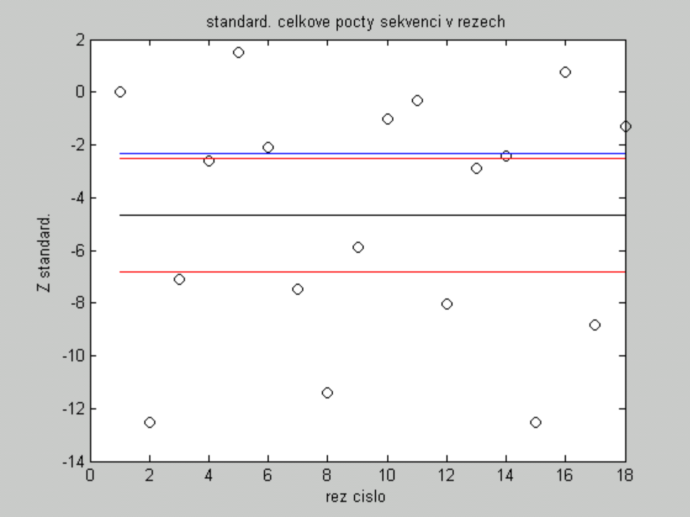
Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report. Research Centre Textile, FT TUL 2003 (Only in Czech).

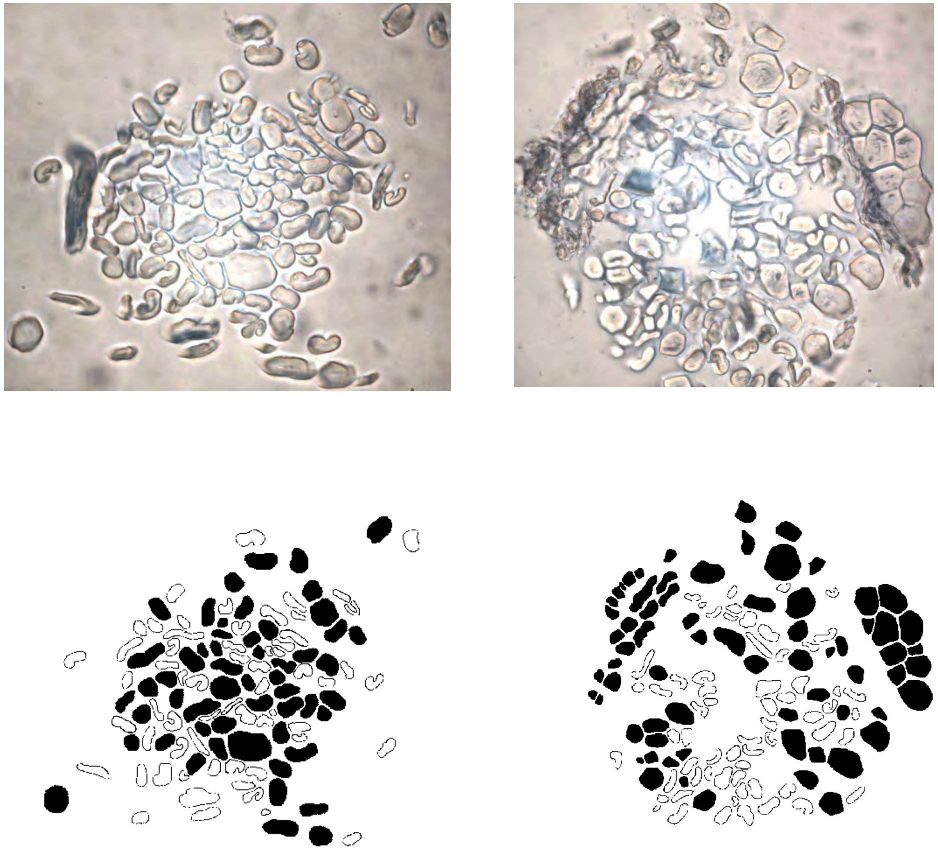
Cox D.R. Some statistical Aspect of Mixing and Blending, *Journal of Textile Institute* 48(113), 1953.

Coplan M.J., Klein W.G. A Study of Blended Woolen Structures, Part V. Methods of Within-Section Blend Analysis, *Textile Research Journal*, December 19, 1958.

Composite yarns - selected qualitative characteristics

	Good configuration Cross section No. 2	Bad configuration Cross section No. 3	Ring spun yarn 24 tex
IBI regular [-]	0,58	1,93	0,98 (0,88; 1,09)
IBI radial [-]	0,42	2,56	0,93 (0,79; 1,06)
IBI segment pie [-]	0,96	1,74	0,98 (0,83; 1,13)
IBI among yarn cross-section [-]	-	-	1,92
Z [-]	2,84		-4,74 (-6,87; -2,60)





a) good arrangement of fibers in yarn cross-section No.2 b) bad arrangement of fibers in yarn cross-section No.3
Fig. 37 An example for ring spun yarn 45 CO/ 55 LI 24 tex (figure is for yarn)

Křemenáková D., Krupincová G. Partial project: Design system for textile structure 3. Research stage. Annual research report, Research Centre Textile, FT TUL 2003 (Only in Czech).

Composite yarns - selected qualitative characteristics

Examples of results:

- ✓ In the case of yarn packing density evaluation by the Secant method, it have to be taken into account that the high variability of fiber fineness distorts the results due to the estimation of fiber diameter d_{ef} based on the mean value of fiber fineness t.
- ✓ The direct method for yarn packing density evaluation uses real image contouring by subjective drawing or by automatic image segmentation. Automatic segmentation and its success is given mainly by the quality of prepared images of yarn cross-sections in terms of contrast between background and objects and the possible dividing of individual components (image data, shape, …).
- ✓ Another method of yarn packing density assessment is described in given references.

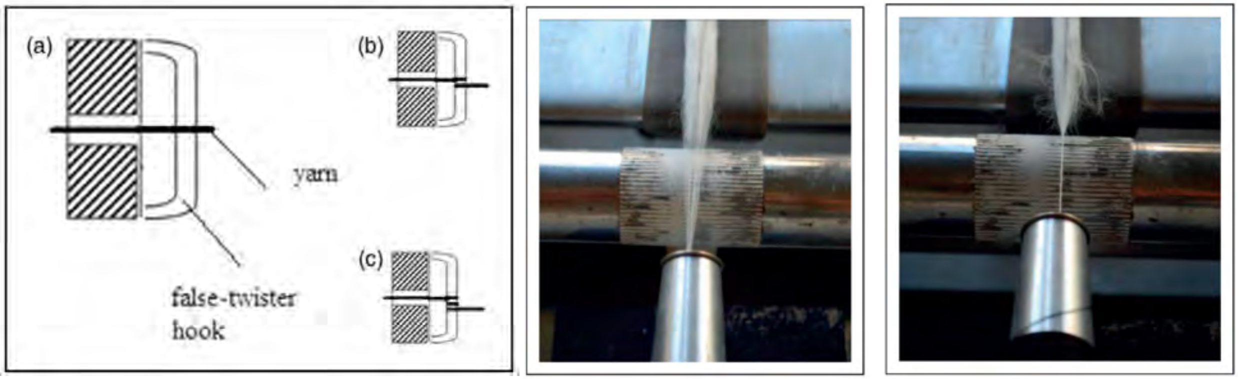
Chiu S. H., Chen J. Y., Lee J. H. Fiber recognition and distribution analysis of PET/Rayon composite yarn cross section using image processing techniques. *Textile Research Journal* 69(6), 1999.

Su Ch. I., Leu CH. S., Chern H. M. Image analysis of composite yarn cross sections. *Textile Research Journal* 69(3), 1999.

Chollakup R., J. F., Sinoimeri A., Drean J. Y. Effects of blending parameters on the cross-section fiber migration of silk/cotton blends. *Textile Research Journal* 78(4), 2008.

Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Discussion and conclusions – example of results 5



a) NFT b) FT c) DFT

a) NFT

b, c) FT , DFT

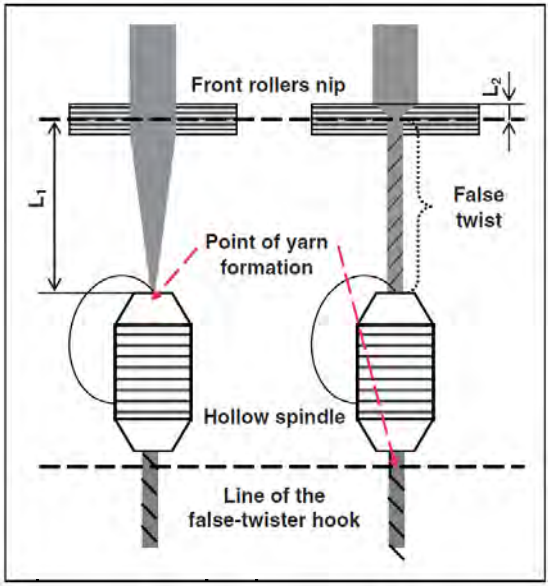


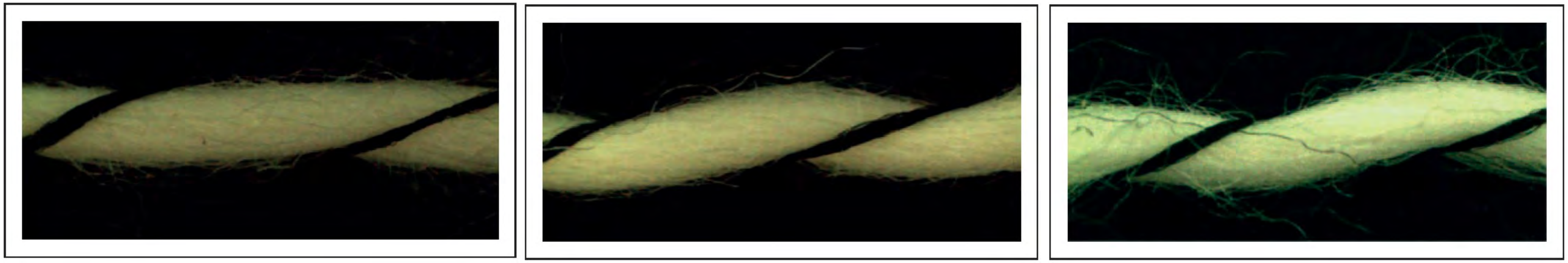
Fig. 38 Experimental setting of false-twister as a yarn formation factor in wrap spinning

Experimental material:

- ✓ roving 50 WO/ 50 PAN 1536 tex, textured multifilament 36 fibrils/3,6 dtex wrapping component, hollow spindle speed 15000 m^{-1}, delivery speed 40 mmin^{-1}, draft 29,5.
- ✓ The 3 variants of setting of false-twister.

Konova H., Anelova R. False-twister as a yarn formation factor in wrap spinning. *Textile Research Journal* 83(18), 2013
Subramaniam V., Mohamed P. A. Wrap spininig technology – A critical review of yarn properties. *Indian Journal of Fibre and Textile Research* 17(12), 1992.

Discussion and conclusions – example of results 5



a) NFT

b) FT

Fig. 39 Yan structure

Parameter	NFT	FT	DFT
T_t (tex)	69.2 ± 0.28	71.2 ± 0.64	71.1 ± 0.51
T_c (1/m)	496 ± 27	514 ± 8	539 ± 10
TL (1/m)	28 ± 5	55 ± 3	63 ± 4
t (mm)	3.6 ± 0.19	3.6 ± 0.17	3.6 ± 0.33
β (deg)	41.3 ± 3.8	30.8 ± 2.5	30.5 ± 1.8
D_y (mm)	0.85 ± 0.02	0.79 ± 0.03	0.79 ± 0.04
D (mm)	0.32	0.32	0.32
PD	0.14	0.16	0.17

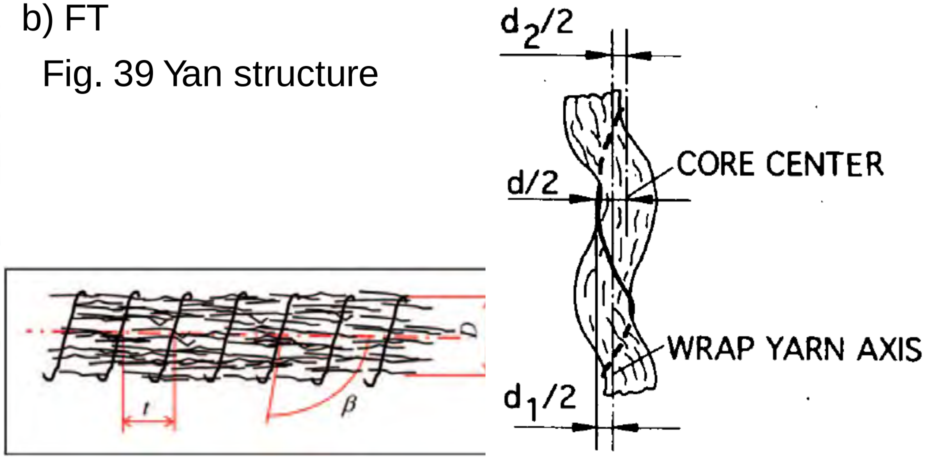


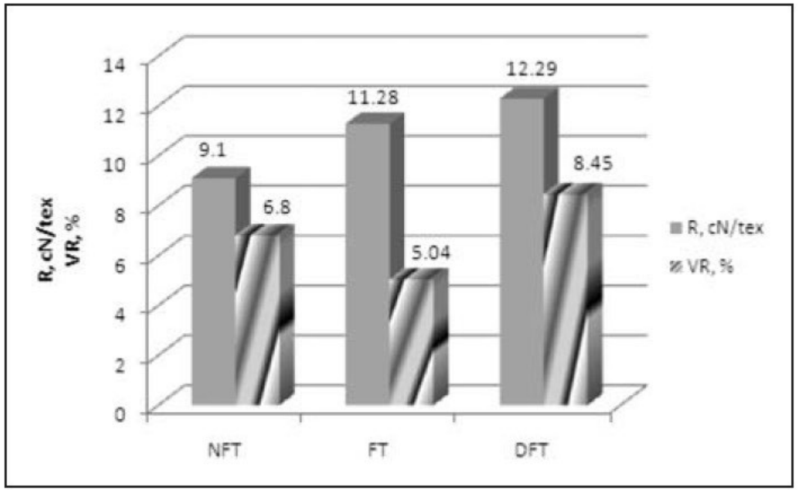
Fig. 40 Yarn structure element

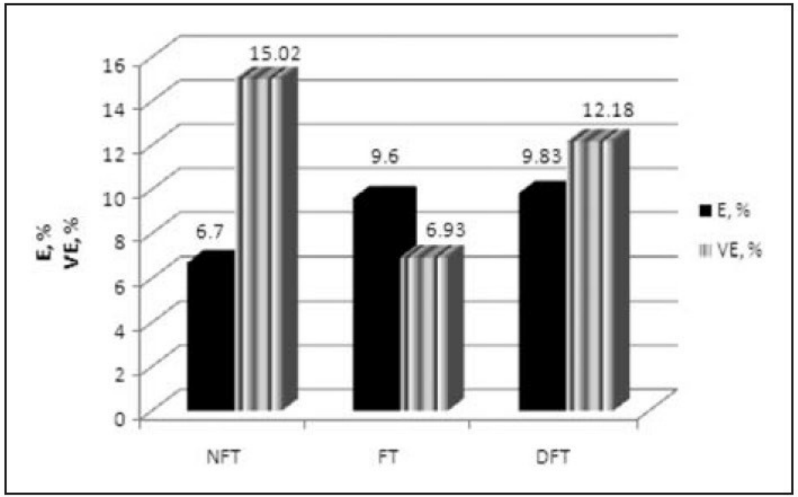
T_t yarn density, T_c yarn twist, β wrap angle, t coil pitch, TL (twist liveliness), D_y real yarn diameter, D limit diameter, $PD = (D/D_y)^2$ yarn packing density.

Konova H., Anelova R. False-twister as a yarn formation factor in wrap spinning. *Textile Research Journal* 83(18), 2013.
Subramaniam V., Mohamed P. A. Wrap spinning technology – A critical review of yarn properties. *Indian Journal of Fibre and Textile Research* 17(12), 1992.
Miao M., How Y. L., Po K., Cheng S. The role of false twist in wrap spinning. *Textile Research Journal* 64(1), 1994.

Discussion and conclusions – example of results 5

- ✓ The false-twister plays an important role in the wrap yarn production. Its application caused the morphology differentiation due to variable position of yarn formation point and changes in the yarn tension during formation, which reflects in higher twist liveliness. This leads to changes in the yarn structural properties; yarn diameter decreases and packing density increases. The differences in the yarn structural properties as well as changes in the yarn tensile behavior lead to significant changes in yarn properties – higher tenacity and elongation.
- ✓ However it is recommended to avoid double wrapped false-twister (DFT) as the regularity of all properties – geometrical and mechanical – are worsened.





Konova H., Anelova R. False-twister as a yarn formation factor in wrap spinning. *Textile Research Journal* 83(18), 2013.
Subramaniam V., Mohamed P. A. Wrap spinning technology – A critical review of yarn properties. *Indian Journal of Fibre and Textile Research* 17(12), 1992.
Miao M., How Y. L., Po K., Cheng S. The role of false twist in wrap spinning. *Textile Research Journal* 64(1), 1994.

Discussion and conclusions – example of results 6

Experimental material:

- ✓ CU/CO (copper/ cotton), core: copper wire of diameter 0,06 mm, 0,07 mm, 0,08 mm, cover: combed cotton roving 716 tex
- ✓ Production of core conductive yarn using modified ring technology and siro technology (see Fig. 30).
- ✓ Evaluated qualitative characteristics: diameter d, cover factor, mechanical characteristics F a ε, bending rigidity, where I is second moment of area and E tensile elastic modulus of yarn.

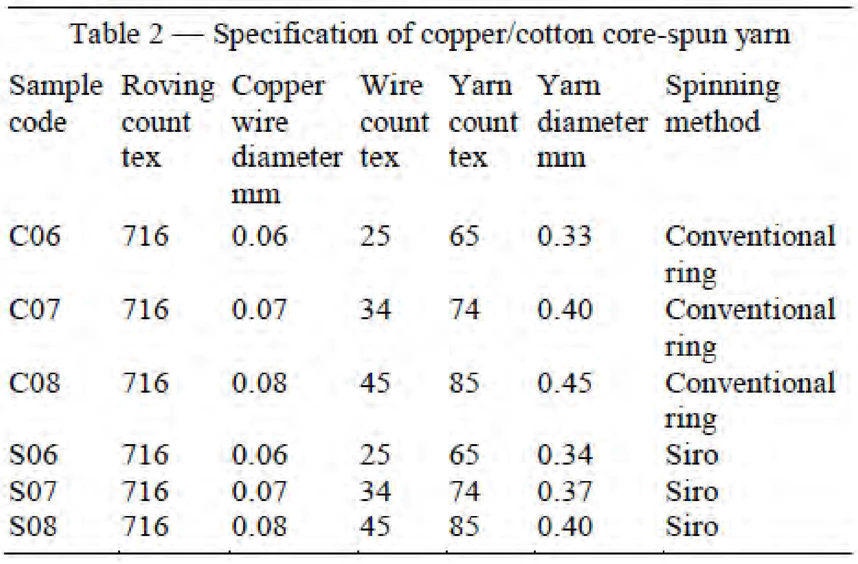


Table 2 — Specification of copper/cotton core-spun yarn

Sample code	Roving count tex	Copper wire diameter mm	Wire count tex	Yarn count tex	Yarn diameter mm	Spinning method
C06	716	0.06	25	65	0.33	Conventional ring
C07	716	0.07	34	74	0.40	Conventional ring
C08	716	0.08	45	85	0.45	Conventional ring
S06	716	0.06	25	65	0.34	Siro
S07	716	0.07	34	74	0.37	Siro
S08	716	0.08	45	85	0.40	Siro

Morarah M. H., Najar s. S., Etrati S. M. Mechanical properties of copper/cotton core-spun yarns produced by siro and ring spinning methods. *Indian Journal of Fibre and Textile Research* 44(12), 2019.

Discussion and conclusions – example of

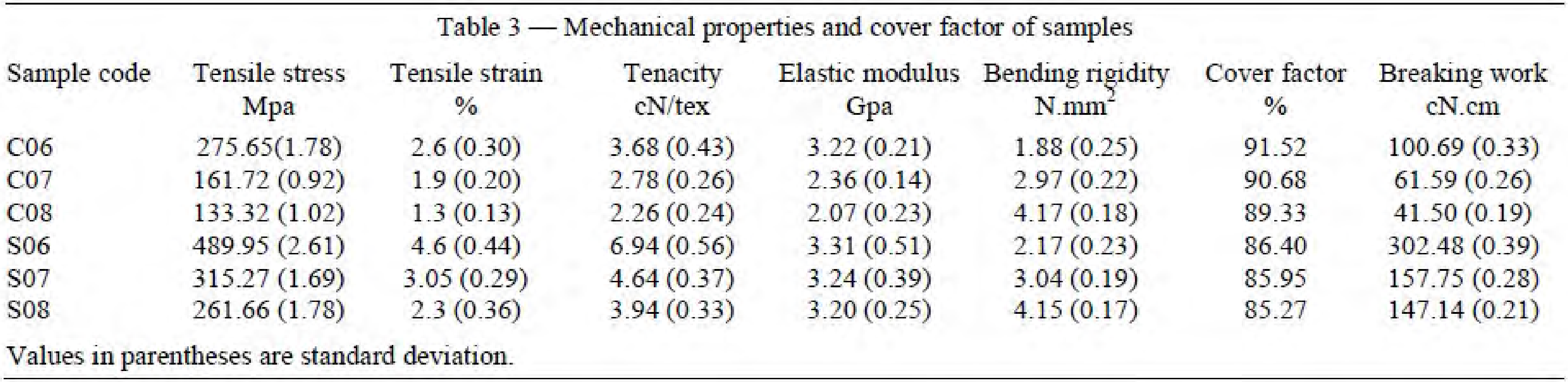
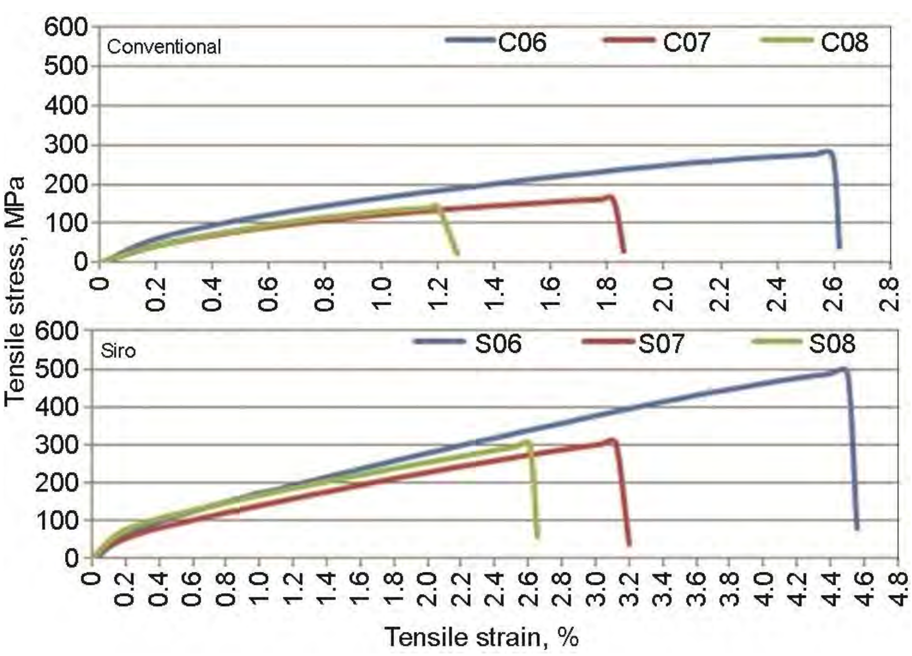
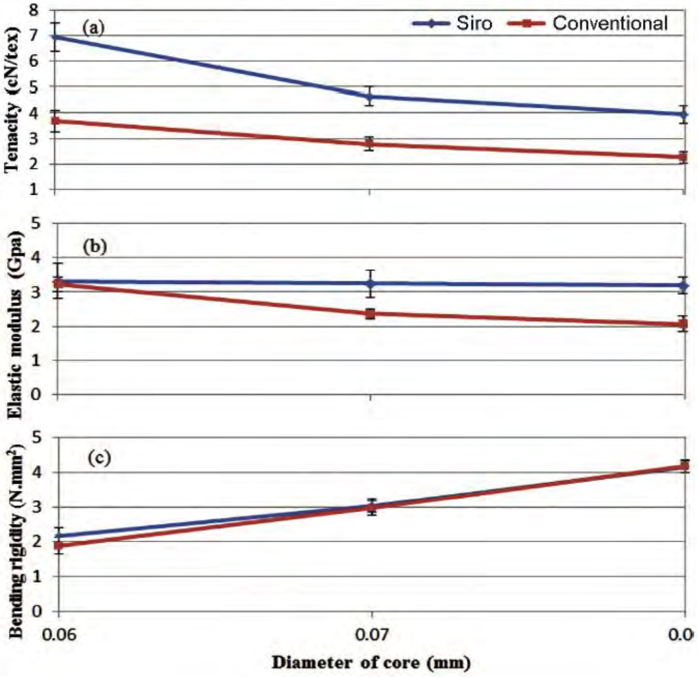


Table 3 — Mechanical properties and cover factor of samples

Sample code	Tensile stress Mpa	Tensile strain %	Tenacity cN/tex	Elastic modulus Gpa	Bending rigidity N.mm^2	Cover factor %	Breaking work cN.cm
C06	275.65(1.78)	2.6 (0.30)	3.68 (0.43)	3.22 (0.21)	1.88 (0.25)	91.52	100.69 (0.33)
C07	161.72 (0.92)	1.9 (0.20)	2.78 (0.26)	2.36 (0.14)	2.97 (0.22)	90.68	61.59 (0.26)
C08	133.32 (1.02)	1.3 (0.13)	2.26 (0.24)	2.07 (0.23)	4.17 (0.18)	89.33	41.50 (0.19)
S06	489.95 (2.61)	4.6 (0.44)	6.94 (0.56)	3.31 (0.51)	2.17 (0.23)	86.40	302.48 (0.39)
S07	315.27 (1.69)	3.05 (0.29)	4.64 (0.37)	3.24 (0.39)	3.04 (0.19)	85.95	157.75 (0.28)
S08	261.66 (1.78)	2.3 (0.36)	3.94 (0.33)	3.20 (0.25)	4.15 (0.17)	85.27	147.14 (0.21)

Values in parentheses are standard deviation.





Morarah M. H., Najar s. S., Etrati S. M. Mechanical properties of copper/cotton core-spun yarns producd by siro and ring spinning methods. *Indian Journal of Fibre and Textile Research* 44(12), 2019.

Discussion and conclusions – example of results 6

Results:

- ✓ Both technologies ensure a high cover factor, (the modified ring spinning technology provides yarns with 5% higher cover factor compared to siro spun technology (which is paradoxical when siro spun technology using two rovings to optimize wrapping twisted ribon during yarn formation).
- ✓ Core yarns produced by siro spun technology provide higher values of absolute strength and elongation compared to the modified ring spinning technology, which is related to the size of the yarn diameter itself (siro technology uses two rovings for production, but the your count was the same due to higher elongation).
- ✓ The use of copper wire with a higher diameter leads to a reduction in core yarn strength and elongation.
- ✓ The differences between the tensile elastic modulus of yarns spun by different technologies increase with increasing diameter of the copper wire.
- ✓ The bending rigidity increases with increasing diameter of the copper wire (connection with the second moment of area where the yarn diameter is used in a form d^4) and the differences between the yarns spun by the modified ring spinning technology and the siro spun technology are statistically insignificant.

Morarah M. H., Najar s. S., Etrati S. M. Mechanical properties of copper/cotton core-spun yarns produced by siro and ring spinning methods. *Indian Journal of Fibre and Textile Research* 44(12), 2019.

Discussion and conclusions – example of results 7

Experimental material:

- ✓ Cover: PAN 3,3 dtex, 90 mm; core: nylon multifilament 4,4 dtex with fibrils fineness 4 den,
- ✓ Analyzed yarns were produced by modified ring spinning technology for long staple fibers TSSM, which is using tree-strand method (see fig. 30), the comparative yarns were spun by standard ring spinning technology and siro spun technology.
- ✓ Evaluated qualitative parameters: yarn count, twist, yarn unevenness, IPI, mechanical parameters *F* and ε, abrasion resistance.

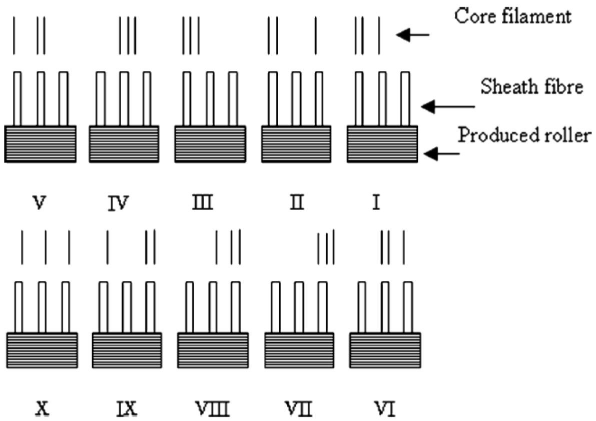
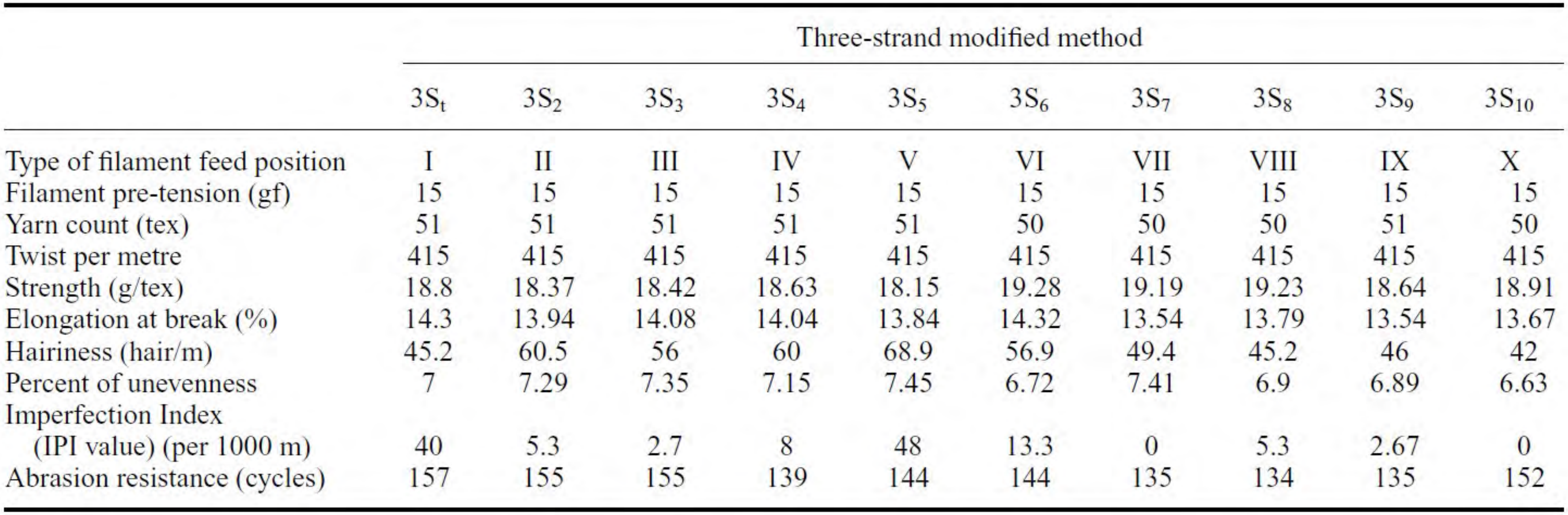


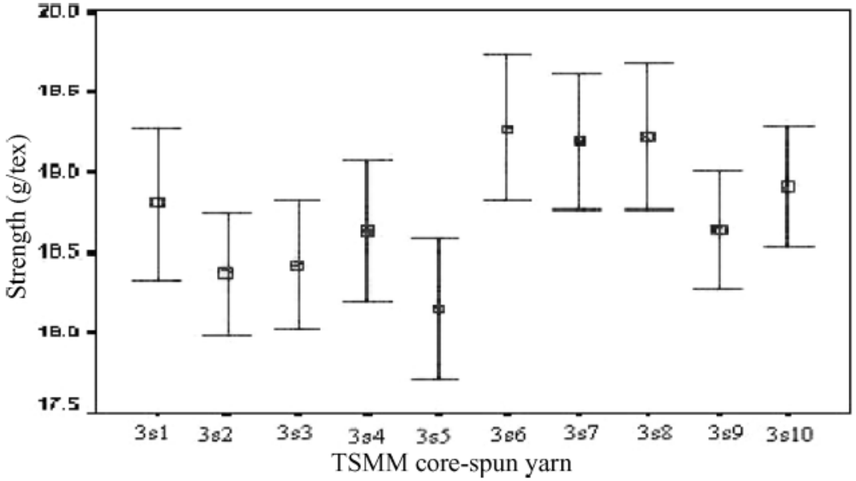
Fig. 40 The way of roving and multifilament guiding during spinning by TSSM

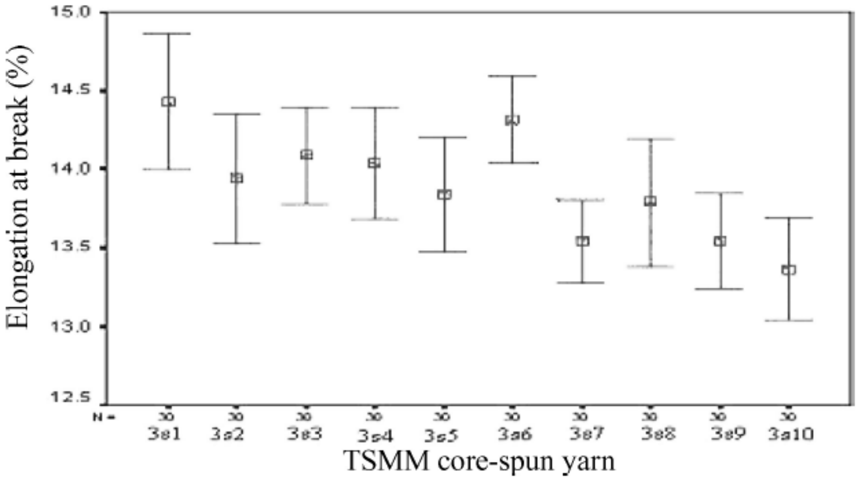
Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Discussion and conclusions – example of results 7



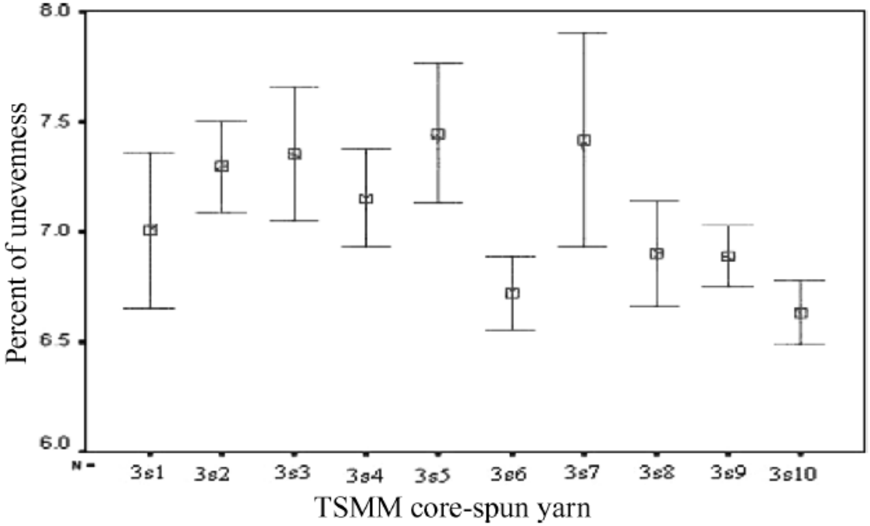
	Three-strand modified method									
	3S$_t$	3S$_2$	3S$_3$	3S$_4$	3S$_5$	3S$_6$	3S$_7$	3S$_8$	3S$_9$	3S$_{10}$
Type of filament feed position	I	II	III	IV	V	VI	VII	VIII	IX	X
Filament pre-tension (gf)	15	15	15	15	15	15	15	15	15	15
Yarn count (tex)	51	51	51	51	51	50	50	50	51	50
Twist per metre	415	415	415	415	415	415	415	415	415	415
Strength (g/tex)	18.8	18.37	18.42	18.63	18.15	19.28	19.19	19.23	18.64	18.91
Elongation at break (%)	14.3	13.94	14.08	14.04	13.84	14.32	13.54	13.79	13.54	13.67
Hairiness (hair/m)	45.2	60.5	56	60	68.9	56.9	49.4	45.2	46	42
Percent of unevenness	7	7.29	7.35	7.15	7.45	6.72	7.41	6.9	6.89	6.63
Imperfection Index (IPI value) (per 1000 m)	40	5.3	2.7	8	48	13.3	0	5.3	2.67	0
Abrasion resistance (cycles)	157	155	155	139	144	144	135	134	135	152

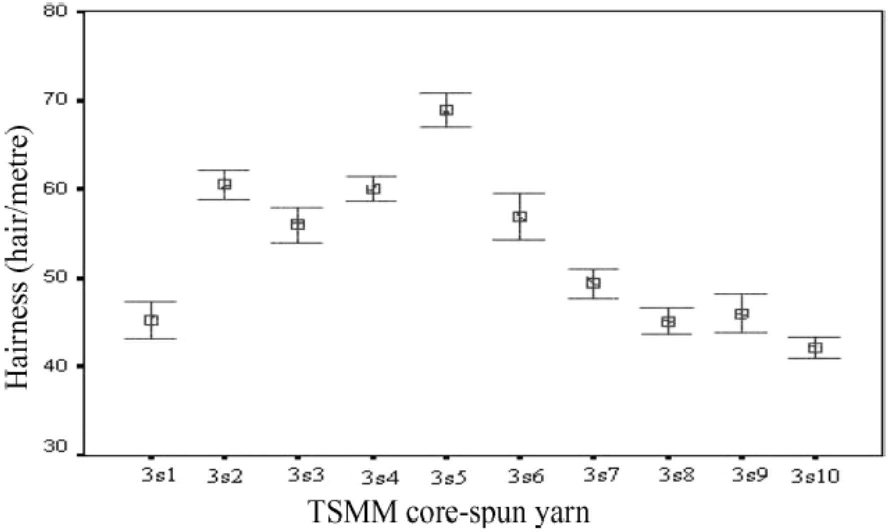


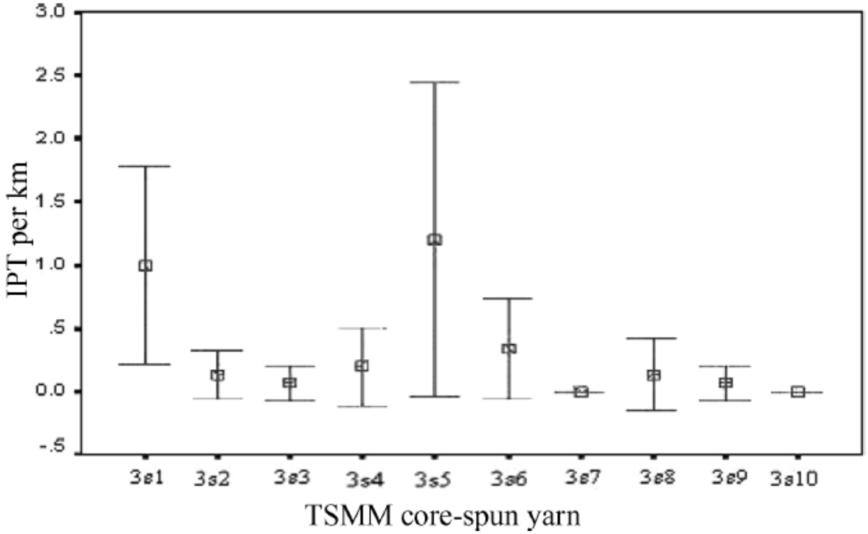


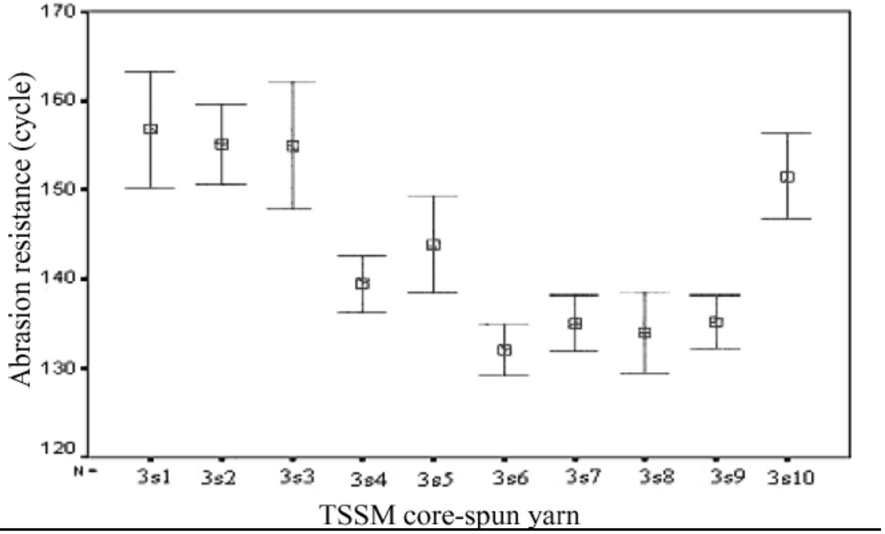
Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Discussion and conclusions – example of results 7







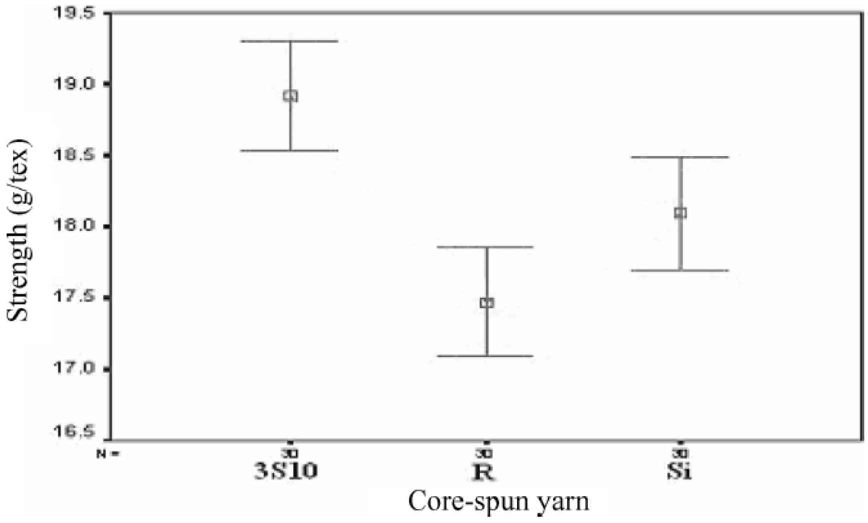


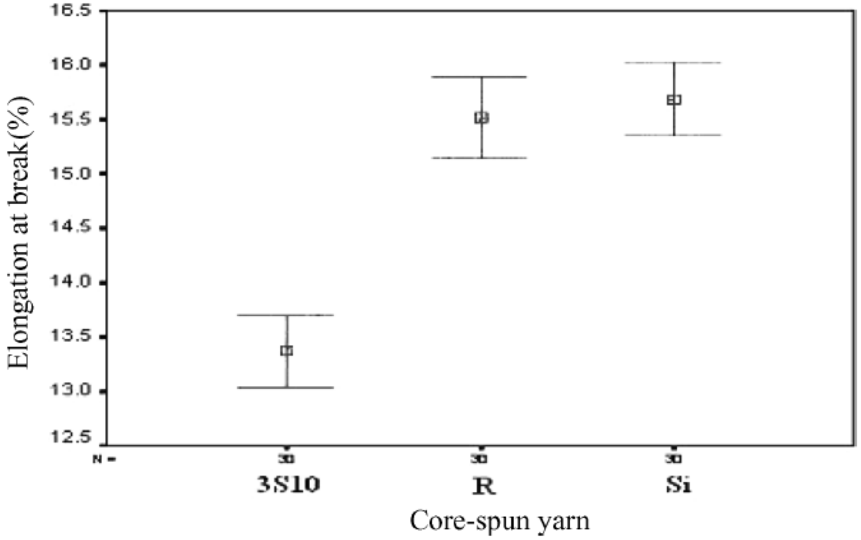
Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Discussion and conclusions – example of results 7

Results:

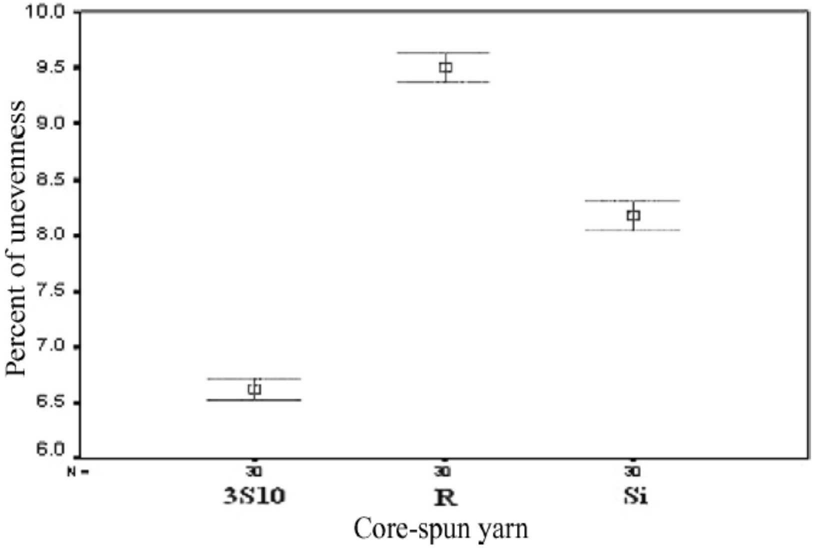
- ✓ Based on the comparison of samples S1 - S10 it is possible to say that different way of core guidance (3x multifilaments) does not significantly affect the monitored quality indicators and the sample marked 3S10 shows the best quality and will be used for further comparison with core yarns spun using modified ring technology. R a siro technology Si.

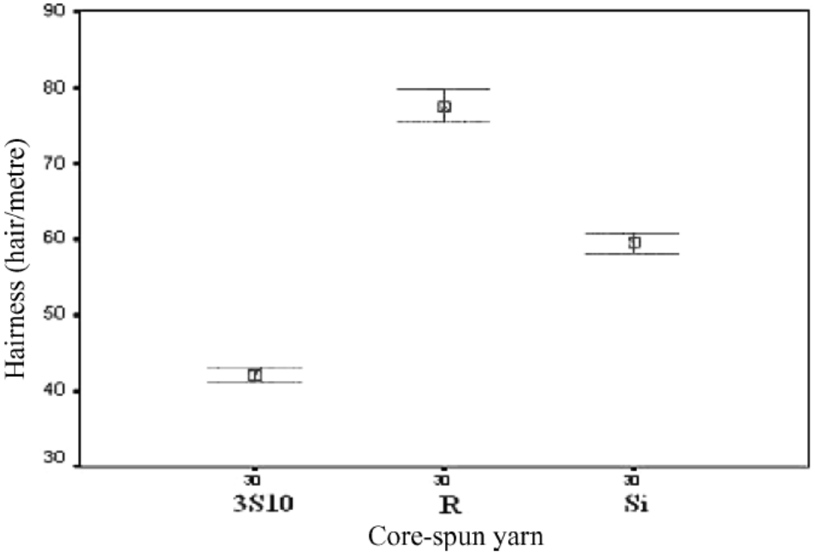


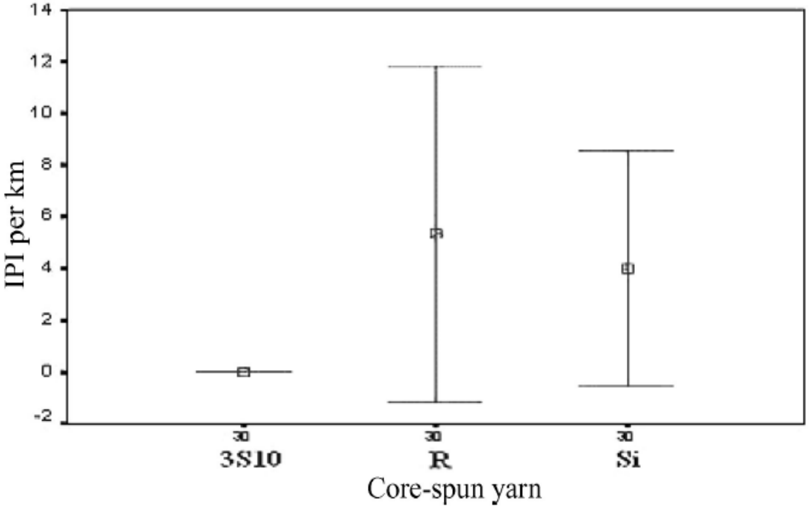


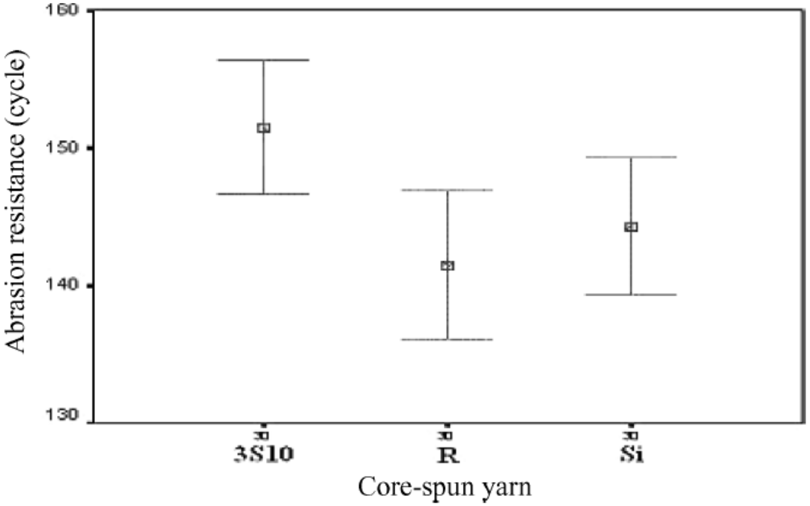
Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Discussion and conclusions – example of results 7









Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Discussion and conclusions – example of results 7

Results:

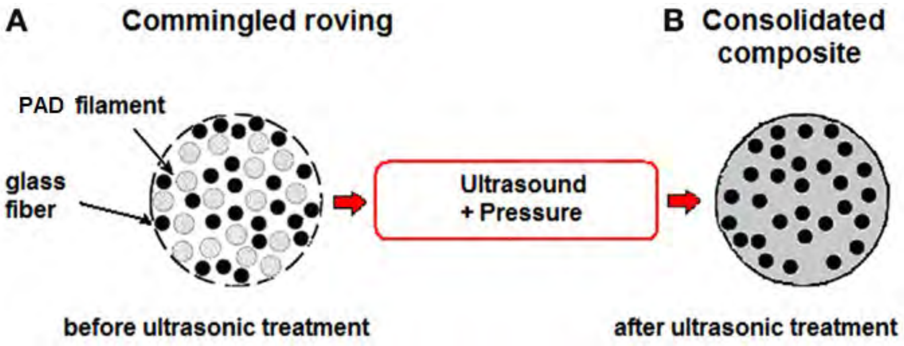
- The yarn unevenness, hairiness, strength and abrasion resistance of the core yarn 3S10 is better in comparison with yarn produced by standard ring spinning technology R or siro spun technology Si. Yarns made of by siro spun technology Si shows better yarn unevenness and hairiness than yarn produced by standard ring spinning technology R.
- The proposed TSSM technology provides significant flexibility in terms of use and production of various types of yarns, it can be used for a wide range of structures of produced yarns (color, fineness, type of material used).

Pourahmad A., Johari M. J. Production of core-spun yarn by the three-strand modified method. *The Journal of The Textile Institute* 100(3), 2009.

Discussion and conclusions – example of results 8

Experimental material:

- ✓ Commingling technology is partly similar to air texturizing technology, in which two components of multifilaments are mixed by air into one hybrid yarn (the fibers and the carrier component, which then form a matrix). Most of thermoplastic composites is based on hybrid commingled yarns. The aim is to blend both components so that there is a good connection among the matrix and fibers in the final product.
- ✓ Multifilament 60 E glass / 40 PAD 6, E glass multifilament 320 tex a PAD 6 140 tex. Tech. parameters: 100 mmin^{-1}, 1x E glass (reinforcement part) + 2x multifilaments PAD 6 (fibers for matrix), the connection ensures technological pressure 9 bar and ultrasound, 1,5 % overfeeding.



Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Kurban M., Babaarslan O, Cagatay I. H. Textile for advance application – Chapter 5, Hybrid yarn composites for construction. INTECHOPEN 2017.

Discussion and conclusions – example of results 8

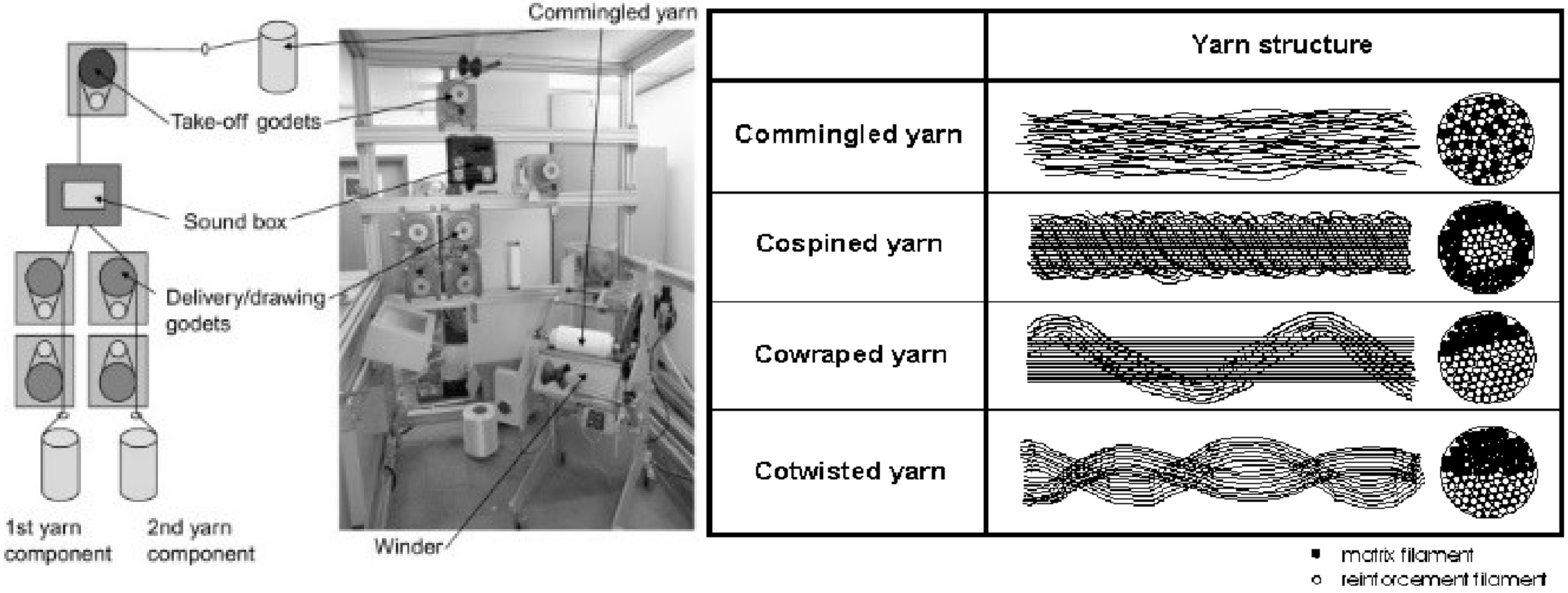


Fig. 41 Commingling technology for hybrid yarn production for reinforcement of composite structure and characteristic structure type of hybrid yarn for thermoplastic composites

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Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Kurban M., Babaarslan O, Cagatay I. H. Textile for advance application – Chapter 5, Hybrid yarn composites for construction. INTECHOPEN 2017.

Discussion and conclusions – example of results 8

Metodologies:

- ✓ Longitudinal views are scanned by using Leica Microscope, cam and software ImageJ. Cross-sections are prepared by the hard methodology. Images are preprocessed by filtration. The segmentation of individual fiber cross-sections are partly manual. The determination of center of gravities follow as the estimation of finding of axis for each component and hybrid yarn. Length of samples are 1m, similarly as a distance between the samples.

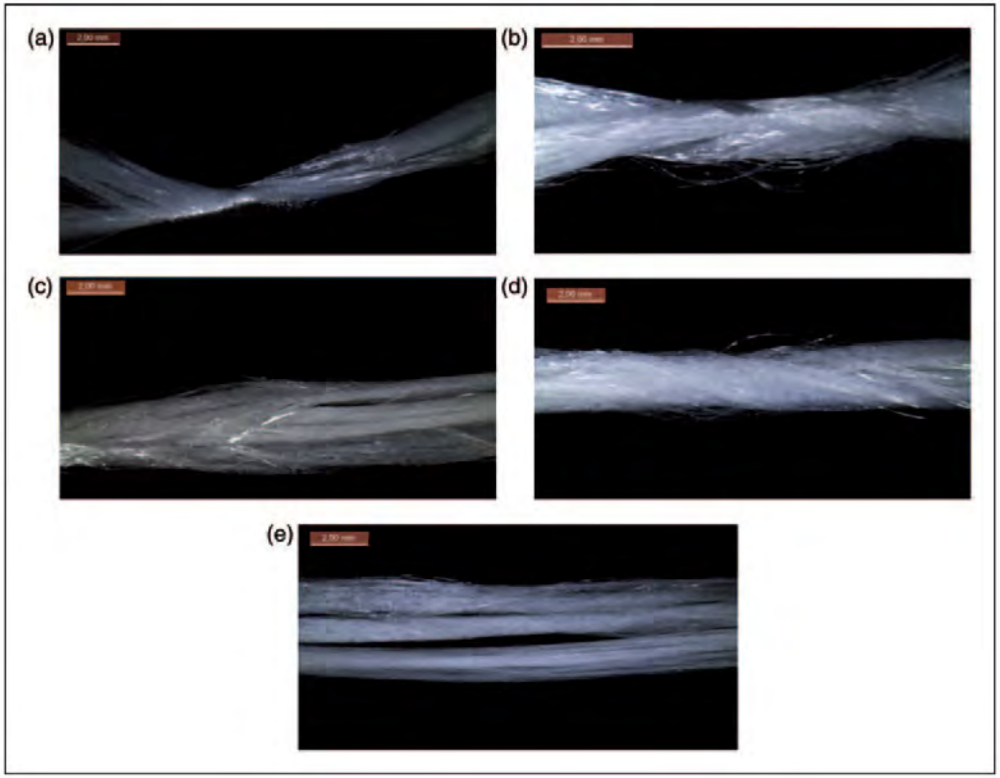
Analysis of longitudinal views:

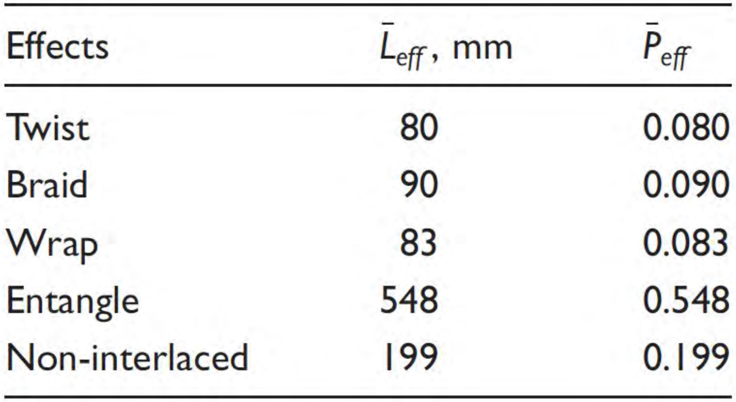
- ✓ The portion of the typical effects in yarn $P_{eff,i}$, where L_j is the length of a single effect in one category, p number of images for given category of typical structure.

$$P_{eff,i} = \frac{\sum_{j=1}^{p} L_j}{1\text{m}} = \frac{L_{eff,i}}{1\text{m}}; \overline{P}_{eff} = \frac{\sum_{i=1}^{n} P_{eff,i}}{n}$$

Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Discussion and conclusions – example of results 8





Effects	$\bar{L}_{eff}$, mm	$\bar{P}_{eff}$
Twist	80	0.080
Braid	90	0.090
Wrap	83	0.083
Entangle	548	0.548
Non-interlaced	199	0.199

Fig. 42 longitudinal view of hybrid yarn for specific structure types a) twist b) braid c) wrap d) entangle e) non-interlaced

Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Discussion and conclusions – example of results 8

Methodologies:

Analysis of hybrid yarn cross-sections

- ✓ Analyzed are index of the radial distribution $R_{d,effi}$ and the lateral distribution index within the effect category $L_{t,effi}$, where N_g is number of fibrils of E glass, N_p is number of fibrils of PAD 6, $[X_{gi}, Y_{gi}]$; $[X_{pi}, Y_{pi}]$ are coordinates of individual fibrils and $[C_x, Y_y]$ are coordinates of hybrid yarn in cross-section. R_g is the average radius of E glass, R_p is the average radius of PAD 6 and R_a is the average radius of all filaments.
- ✓ The radial distribution is uniform when it is valid $R_{d,effi} \cong 1$. If it is valid $R_{d,effi} > 1$ than the filaments tend to be separated in hybrid yarn cross-section. If it is valid $R_{d,effi} < 1$ the filaments tend to aggregate in hybrid yarn cross-section.

$$R_{d,effi} = \frac{R_g}{R_a} = \frac{\dfrac{\sum_{i=1}^{N_g}\sqrt{\left[X_g(i)-C_x\right]^2+\left[Y_g(i)-C_y\right]^2}}{N_g}}{\dfrac{\sum_{i=1}^{N_g}\sqrt{\left[X_g(i)-C_x\right]^2+\left[Y_g(i)-C_y\right]^2}}{N_g+N_p}+\dfrac{\sum_{i=1}^{N_p}\sqrt{\left[X_p(i)-C_x\right]^2+\left[Y_p(i)-C_y\right]^2}}{N_g+N_p}}$$

$$L_{t,effi} = \frac{\sqrt{\left(C_{xg}-C_x\right)^2+\left(C_{yg}-C_y\right)^2}}{R_a}$$

Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Discussion and conclusions – example of results 8

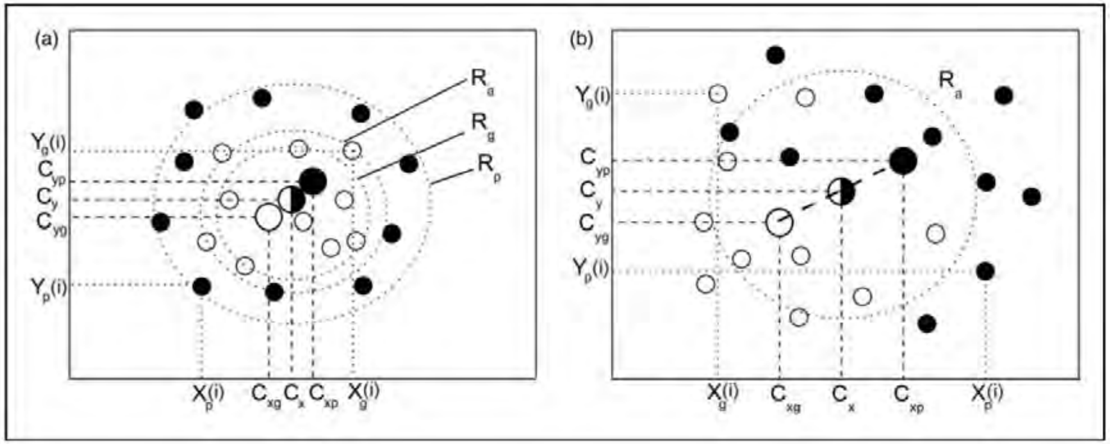
Methodologies:

Blending quality

- ✓ Blending coefficient $k_{B,effi}$ is based on the distance to the perfect radial distribution $R_{d,eff}$ of the filaments in the cross section, $L_{t,eff}$ represents the distance between the geometric centres of the E glass and PAD6 filament components.
- ✓ Yarn blending coefficient Index $k_{B,Yarn}$. Yarns with perfect distribution of the components in their cross section exhibit a blending index $k_{B,yarn}$=0. A blending index $k_{B,yarn} > 0,2$ is typical for yarns with a side by side structure.

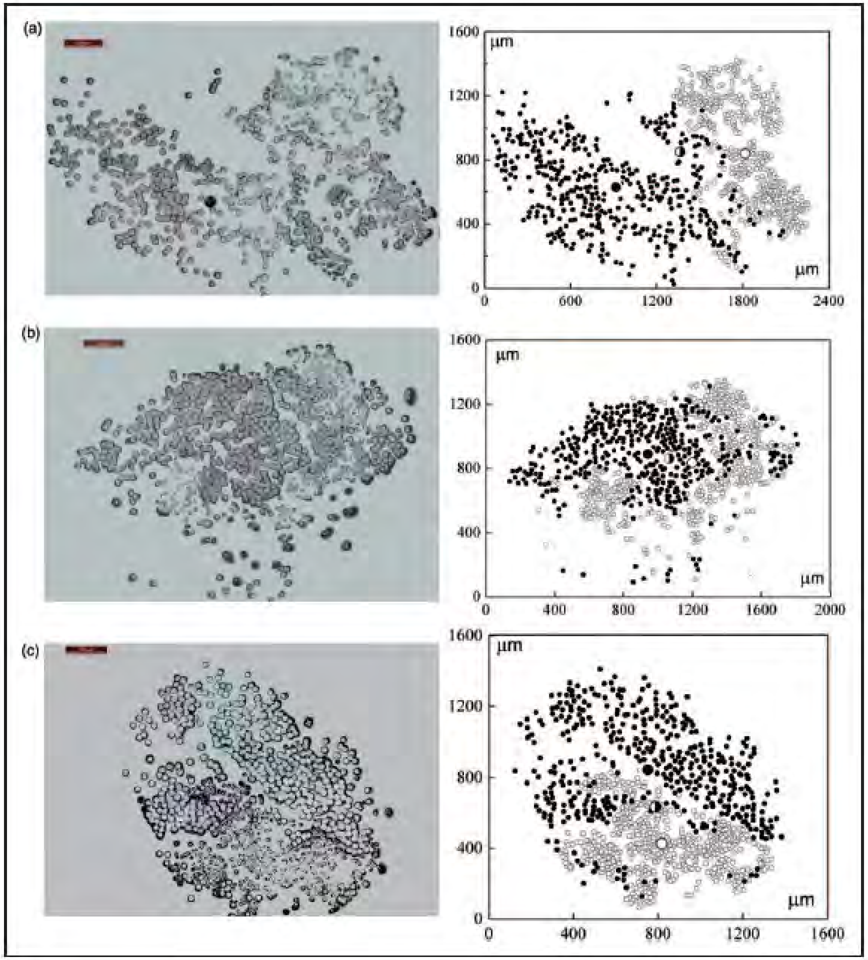
$$\overline{k}_{B,effi} = f(\overline{R}_{d,eff}, \overline{L}_{t,eff}) = \left|1 - \overline{R}_{d,eff}\right| \overline{L}_{t,eff}$$

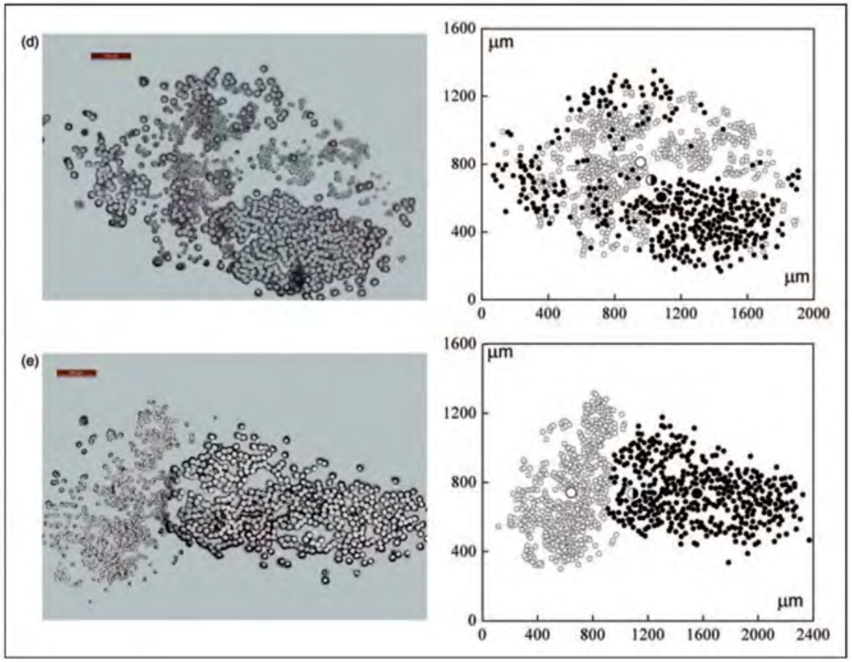
$$\overline{k}_{B,yarn} = \sum_{eff} \overline{P}_{eff} \overline{k}_{B,eff}$$



Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Discussion and conclusions – example of results 8





Type of effects		Twist	Braid	Wrap	Entangle	Non-interlaced
$\bar{R}_{d,eff}$	Glass	0.82	0.96	0.83	0.92	0.74
	PA	1.24	1.06	1.23	1.12	1.30
$\bar{L}_{t,eff}$		0.99	0.79	0.69	0.53	0.84
$\bar{k}_{B,eff}$		0.18	0.03	0.12	0.05	0.21

Fig. 44 Hybrid yarn cross-section – typical structures a) „twist“ b) „braid“ c) „wrap“ d) „entangle“ e) „non-interlaced“

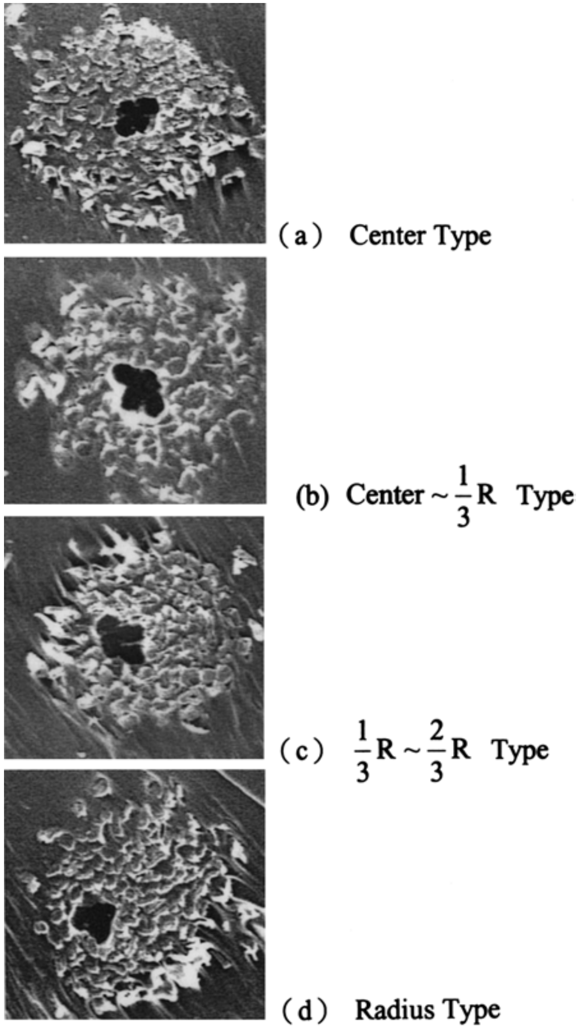
Kravaev P., Stolyrov O., Seide G., Gries T. A method for investigating blending quality of commingled yarns. *Textile Research Journal 83(2), 2013.*

Discussion and conclusions – example of results 9

Methodologies:

Blending quality

- ✓ In the case of core yarns, the blending quality can also be evaluated as the distance of the core from the center of gravity (axis) of the yarn.
- ✓ When we will compare the distance of coordinates of core yarn axis and coordinates of core itself, we can have the possibilities shown on pictures a) to d).



(a) Center Type

(b) Center $\sim \frac{1}{3}$R Type

(c) $\frac{1}{3}$R $\sim \frac{2}{3}$R Type

(d) Radius Type

Fig. 44 Core yarn cross-section (cover 100% cotton fibers, core elastan monofilament)

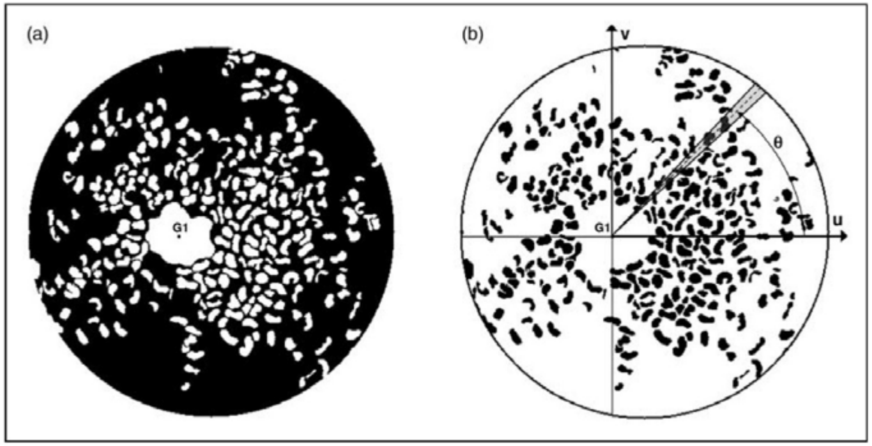
Su Ch. I., Maa M. Ch., Yang H. Y. Structure and performance of elastic core spun yarn. *Textile Research Journal* 74(7), 2004.

Discussion and conclusions – example of results 10

Methodologies:

Blending quality another possibilities

- ✓ Core yarn cross-sections are processed in Image analysis and the binary images of fiber cross-sections are at disposal.
- ✓ Covering ability is calculated from areal definition (area covered by fibers in selected section divided to area of whole section).
- ✓ It is possible to interpreted also for each pxls in partial core yarn cross-sections.



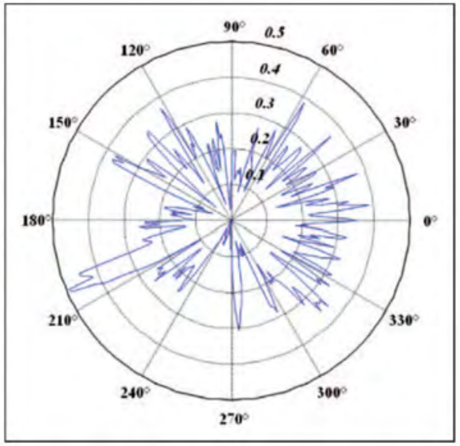


Fig. 45 Core yarn cross-section (cover - 100% cotton fibers, core - spandex multifilamentes), a) Binary image including 95% of all fibers, b) schema of covering ability calculation for given section

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Jaouachi B., Moussa A., Hassen M. B. Image analysis of the elastane position effect on the appearance of wet pneumatic spliced elastic core-spun yarn. *Textile Research Journal* 81(14), 2011.

Other references to the topic

Fancy yarn, composite yarn (structure, quality and the way of its production, …)

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Questions for knowledge verification and repetition

- ✓ How the Slub yarn can be describe and define, what types of these yarns exist (in terms of production and effects) and for what types of textiles are they used?
- ✓ What qualitative indicators are used to describe Slub yarn and is it possible to use standard procedures?
- ✓ What is the character of chenille yarns and how are they produce (a brief description is satisfactory)?
- ✓ How can the quality of chenille yarn be evaluated using image analysis?

- ✓ What is the character of the wrapped yarn, how is it produced and how is it specify?
- ✓ What characteristics are used for quality evaluation of the wrapped yarn? Give examples…
- ✓ What is a core yarn, what is typical for them and how is it produced (a brief description is satisfactory)?
- ✓ What characteristics are used to describe the quality of core yarns and how are they determined?
- ✓ What factors can affect the quality of fancy yarns? Give examples…

Thank you for your attention…

TŘENÍ A ODĚR DÉLKOVÝCH TEXTILIÍ / YARN FRICTION AND ABRASION RESISTANCE

Ing. Gabriela Krupincová, Ph.D. / **Department of technologies and structures**

Aims and motivation

Motivation:

- ✓ Abrasion of the yarn has a negative effect not only in its production process, but also during winding/ rewinding, finishing and subsequent processing (e.g. knitting, weaving, sewing) into the final product and also in its use.
- ✓ The aim is to understand this phenomenon and its principle, which can be observed and exactly described. This knowledge can help to find ways to make yarns or multifilamentes resist this process as much as possible.
- ✓ In order to find the optimal technological parameters and the method of preparation of yarns or multifilamentes for subsequent use, it is necessary to define the requirements for yarn or multifilamentes in connection with the purpose of its use in the final product and the process of its production.

Aims and motivation

Study of yarn abrasion resistance:

- ✓ It allows to define a selected range of technological parameters of yarns or multifilamentes to meet the requirements of the final product and its production process.
- ✓ It facilitate the selection of used processes for the treatment effectively (quality, cost, energy).
- ✓ It verifies the quality of yarns or multifilamentes for a given area of application, eventually modify the production process accordingly.
- ✓ Indirectly, it will provide information to understand the wear rate of machine parts that are in contact with yarns or multifilamentes.
- ✓ It provides information related to the friction between yarns or multifilamentes and the surface to be measured (metal surface, abrasive material).

Overview of the current state and possibility of evaluations yarn friction and abrasion at FT TUL

- ✓ Definition of friction of yarns or multifilaments
- ✓ Definition of abrasion resistance of staple yarns or multifilaments
- ✓ Principles of measurement for the evaluation of friction and abrasion resistance of yarns or multifilamentes - methodologies and instruments
- ✓ Factors influencing the friction and abrasion resistance of yarns or multifilaments

Definition of friction leading potentially to abrasion

- ✓ Friction is necessary to ensure cohesion between the fibers in the fiber formations and assemblies. On the other hand, high friction is the cause of surface damage and problems in the processing of yarns or multifilamentes into areal fabric and in their use.
- ✓ The friction force is proportional to the size of the contact area between the friction surfaces and increases with a power dependence on the normal force.

$$\text{static friction } F_t = \mu F_N, \ \mu = \frac{F_t}{F_N};$$

$$\text{dynamic friction } F_{t1} = aF_N{}^n.$$

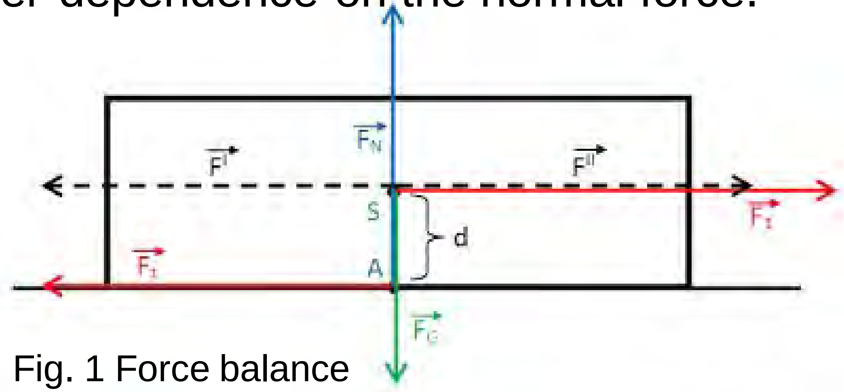

Fig. 1 Force balance

μ static friction coefficient, F_t friction force, F_N normal force, F_G gravitational force, F_{t1} applied friction force during dynamic friction, *a* and *n* coefficients based type of fiber material ($0{,}75 < n > 0{,}95$ for standard fibre materials $n = 0{,}9$), very low friction coefficient have polytetrafluoroethylene fibers $\mu = 0{,}04$. *S* center of gravity, A is the point of contact with the pad , F^I a F^{II} balance forces.

Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN 978-1-85573-920-8.
Saville B. P. *Physical testing of textile*. The Textile Institute Woodhead Ltd and CRC Press, 2000. ISBN 0-8493-0568-3 Militký J. *Textile fibers, Classical fibers and special fibers*. TUL 2012 (In Czech).
Howell H. G., Mieszkis K. W., Tabor D. *Friction in textile*, The Textile Institute 1959.

Definition of friction leading potentially to abrasion

- The force required to initiate the sliding motion of one object against another is greater than the force required to maintain the sliding motion once it has begun. The reason for this is that the contact area is grooved due to creep, the junctions are increased due to the inter-diffusion of surface atoms across the interface.
- The dynamic friction force has in case of textile materials stick slip character, although the magnitude of it is determined by many factors (material composition, yarn or multifilament parameters – count, twist, technology of production, sizing, used methodology, speed, temperature, air humidity).
- Fibers are semi-crystalline materials with viscoelastic properties.

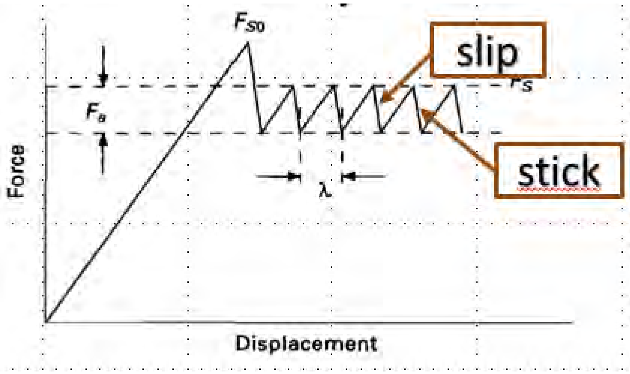

Fig. 2 Hypothetical friction trace for textile material

F_{so} the static friction force, F_s the dynamic friction force, F_a amplitude of frictional resistance, λ wavelength of the fluctuations

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Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN 978-1-85573-920-8.
Saville B. P. Physical testing of textile. The Textile Institute Woodhead Ltd and CRC Press, 2000. ISBN0-8493-0568-3 Militký J. *Textile fibers, Classical fibers and special fibers*. TUL 2012 (In Czech).
Howell H. G., Mieszkis K. W., Tabor D. *Friction in textile*, The Textile Institute 1959.

Definition of friction leading potentially to abrasion

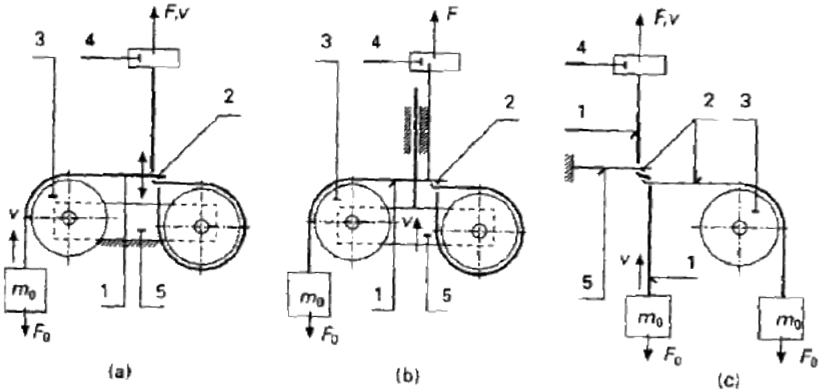


Fig. 3a Basic principles of yarn to yarn friction

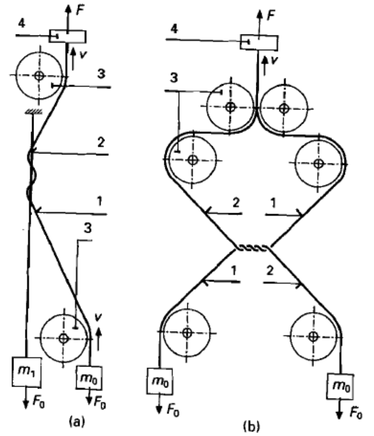


Fig. 3b Basic principles of yarn to yarn friction (yarn wrapped on yarn in higher angle)

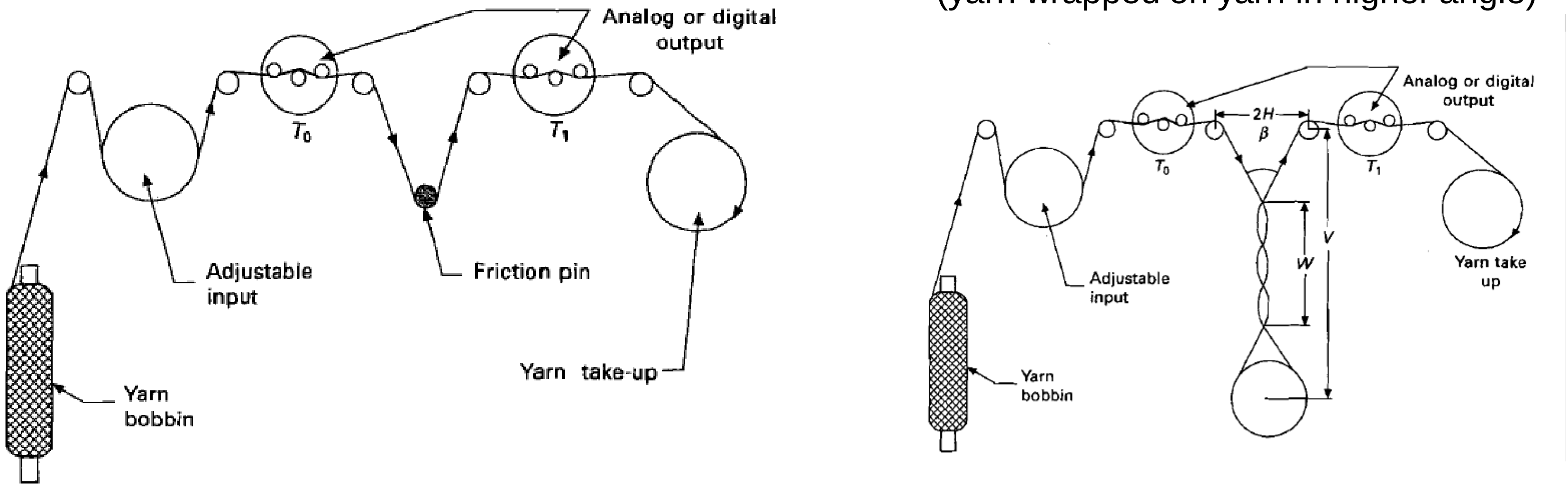
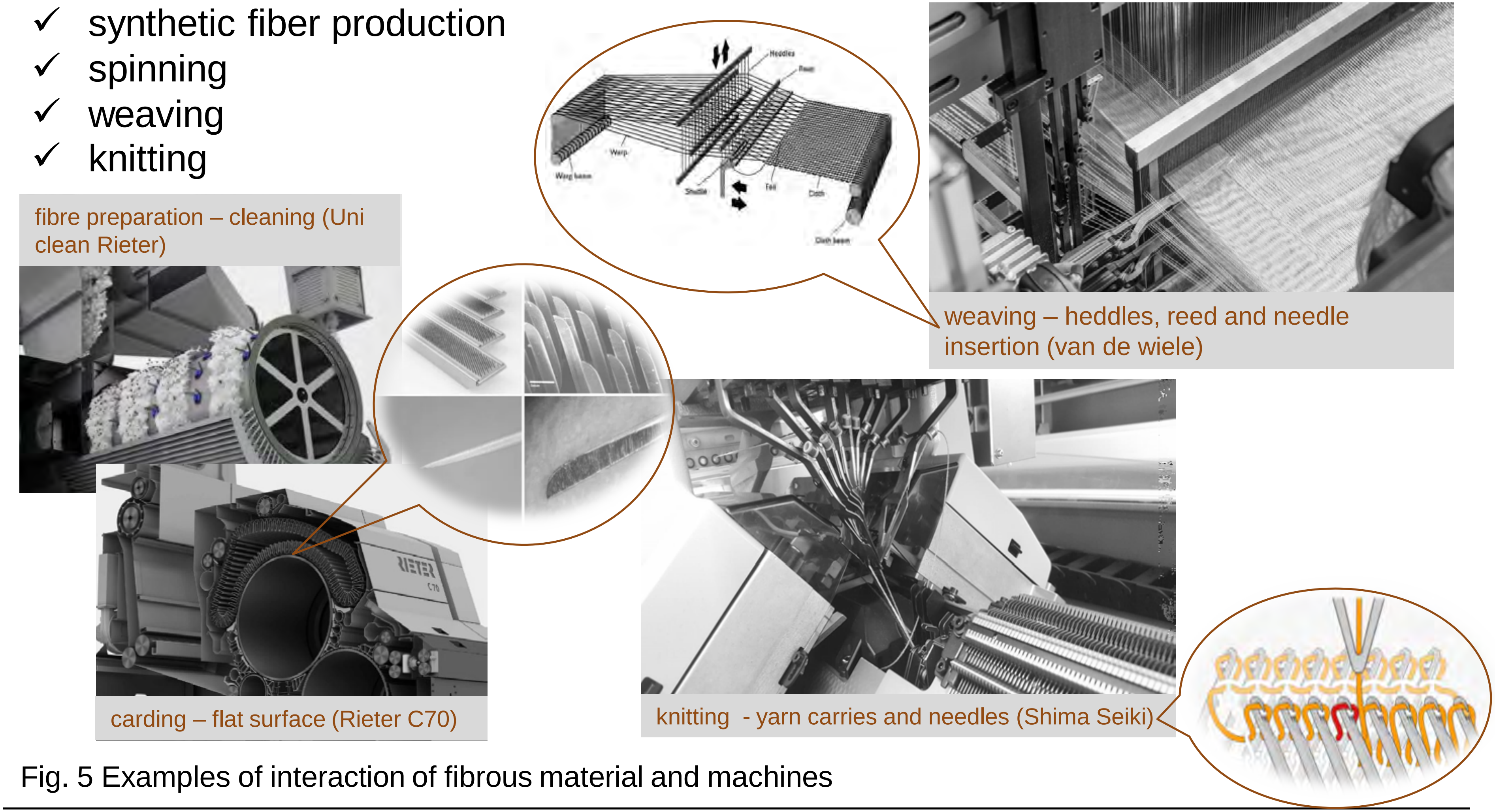


Fig. 4a, b Analysis of yarn friction on defined surface according to ASTM D3108 and yarn on yarn ASTM D3412

Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN: 978-1-85573-920-8.
ASTM D3108 / D3108M-13(2020), Standard Test Method for Coefficient of Friction, Yarn to Solid Material, ASTM International, West Conshohocken, PA, 2020.

Friction in processing of fibers into final textile is important in all stages of textile production

- ✓ synthetic fiber production
- ✓ spinning
- ✓ weaving
- ✓ knitting



fibre preparation – cleaning (Uni clean Rieter)

weaving – heddles, reed and needle insertion (van de wiele)

carding – flat surface (Rieter C70)

knitting - yarn carries and needles (Shima Seiki)

Fig. 5 Examples of interaction of fibrous material and machines

Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN: 978-1-85573-920-8.

Howell H. G., Mieszkis K. W., Tabor D. *Friction in textile*, The Textile Institute 1959.

Definition of friction leading potentially to abrasion

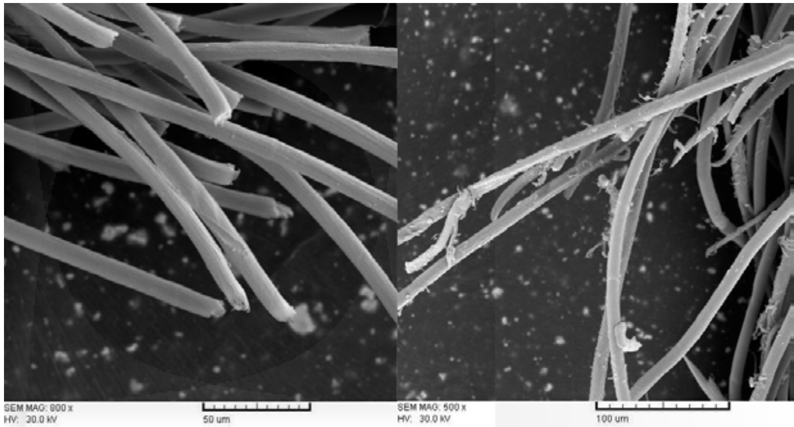


Fig. 6 PES fibers a) before and b) after abrasion

Wear mechanisms of textiles:

- ✓ Adhesive wear, occurs between surfaces during frictional contact and generally refers to unwanted displacement and attachment of wear debris and material compounds from one surface to another. The adhesive wear and material transfer due to direct contact and plastic deformation are the main issues in adhesive wear.
- ✓ Abrasive wear, occurs when a hard rough surface slides across a softer surface. ASTM (American Society for Testing and Materials) defines it as the loss of material due to hard particles or hard protuberances that are forced against and move along a solid surface. Abrasive wear is commonly classified according to the type of contact and the contact environment.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Saville B. P. *Physical testing of textiles*. Woodhead Publishing Limited 1999. ISBN 978-185-573-367-1.

Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN: 978-1-85573-920-8.

Definition of friction leading potentially to abrasion

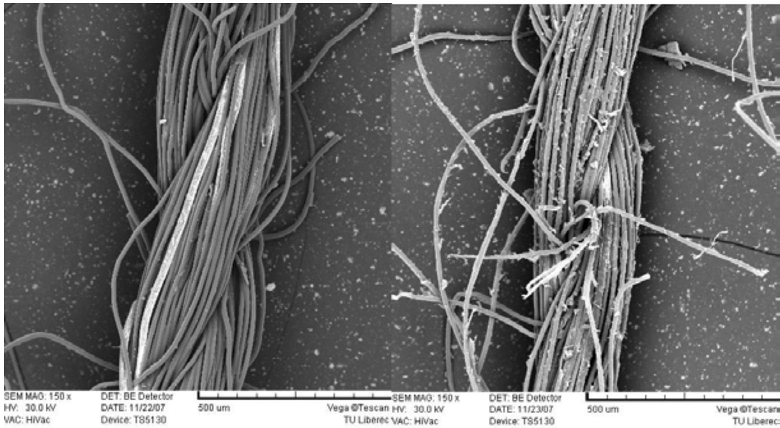


Fig. 7 Sewing thread 19,8tex x 2 92% PES/ 8% PES Silver Stat a) before and b) after abrasion

Wear mechanisms of textiles:

- ✓ Fatigue wear of a material is caused by a cycling loading during friction. Fatigue occurs if the applied load is higher than the fatigue strength of the material. Fatigue cracks start at the material surface and spread to the subsurface regions. The cracks may connect to each other resulting in separation and delamination of the material pieces. One of the types of fatigue wear is fretting wear caused by cycling sliding of two surfaces across each other with small amplitude (oscillating).
- ✓ Wear is affected by the energy that is absorbed during cyclic stress. First, the surface is damaged and then there are changes in the internal structure. If the applied energy in total is higher than the ability of the material to withstand stress (elastic and viscoelastic component of deformation), damage occurs.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Saville B. P. *Physical testing of textiles*. Woodhead Publishing Limited 1999. ISBN 978-185-573-367-1.

Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN 978-1-85573-920-8.

Sizing (slashing) or lubrication

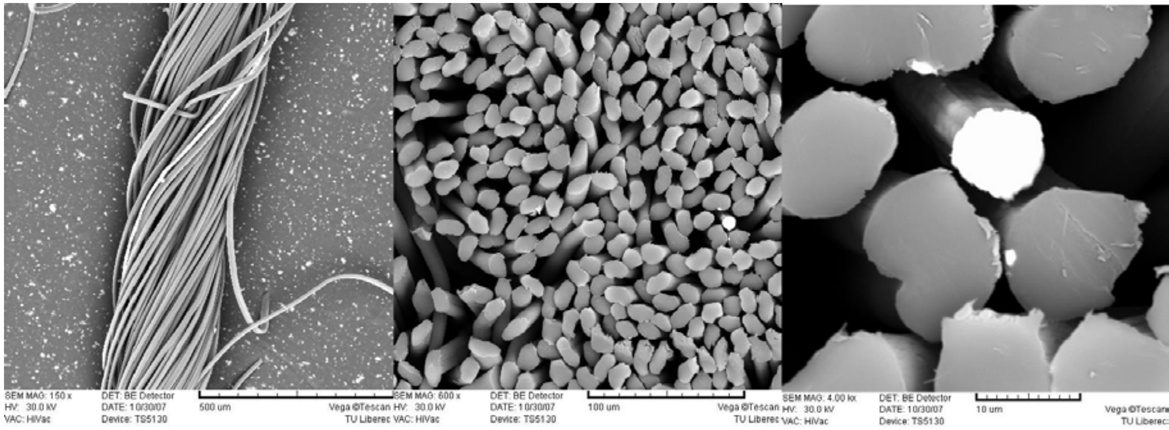


Fig. 8a, b and c Views of 25 tex meta-aramide staple yarn including metal fibers (98,8%Conex/ 1,2% metal fibers)

- ✓ Staple yarn - processability improvement (friction reduction, hairiness reduction, mechanical properties improvement, abrasion resistance improvement).
- ✓ Filament yarn - processability improvement (protective coating to eliminate broken filaments, abrasion resistance improvement).
- ✓ Way of sizing (slashing) depends on - fiber material (fineness, length, mechanical properties, friction, ...), yarn fineness and twist level, technology of production, final application and way of processing (weaving, knitting, requirements for optimal processing in terms of machine parameters), used sizing agents, technology of its application and way of desizing.

Saville B. P. *Physical testing of textiles*. Woodhead Publishing Limited 1999. ISBN 978-185-573-367-1.
Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN 978-1-85573-920-8.
Goswami B. C. Anandjiwala R. D. Hall D. M. Textile Sizing, Marcel Dekker Inc. 2004. ISBN 0-8247-5053-5.

Sizing (slashing) or lubrication

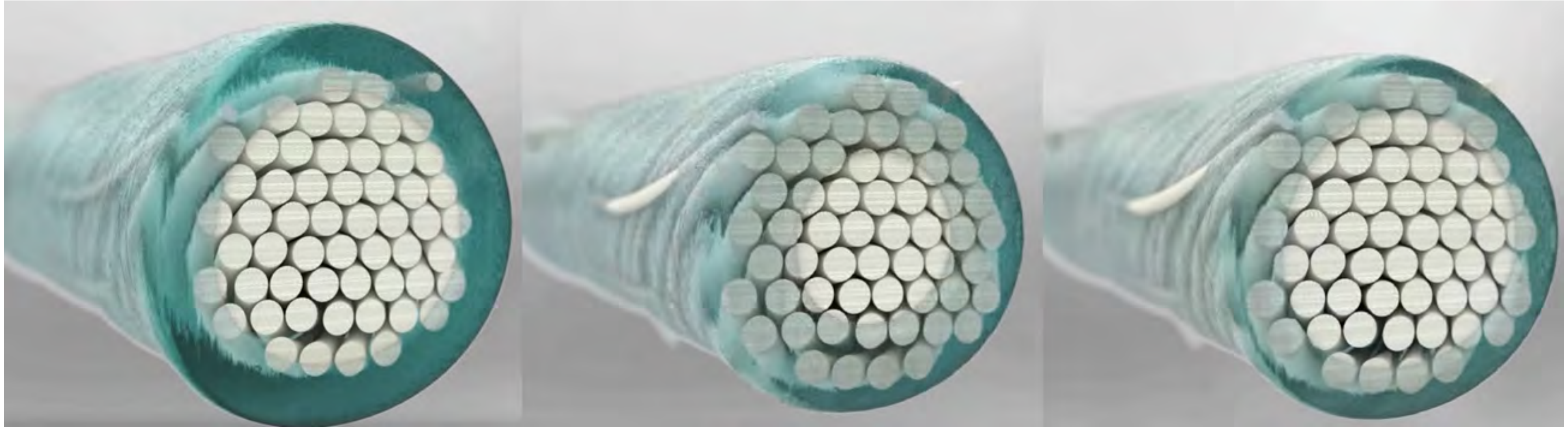


Fig. 9 Sizing a) too low penetration, b) too much penetration, c) optimal penetration

- ✓ Type of sizing agents - natural starch with modifications and binders, PVA, CMC (carboxymethyl celulose), HMC (hydroxymethyl celulose), Sodium alginate, Acrylic.
- ✓ Important factors are - cost, processability of sizing yarns, ability to recover sizing agent and complexity of effluent treatment.

Saville B. P. *Physical testing of textiles*. Woodhead Publishing Limited 1999. ISBN 978-185-573-367-1.
Gupta B. C. *Friction in textile materials*. Woodhead Publishing Limited, The Textile Institute 2008. ISBN 978-1-85573-920-8.
Goswami B. C. Anandjiwala R. D. Hall D. M. Textile Sizing, Marcel Dekker Inc. 2004. ISBN 0-8247-5053-5.

Definition of abrasion resistance of yarns or multifilamentes after sizing

- ✓ is usually defined as the number of cycles required to break of test yarn *o* [-] due to friction stress which leads to abrasion. If the results of testing of different samples are to be compared, it is more advantageous to work with a relative abrasion resistance *O* [tex^{-1}] ;
- ✓ it can also be defined as the weight loss Δm [g] or the mass of separated particles *Lint generation* [mgkm^{-1}];
- ✓ it can be defined as a change in selected yarn properties before and after abrasion (usually expressed as unit less [-] or in percentages [%]):
  - → change of diagonal yarn dimension ZD_{min} , ZD_{max}, ZMax_s, ZMin_s;
  - → change in yarn hairiness;
  - → change of mechanical properties (strength, relative strength, elongation);
  - → change of appearance.

Definition of friction leading potentially to abrasion

What is good to refresh or study again

- ✓ What kind of stresses act during yarn or multifilament production and rewinding;
- ✓ requirements and preparation of yarn or multifilament for knitting and weaving, what kind of stress act during processing of yarn or multifilament by weaving or knitting;
- ✓ requirements for sewing threads and what kind of stress act during sewing.

Lawrence C. A. Fundamentals of spun yarn technology. Boca Raton: CRC Press LLC, 2003. ISBN 1-56676-821-7.

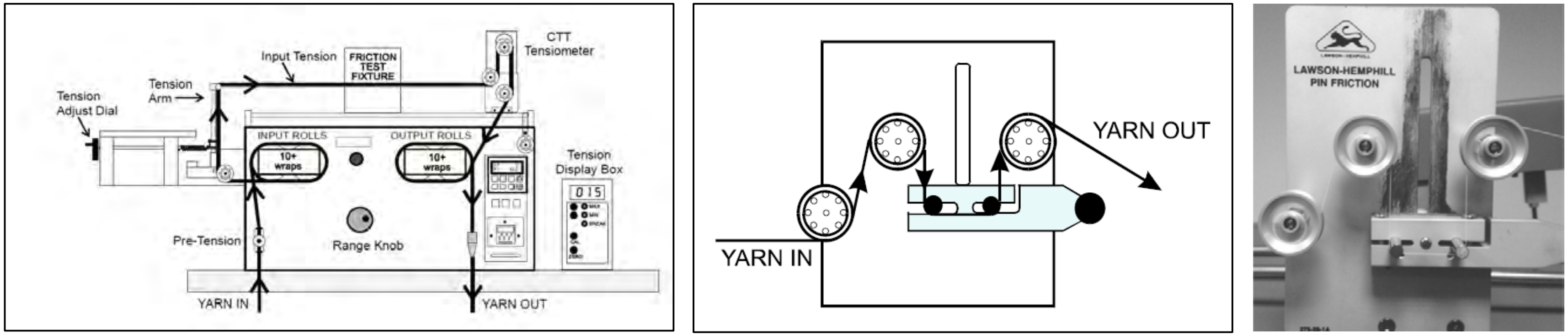
Tumajer P., Bílek M., Dvořák J. *Základy tkaní a tkací stroje, Skriptum TUL.* TUL, 2015. ISBN 978-80-7494-215-0 (Only in Czech).

Sabit A. *Handbook of Weaving*. Boca Raton: CRC Press, 2001. ISBN 978 1 58716 013 4.

Spencer D. J. *Knitting technology*. Leicester Polytechnic, Pergamon Press, England, 1983. ISBN 9780080247632.

Howell H. G., Mieszkis K. W., Tabor D. *Friction in textile*, The Textile Institute 1959.

Lawson Hemphill Constant Tension Transport CTT – friction of yarn on metallic



a b c

Fig. 10 Schema of CTT with yarn on metallic pin friction assessment, detail of yarn path in measuring zone

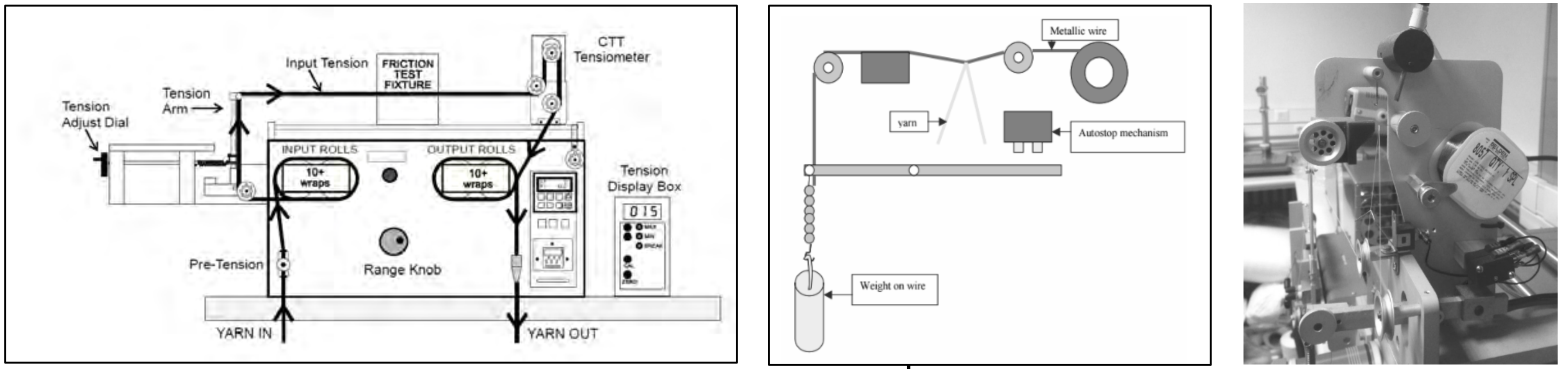
- ✓ The measurement of yarn on metallic pin is realized by using $\theta = 180° = \pi$ and the friction coefficient μ is the output.
- ✓ Typically used for staple yarns and multifilamentes.

$$\mu = \frac{\ln\left(T_0 / T_1\right)}{\theta}$$

μ friction coefficient, T_0 [gtex^{-1}] output tension, T_1 [gtex^{-1}] input tension, θ[rad] cumulative wrap angle.

Lawson Hemphill. CTT Constant Tension Transport: User Manual. Swansea, USA.
Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Lawson Hemphill Constant Tension Transport CTT – damage to metal parts by yarn



a b c

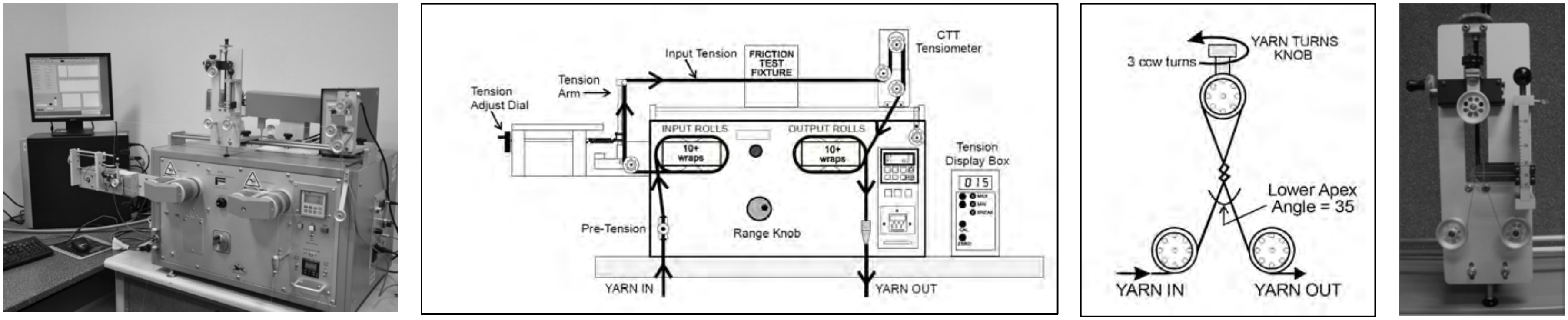
Fig. 11 Schema of CTT with yarn on metallic wire abrasion assessment, detail of yarn path in measuring zone

- ✓ The yarn is cross-wound at a speed of 360 mmin^{-1} over a metallic copper wire of specific parameters under tension and the length of yarn required to damage this wire is monitored in *l* [km]. The greater the length required to break the wire, the less damage to s machine components can be expected during yarn processing.
- ✓ Typically used for staple yarns and multifilamentes.

Lawson Hemphill. CTT Constant Tension Transport: User Manual. Swansea, USA.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Lawson Hemphill Constant Tension Transport CTT – yarn on yarn



a b c d

Fig. 12 Schema of CTT with yarn on yarn friction assessment, detail of yarn path in measuring zone

- ✓ Measures yarn on yarn friction and the output is friction coefficient μ.
- ✓ Typically used for staple yarns and multifilamentes.

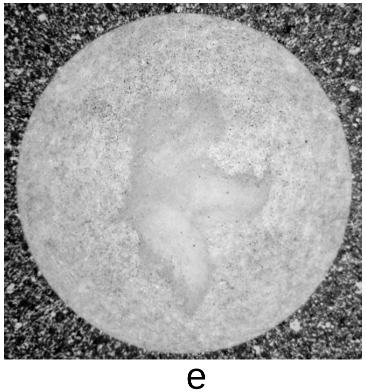
$$\mu = \frac{\ln\left({}^{T_0}\!/\!_{T_1}\right)}{4\pi(n-0{,}5)\sin{}^{\beta}\!/\!_{2}}$$

μ friction coefficient, T_0 [gtex^{-1}] output tension, T_1 [gtex^{-1}] input tension, n [-] number of wraps, β [°] apex angle between two yarns.

Lawson Hemphill. CTT Constant Tension Transport: User Manual. Swansea, USA.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Lawson Hemphill Constant Tension Transport CTT – abrasion resistance



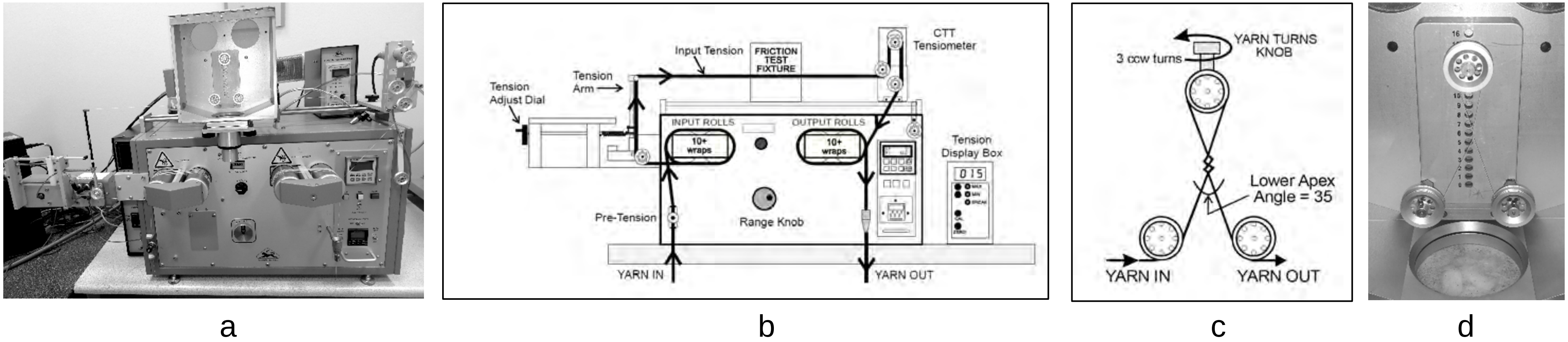


Fig. 13 Schema of CTT with module for lint generation assessment, detail of yarn path in measuring zone and generated lint detail on filter

- ✓ Measures the abrasion and breakage tendency before further processing. The yarn runs with constant tension to the testing zone, where the yarn is wrapped and the yarn-on-yarn abrasion is realized.
- ✓ Lint generation from 1km length of yarn sample is evaluated *Lint generation* [mg/km].
- ✓ Typically used for staple yarns.

Lawson Hemphill. CTT Constant Tension Transport: User Manual. Swansea, USA.
Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Zweigle staff tester G 556

a b

Fig.14 Schema of Zweigle staff tester G 556 and detail of wrapped yarn in testing zone

- ✓ Measures accurately abrasion and breakage tendency before further processing. The yarn runs with constant tension to the testing zone, where the yarn is wrapped and the yarn-to-yarn friction is realized or the specific various metal or ceramic elements can be placed into the running path of the thread.
- ✓ Lint generation from 1km length of yarn sample is evaluated *Lint generation* [mg/km^{-1}].
- ✓ Typically used for staple yarns.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Standard Test Method for Wet and Dry Yarn-on-Yarn Abrasion Resistance

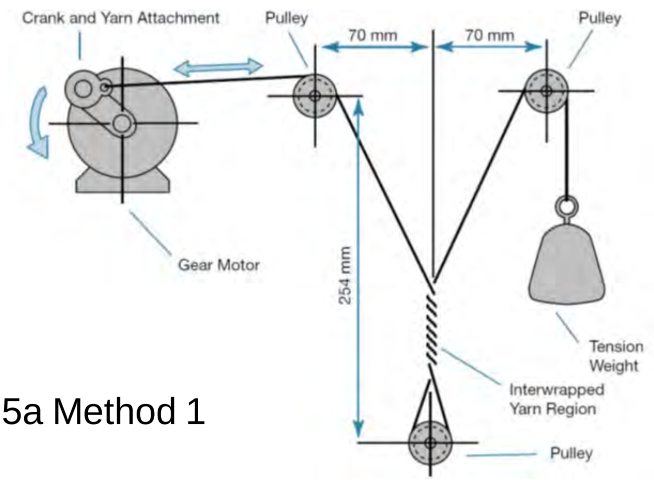


Fig. 15a Method 1

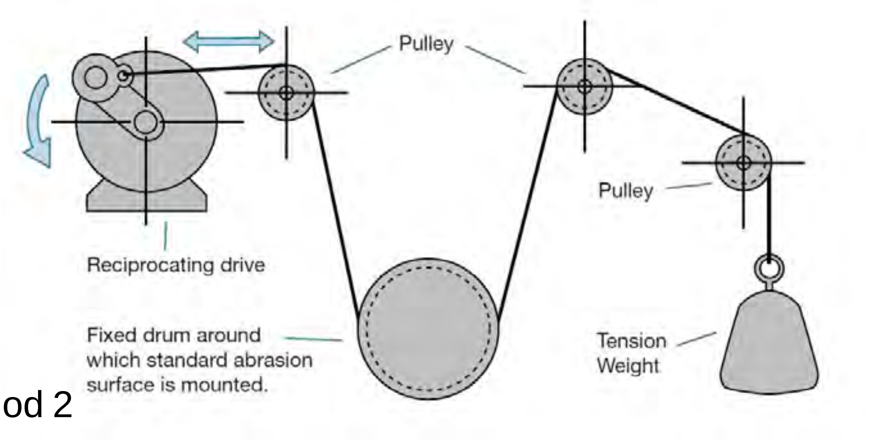


Fig. 15b Method 2

- ✓ Evaluation of number of cycles need for sample (yarn, multifilament, rope) destruction *o* [-], O [tex^{-1}].
- ✓ Method 1 Yarn to yarn friction, method 2 Yarn friction on specific surface.
- ✓ The pretensioned yarn is guided according to schema. The stress is performed at a defined speed and the number of cycles to failure in the dry or wet state is monitored and analysed.
- ✓ Designed for yarns used for the production of ropes, primarily for contact with seawater in the range from 70 tex to 300 tex, ASTM D6611-16.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.
ASTM D6611-16, Standard Test Method for Wet and Dry Yarn-on-Yarn Abrasion Resistance, ASTM International, West Conshohocken, PA, 2016.

Zweigle G 552 a XHX 23

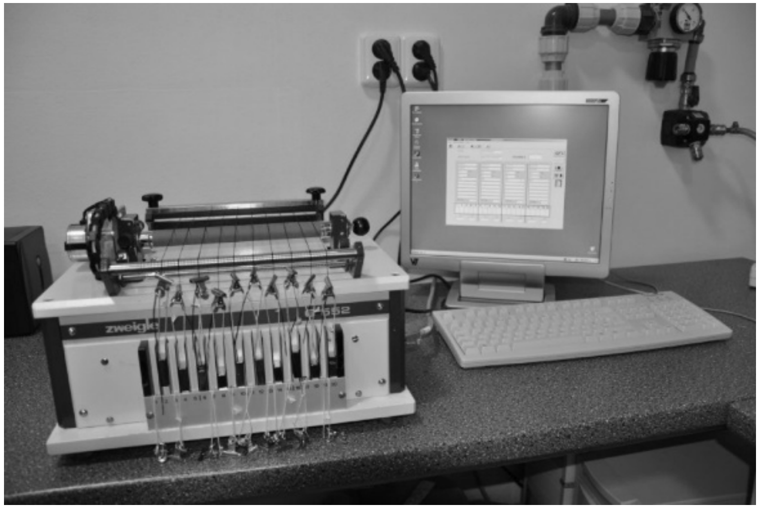


Fig. 16 Zweigle G 552

Fig. 17 XHX-23 Yarn abrasion tester

- ✓ Measurement of the number of cycles to break of yarn samples due to the abrasion *o* [-], *O* [tex^{-1}];
- ✓ It is also possible to evaluate the diagonal change of the dimension after reaching the defined number of cycles according to IS 32-203-01 / 01.
- ✓ Typically used for staple yarns

Operating instructions Zweigle G 567. [www.zweigle.com.](http://www.zweigle.com) Last Update 20.10. 2007.
IS 32-203-01/01 Evaluation of yarn abrasion resistance. FT TUL 2009.
http://www.xhinstruments.com/yarn-fiber-testing-machines/295-xhx-23-yarn-abrasion-tester.html

Shirley Yarn abrasion tester and similar instruments

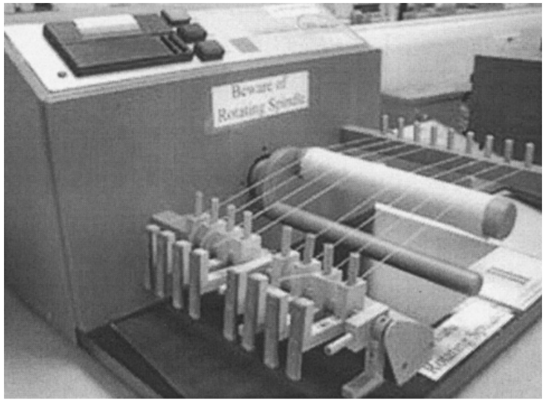


Fig. 18 Shirley Yarn abrasion tester

Fig. 19 Kardo Tech Yarn abrasion tester

Fig. 20 Tonny International Co LTD Yarn abrasion tester

- ✓ Measurement of the number of cycles to break of yarn samples due to the abrasion o [-], O [tex^{-1}];
- ✓ The friction is realized by using metal or other specific surface.
- ✓ Typically used for staple yarns.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.
www.kardotech.com/en/portfolio/yarn-abrasion-tester/
https://tonny.en.ecplaza.net/products/tnf04-yarn-abrasion-tester_584604

Honigmann Abrasion tester

Fig. 21 Honigmann abrasion tester

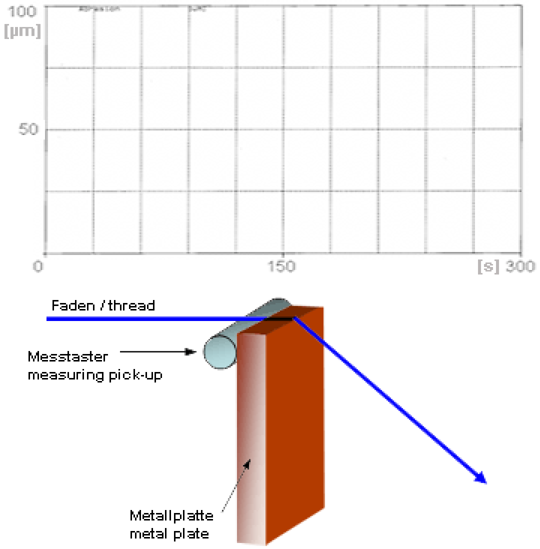


Fig 22 a, b Schema of the principle

- ✓ Determination of abrasion resistance based on monitoring of friction change during measurement. The yarn is guided over a defined metal surface at standard pretension and speed.
- ✓ Designed for different types of materials (yarns, monofilamentes, multifilamentes), it is possible to compare using of various types finishing or coating.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

www.kardotech.com/en/portfolio/yarn-abrasion-tester/

https://tonny.en.ecplaza.net/products/tnf04-yarn-abrasion-tester_584604

Wira Abrasion tester YAT 001

Fig. 23 Wira abrasion tester YAT 001

- ✓ Simulation of yarn stress during weaving by three-pin head. Yarns are guided in a defined manner to the test zone and loaded with a pretension. The test head moves 200 min^{-1}. The number of cycles need for samples failure is evaluated.
- ✓ Designed primarily for staple yarns used as warp yarns.

YAT 001, Wira LTD., available online z www.wira.com.

Sulzer Ruti web tester Reutlingen

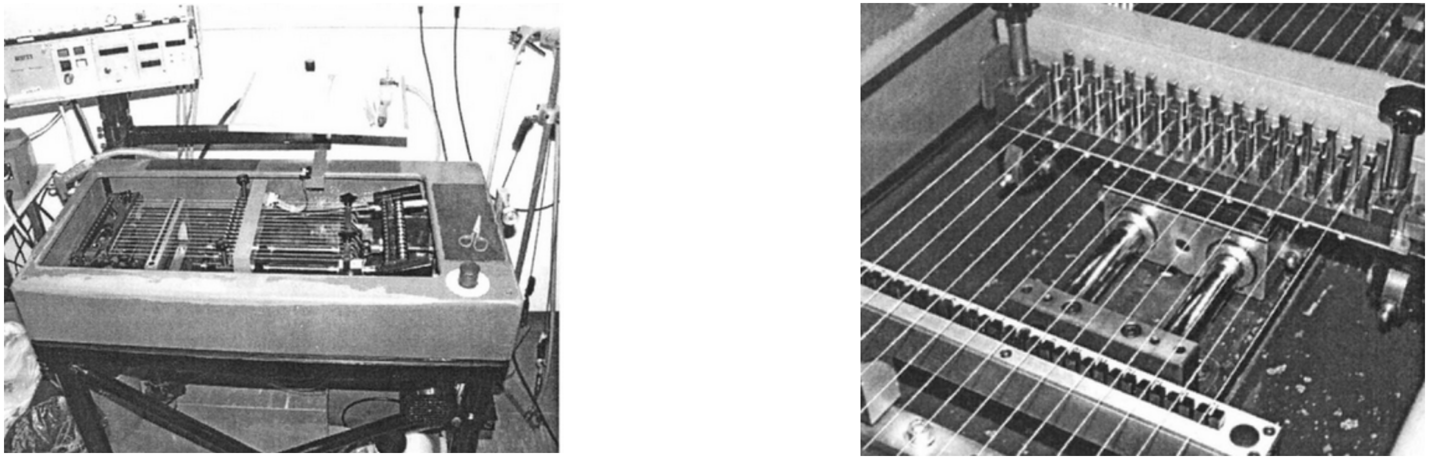


Fig. 24 Sulzer Ruti web tester, Reutlingen

- ✓ Simulation of yarn stress during weaving by three-pin head (static warp tension, cyclic stress corresponding to the exchange of heddles, abrasion on the metal elements of the reed during weaving, bending in the eyelets of the heddles). Yarns are guided in a defined manner to the test zone and loaded with a pretension. The test head moves in given range of cycles min^{-1}. The number of cycles need for samples failure is evaluated for 15 samples with a 50 cm length.
- ✓ Designed primarily for staple yarns used as warp yarns.

Goswami, B. C., Anadjiwala, R. D., Hall, D. M. *Textile Sizing*, Marel Dekker, InC. 2004. ISBN: 0-8247-5053-5.

Yarn abrasion testing method and machine

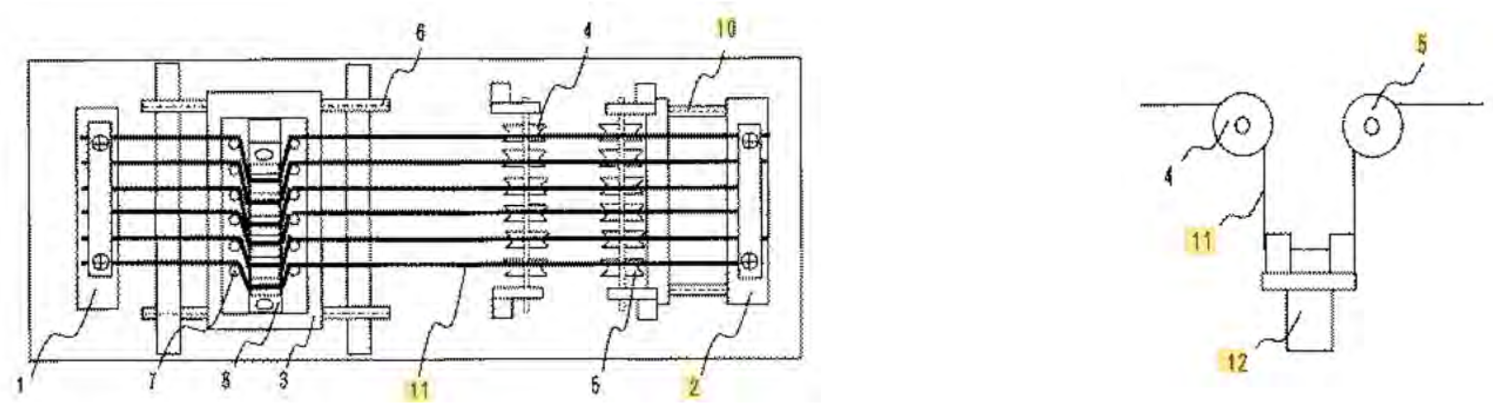


Fig. 25 Yarn abrasion testing method and machine – upper and side view of testing zone

- ✓ To provide a yarn abrasion testing method capable of examining whether fibrils easily occur in filament yarn in a preceding stage before weaving and knitting processes and to provide a testing machine used for the yarn test.
- ✓ When test yarn is mounted between a pair of sample fixing chucks 1 and 2, the test yarn is bent and mounted by a guide pin 7 and a metal piece for friction provided between the pair of sample fixing chucks. The test yarn is stretched over two pulleys 4 and 5. A weight is made to act on the test yarn between the two pulleys to provide tensile force. By integrally reciprocating the guide pin and the metal piece for friction in parallel with the direction of the yarn axis of the test yarn, the action of friction is provided for the test yarn.
- ✓ Designed primarily for multifilamentes used as warp yarns.

JP2004163255A Yarn abrasion testing method and machine. Tetsuya Akamatsu, Yasuhiro Iwashige, Hideki Okochi World Patent 2002. Now can be freely used.

Abrasion resistance tester for fishing line or thread of fishing net

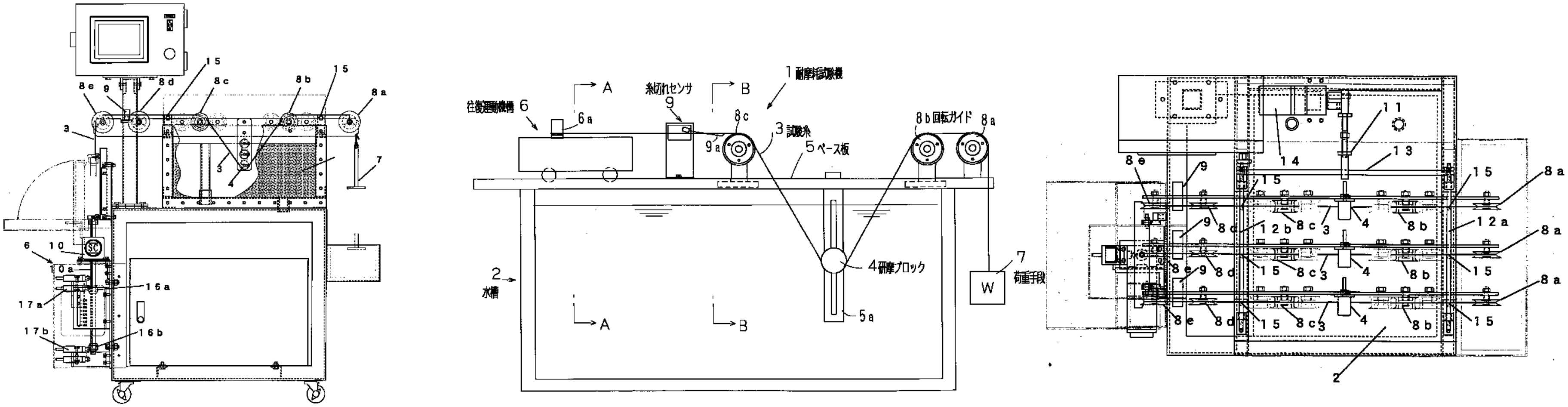


Fig. 26 Abrasion resistance testing method and abrasion resistance tester for fishing line or thread of fishing net, testing equipment, side view of testing zone with water tank, upper view of testing zone

- ✓ An abrasion resistance test method capable of performing an abrasion resistance test not only when a yarn is in the air but also in a state of being in the water, and further, does not cause an error by a measurer. The yarn to be tested is brought into frictional contact with the polishing block a plurality of times by a reciprocating motion mechanism, the yarn breakage is detected by a yarn breakage sensor, and the wear resistance is measured by the number of reciprocations until the yarn breakage occurs.
- ✓ A method for testing abrasion resistance of a fishing line, a fishing net line.

JP2001208663A Abrasion resistance testing method and abrasion resistance tester for fishing line or thread of fishing net. Yorihito Nakasaki. World Patent 2000. Now can be freely used.

High-speed Yarn Abrasion Tester TM 200iA

Fig. 27a, b High-speed Yarn Abrasion Tester TM 200iA, detail of measuring zone

- ✓ Simulation of yarn stress during weaving by three-pin head. Yarns are guided in a defined manner to the test zone and loaded with a pretension. The test head moves 200 min^{-1}. The number of cycles need for samples failure is evaluated.
- ✓ Designed primarily for staple yarns used as warp yarns.

High-speed Yarn Abrasion Tester TM 200iA, DAIEI Kagaku Seiki, available online http://www.daieikagakuseiki.co.jp/en/products/product.php?selected_category_no=12&item_no=90.

TRI Cyclic tensile abrader

- ✓ Simulation of stress during weaving (tension, bending, friction, abrasion). by using of one or three pin is realized. The experiment can be done under the various temperatures. The sample is via the pulley guided under the 270° and pretended by weight. Cyclic loading is applied. The number of cycles need for samples failure is evaluated.
- ✓ Design for testing of staple yarns and multifilamentes.

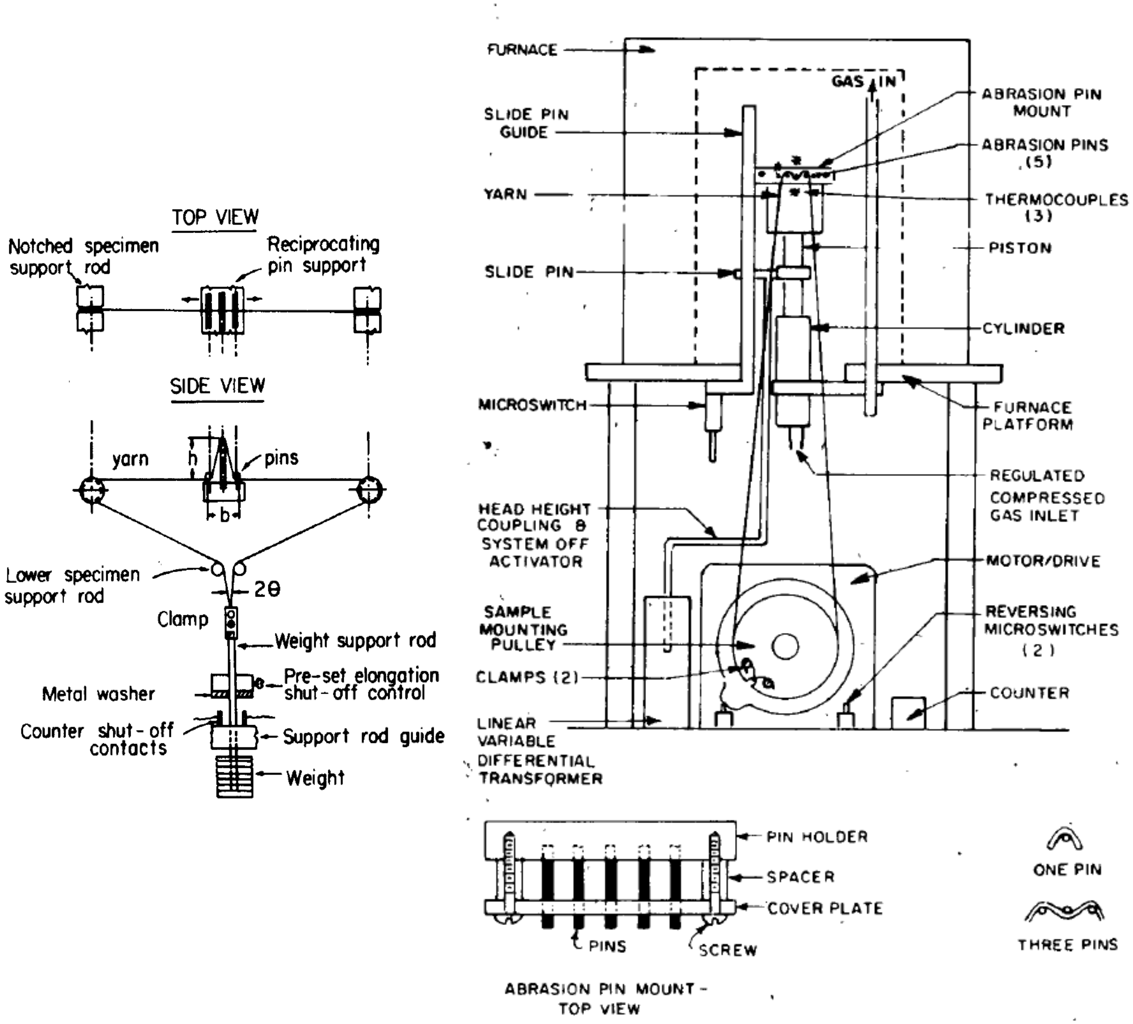


Fig. 28 Cyclic tensile abrader

Friedman H. L., Zhou Y. Y., Miller B. Development of hairiness of sized warp yarns during flexabrasive wear. *Textile Research Journal* 59 (9), 1988.

Miller B., Friedman H.L., Turner R. Design and use of cyclic tensile abrader for filaments and yarn – A study of polyester monofilament wear. *Textile Research Journal* 53 (12), 1993.

Simulator abrader tester

1 support of bracket, 2 variable eccentric, 3 table, 4 cam, 5 electric box, 6 control panel, 7 bracket for reed, 8 drive pulley, 9 pulley, 10 motor, 11 static reed, 12 oscillating reed, 13 smooth, 14 setting, 15 rod, 16 reed, 17 toothed rack, 18 yarn bracket, 19 warp stop motion, 20 frequency inverter, 21 potentiometer

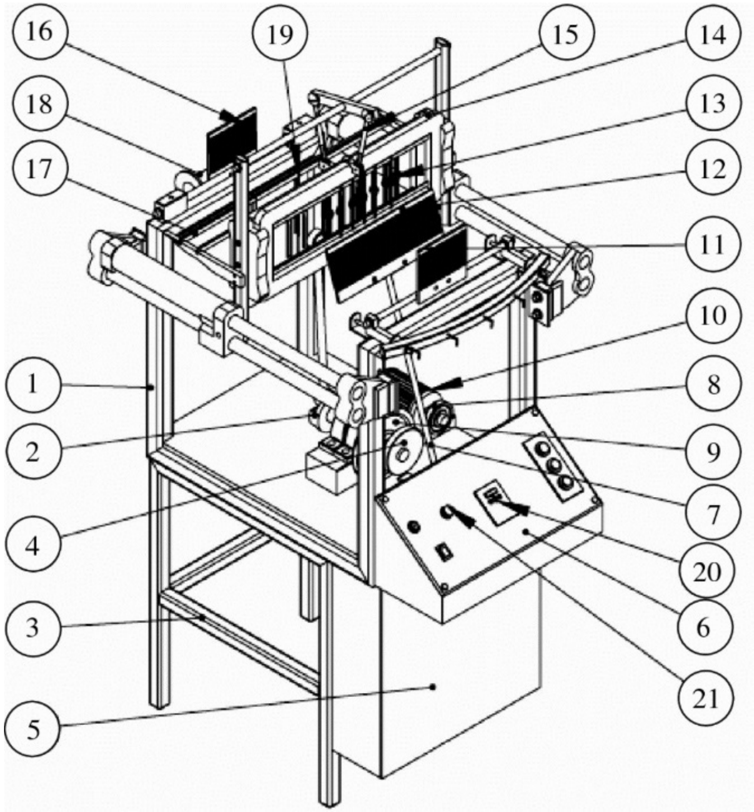


Fig. 29 Simulator abrader tester

- ✓ Yarns are guided in a defined manner to the test zone and loaded with a pretension. The number of cycles need for samples failure is evaluated.
- ✓ Designed primarily for staple yarns used as warp yarns.

Boubaker J., Hassen M. B. and Sakli F. Abrasion evaluation of spliced and parent yarns with a new simulator abrader tester. *Journal of the Textile Institute* 103 (4), 2012.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.

Yarn abrasion tester

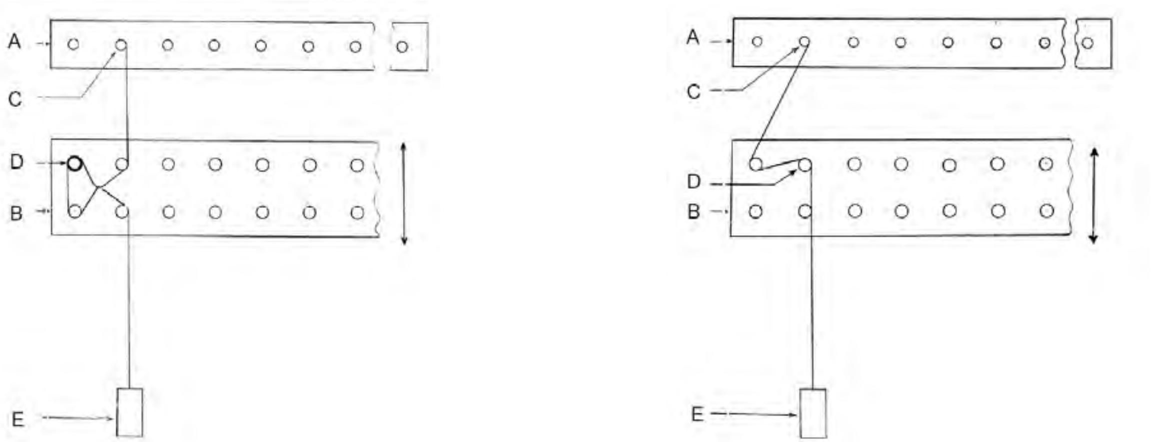


Fig. 30 Yarn abrasion tester method 1 yarn to yarn friction, method 2 yarn friction on given material - pin A fixed part, B moving part with yarn guides, C fixing jaw, D yarn guide element, E weights

- ✓ Evaluation of yarn on yarn friction or the friction of yarn on given material (steel pin or other abrasion material). Emery paper can be placed on guiding bar D. Method 1 or 2 is used in respect to the requirements of evaluator. Simulation of yarn sample stress during rewinding, weaving or sewing in a needle is provided.
- ✓ The number of cycles need for samples failure is evaluated.
- ✓ Designed primarily for staple yarns used as warp yarns.

Kolandaisamy P., Peer M. Effect of the single-yarn twist and ply to single-yarn twist ratio on the hairiness and abrasion resistance of cotton two –ply yarn. *Autex Research Journal* 6 (2), 2006.

Yarn abrasion tester (Versa machine)

- ✓ Yarn is abraded in winding process. The abrasion element is placed close to yarn cleaner at a defined angle. After five rewinds of yarn sample, selected yarn properties are determined.
- ✓ Change of yarn hairiness and change of yarn mechanical properties due to abrasion (strength, elongation) are evaluated.
- ✓ Designed primarily for staple yarns.

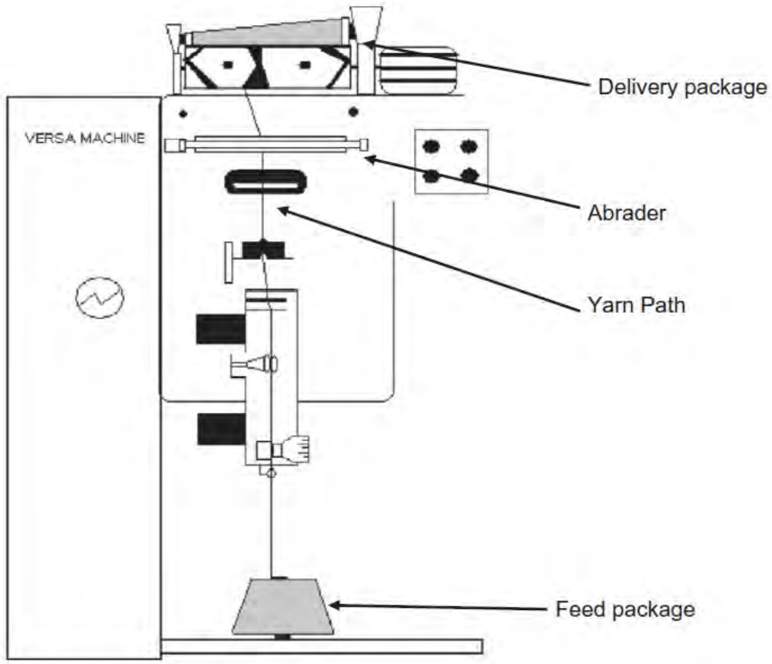


Fig. 31 Yarn abrasion tester

Mukhopadhyay A., Midha K. V., Ray N. Ch. Effect of structural parameters of injected slub yarn on its tensile properties and abrasion resistance. *Journal of The Textile Institute* 108 (9), 2016.

Experimental devices

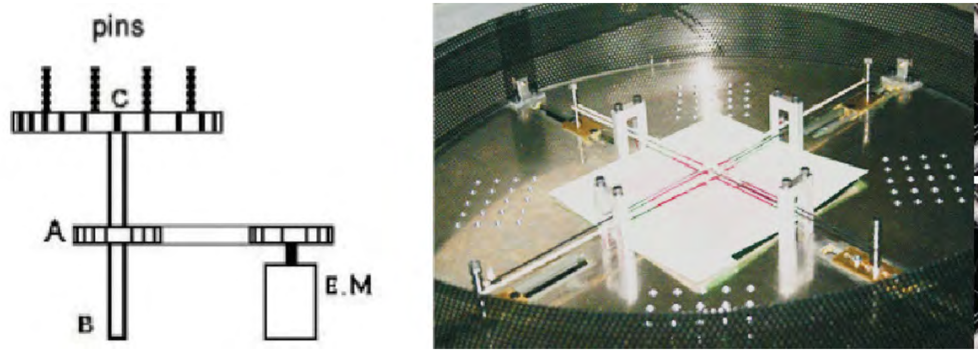


Fig. 32 Schematic of the instrument; a) Slotted cam movements. b) Pins and their locations

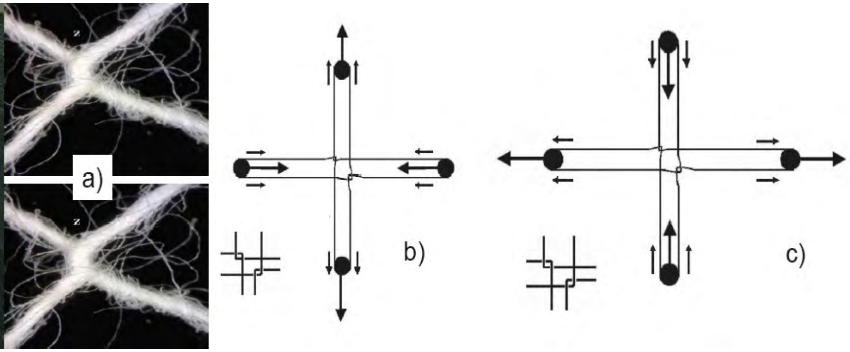


Fig. 33 Yarn layout and pins inward and outward movements

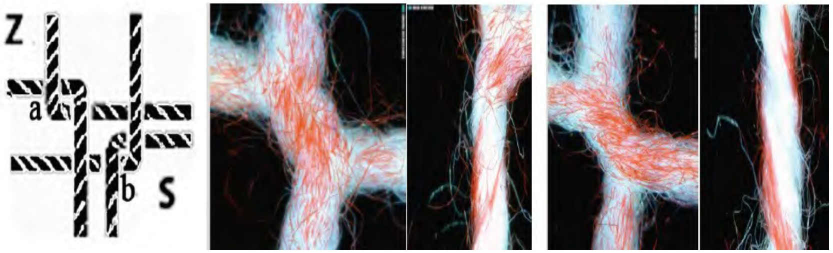


Fig. 34 Crossing points and yarn twist directions Z/S

- ✓ The influence of yarn crossing way on yarn to yarn friction is evaluated in respect to the yarn twist direction. Yarns are guided in a defined manner to the test zone and loaded with a pretension. The number of cycles need for samples failure is evaluated.
- ✓ Designed primarily for staple yarns.

Alamdar Yazdi A., Heppler G. R. Abrasion behaviour of yarns at right angle for ring and rotor spun yarn. *Fibres and Textile in Eastern Europe* 20 6A(95), 2012.

Metafem

- ✓ The test consists in monitoring the number of cycles until tread damage or up to a defined number of cycles. The results of threads sample is compared with the behaviour of thread standard. Selected types of needles are located in the measuring zone, their rectilinear reciprocating movement is ensured by a drive from the main shaft and is read by a speed counter. The tested thread is firmly attached in the upper part and further guided by means of brakes into the eye of the needle and subsequently loaded with weights.
- ✓ AMANN Rassant comparative thread standards of PES / CO blend in relevant yarn count are used to evaluate the test.
- ✓ Designed for sewing threads.

Fig. 35 Metafem

Alamdar Yazdi A., Heppler G. R. Abrasion behavior of yarns at right angle for ring and rotor spun yarn. *Feibres and Textile in Eastern Europe* 20 6A(95), 2012.

Evaluation of yarn abrasion resistance

Change of single yarn diagonal dimension due to abrasion:

$$ZD_{\min} = \frac{abs(D - Do_{\min})}{D}\,10^2, \quad ZD_{\max} = \frac{abs(D - Do_{\max})}{D}\,10^2.$$

Change of diagonal two-ply yarn dimension due to abrasion:

$$ZMax_s = \frac{abs(Max_s - Max_{so})}{Max_s}\,10^2, \; ZMin_s = \frac{abs(Min_s - Min_{so})}{Min_s}\,10^2,$$

$$ZD_1 = \frac{abs(D_1 - D_{1o})}{D_1}\,10^2.$$

Fig. 36 Real two-ply yarn with marked dimensions Max_s, Min_s, D_1

- ✓ Evaluation of change of diagonal dimension due to abrasion after acchiving of given number of cycles is realized by using Zweigle G 567 in accordance with IS 32-203-01/01.
- ✓ Diagonal dimensions of single staple yarn are D, D_o, D_{omin}, D_{omax}; diagonal dimensions of two-ply staple yarn are D_1, Max_s, Min_s, D_{1o}, Max_{so}, Min_{so}.
- ✓ Design for staple single, two- ply (two folded) yarn.

Operating instructions Zweigle G 567. www.zweigle.com. Last Update 20.10. 2007.
IS 32-203-01/01 Evaluation of yarn abrasion resistance. FT TUL 2009.

Principles of measurement, methodologies, instruments

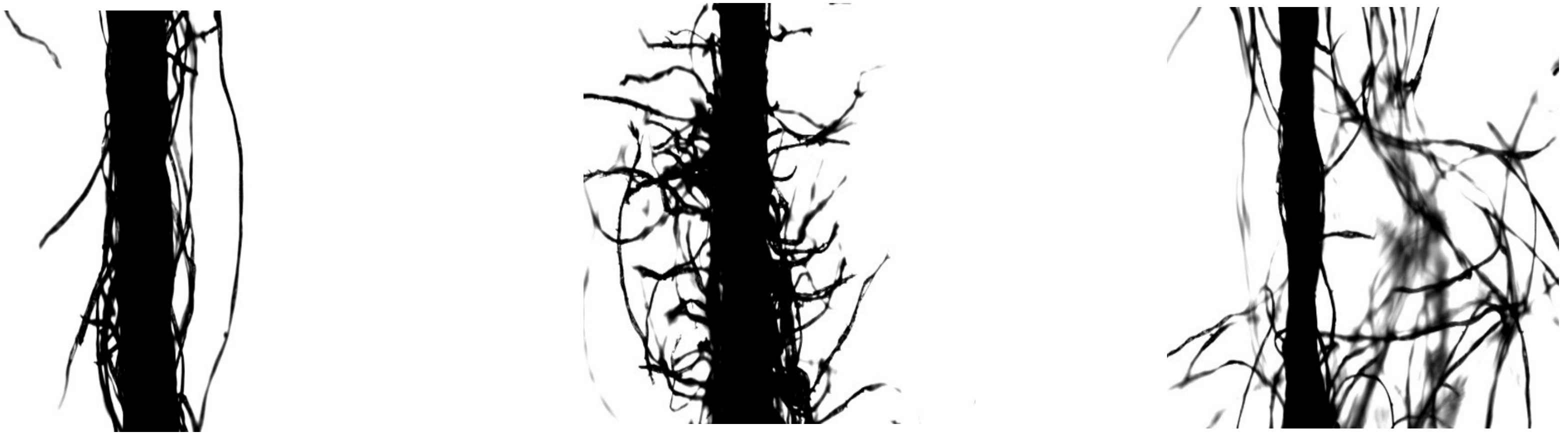


Fig. 37 100% CO 25 tex before and after abrasion by applying 50 % of cycles need for yarn destruction (calibration 2,23µmpx^{-1}, image resolution 548 pxl x 704 pxl)

Fig. 30 100% CO 25 tex – after abrasion by applying 50 % of cycles need for yarn destruction (calibration 3,72 µmpx^{-1}, image resolution 548 pxl x 704 pxl)

Operating instructions Zweigle G 567. [www.zweigle.com.](http://www.zweigle.com) Last Update 20.10. 2007.
IS 32-203-01/01 Evaluation of yarn abrasion resistance. FT TUL 2009.

Principles of measurement, methodologies, instruments

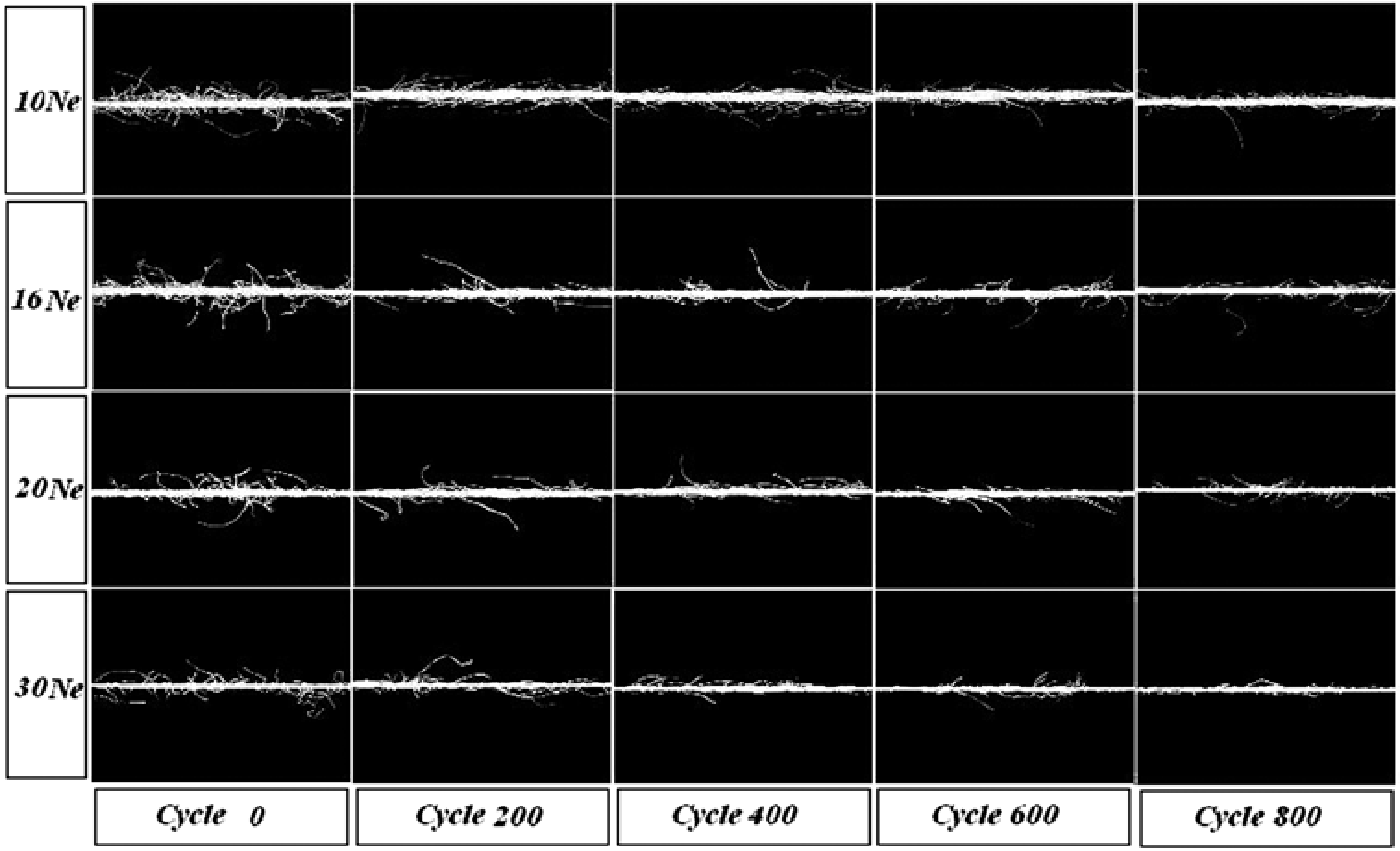


Fig. 38 100% CO staple yarn after cyclic loading by using Shirley abrasion tester, evaluation of chance of characteristic dimension of yarn and weight reduction of samples

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Asgari H., Mokhtari F., Latifi M. and Amani-Teheran M. Characterizing cotton yarn appearance due to yarn to yarn abrasion by image processing, *The Journal of The Textile Institute* 105(5), 2014.

Principles of measurement, methodologies, instruments

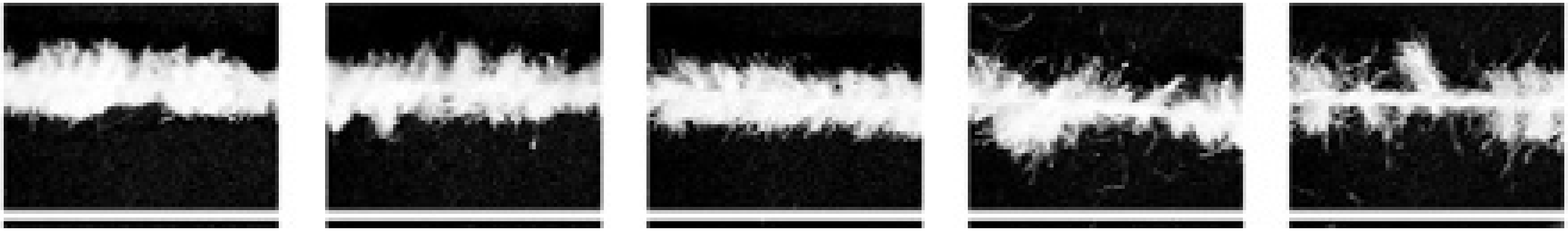

Fig. 39 Evaluation of visual change after cyclic loading by friction (original yarn, yarn after 50, 75, 100 and 150 abrasion cycles)

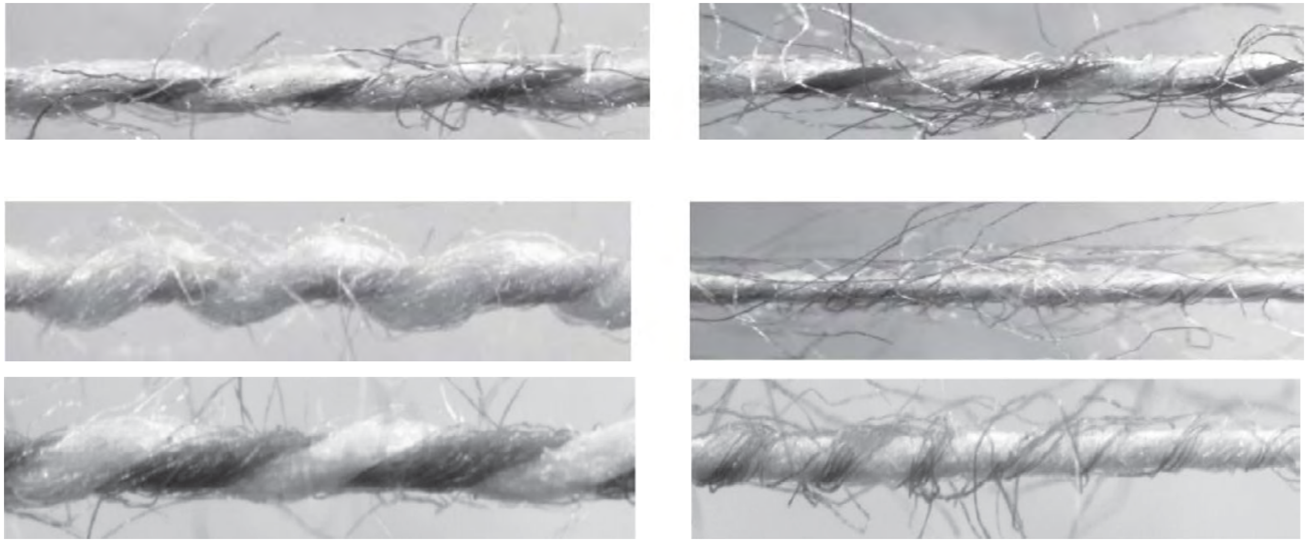

Fig. 40 Fancy yarn before and after cyclic loading by friction

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Ceven E. K., Özdemir Ö. Evaluation of Chenille Yarn Abrasion Behavior with Abrasion Tests and Image Analysis. *Textile Research Journal* 76(4), 2006.

Effect of structural parameters of injected slub yarn on its tensile properties and abrasion resistance. *Journal of The Textile Institute* 108 (9), 2017.

Factors influencing the abrasion resistance of yarn and multifilamentes

- ✓ **fiber properties** (type, length, fineness, diameter and cross-sectional shape, flexural and torsional stiffness, strength and elongation, coefficient of friction; for cotton fibers also the purity of the raw material and for wool or synthetic fibers the degree of crimp and resistance to compression, surface energy and surface roughness),

- ✓ **geometric parameters of the yarn** (yarn count, level of twist, or mixed proportion, type of staple yarns in terms of - single, folded, fancy, multifilament),

- ✓ **production technology** (type of production technology settings or way of yarn finishing related to arrangement of the fibers in the yarn),

- ✓ the obtained results may be influenced by the type of used instrument, the measurement methodology, the procedure for data processing, the parameters used for characterization of the friction and abrasion resistance, the testing conditions (humidity, speed testing, number of measurements) and the sampling method and realization of experiment in various media.

Discussion and conclusions

- ✓ Fibers with higher elongation and degree of elastic recovery are able to better withstand cyclic stress due to friction. Usually polyamide, polyester and polypropylene fibers show very good resistance to frictional stress. Acrylic fibers, wool, cotton and some high modulus fibers show moderate wear resistance. Viscose and acetate fibers show the lowest level of friction resistance.

- ✓ Yarns with higher count show higher resistance to frictional stress due to higher cohesion due to friction between the fibers, which is more significant with increasing number of fibers. In the case where the yarn of the same count is made of finer fibers, this phenomenon manifests itself in an increase of strength.

- ✓ A higher twist leads to a higher degree of compression of the fibers, an increase in the number of contacts between them what means higher application of inter-fiber friction. If fibers with a longer length are used for yarn production, the wear resistance is higher due to the better cohesion of the yarn due to the fact that the fibers cannot simply be removed from the structure. The force required for fiber movement from yarn structure is influenced by twist direction and acting force direction.

Özdil N., Kayseri Ö., Mengüc G. S. *Abrasion Resistance of Materials*. Chapter 7: Analysis of yarn abrasion Characteristics in Textile. 2012. ISBN: 978-953-51-0300-4. In Tech Open.
Militký J. Textile fibers, Classical fibers and special fibers. TUL 2012 (In Czech).
Saville B. P. *Physical testing of textiles*. Woodhead Publishing Limited 1999. ISBN 978-185-573-367-1.

Discussion and conclusions

- ✓ Combed ring yarns and compact yarns show slightly better wear resistance than carded yarns. While the same technological parameters is used, the rotor yarns have a lower resistance to frictional stress. In the case, that the rotor yarn are spun with higher level of twist, that the wear resistance is comparable with carded ring yarn. The way of setting individual technological processes during yarn production can also have an effect on wear resistance.

- ✓ In the case of chenille yarn, in addition to the basic technological parameters and the type of fibers used, the type and character of the pile material (material, length, fineness, surface properties - friction) play an important role.

- ✓ In the case of slub yarns, it is necessary to include among the factors influencing the abrasion resistance of the yarn (length, frequency and height of individual slubs).

Comparative assessment of Eli-Twist and Siro yarn made from polyester and its blend with cotton. *Indian Journal of Fiber and Textile Research* 44, 2019.

Ceven E. K., Özdemir Ö. Evaluation of Chenille Yarn Abrasion Behaviour with Abrasion Tests and Image Analysis. *Textile Research Journal* 76(4), 2006.

Effect of structural parameters of injected slub yarn on its tensile properties and abrasion resistance. *Journal of The Textile Institute* 108 (9), 2017.

Discussion and conclusions

- ✓ In the case of folded (ply) yarn, the direction and number of twists and their combination are important. The choice of structure (folded yarn or wrapped yarn) is also important.
- ✓ In the case where the yarns are coated with a size or other lubricant their abrasion resistance depends on the type of used size or lubricant, its concentration and amount of coating (usually expressed in per mille).
- ✓ The behaviour of yarns, multifilamentes or monofilamentes is also affected by the testing conditions (humidity, temperature, speed of testing and the way of applied stress).

Kolandaisamy P., Peer M. Effect of the single-yarn twist and ply to single-yarn twist ratio on the hairiness and abrasion resistance of cotton two –ply yarn. *Autex Research Journal* 6 (2), 2006.

Goswami B. C., Anandjiwala R. D., Hall D. Textile Sizing. Marcel Dekker INC. 2004. ISBN 0-8247-5053-5.

Friedman H. L., Zhou Y. Y., Miller B. Development of hairiness of sized warp yarns during flexabrasive wear. *Textile Research Journal 59* (9) 1988.

Miller B., Friedman H.L., Turner R. Design and use of cyclic tensile abrader for filaments and yarn – A study of polyester monofilament wear. *Textile Research Journal 53* (12) 1993.

Boubaker J., Hassen M. B. and Sakli F. Abrasion evaluation of spliced and parent yarns with a new simulator abrader tester. *Journal of the Textile Institute* 103 (4) 2012.

Kovačević S., Mijović B. Gancarić A. M. Influence of Rheological Size Parameters on Yarn Properties. Fibers and Textile in Eastern Europe. 20(4) 2012.

Discussion and conclusions – an example of results

Evaluation of friction of yarn on metal pin:

- ✓ Yarns: single ring spun 100% CO yarns with and without finishing.

- ✓ Assumptions: Assumptions: finer yarns will have a lower coefficient of friction on the metal pin than coarser yarns (due to smaller contact area), treated yarns will have lower friction on the metal pin than untreated yarns.

- ✓ Measurement condition and testing device: Lawson Hemphill CTT

parameter	**value**
test type	pin friction
input tension	1 g/tex
wrap angle	180º
test speed – [mpm]	100
sample length [m]	10
number of tests per sample	30
total test length [m]	900
waste length [m]	0

- ✓ Results:

sample	**no treatment**	**with treatment**	**no treatment**	**with treatment**
fineness [tex]	7,3	7,3	9,8	9,8
coefficient of friction μ [-]	0,23	0,17	0,25	0,18

Discussion and conclusions – an example of results

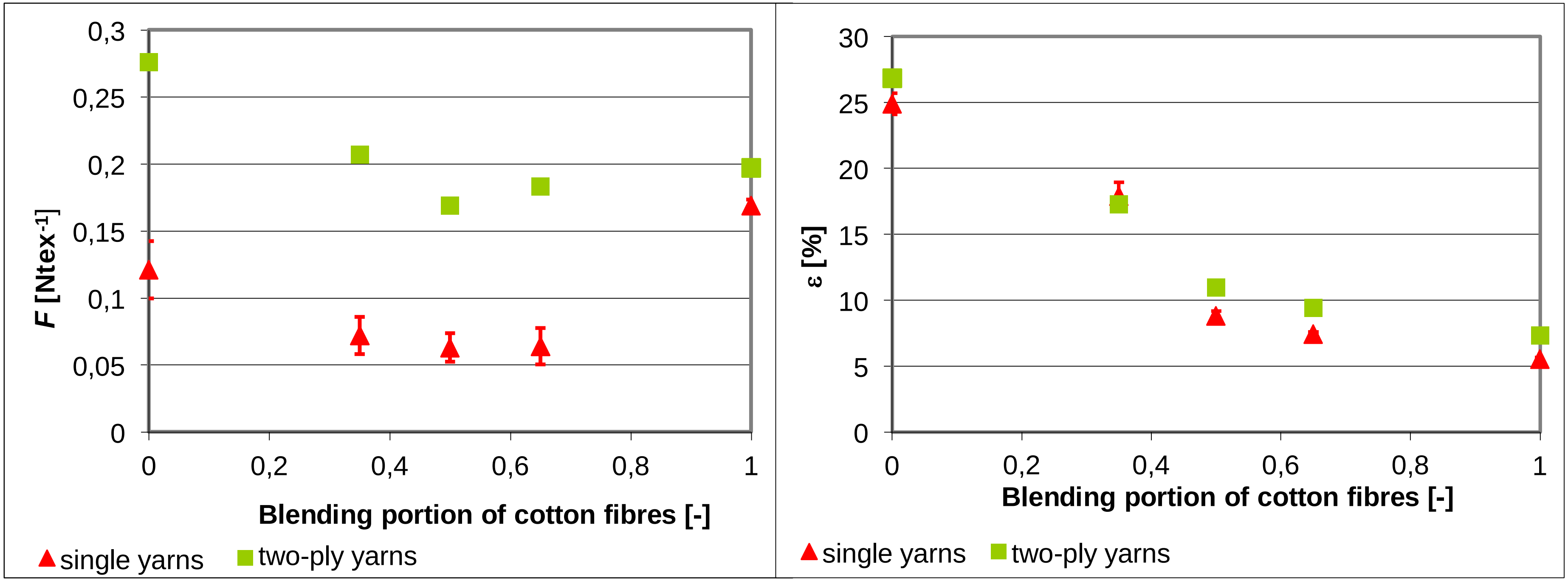
Evaluation of yarn abrasion:

- ✓ Yarns: single and two-ply yarn of 29,5 tex and 2x29,5tex, single-component and blended (100% CO, 65 CO / 35 PP, 50 CO / 50 PP, 35 CO / 65 PP and 100% PP).

- ✓ Assumptions: single yarns will show lower stress resistance than two-ply yarns (influence of structure and arrangement).

Krupincová G., Hatipoglu Y. Testing of yarn abrasion. *Autex Research Journal*, 13(1), 2013.

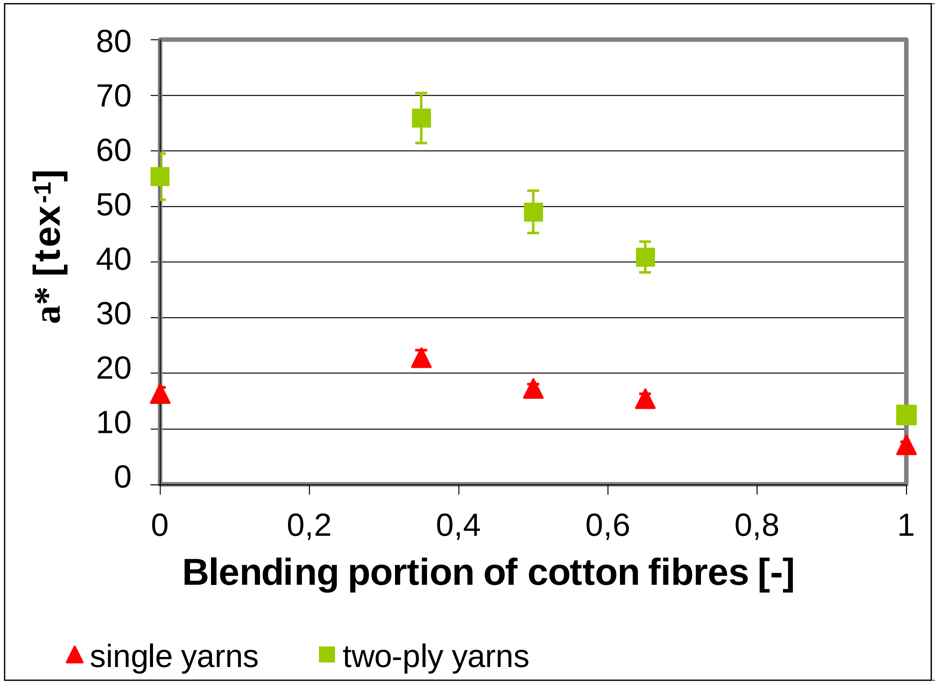
Discussion and conclusions – an example of results

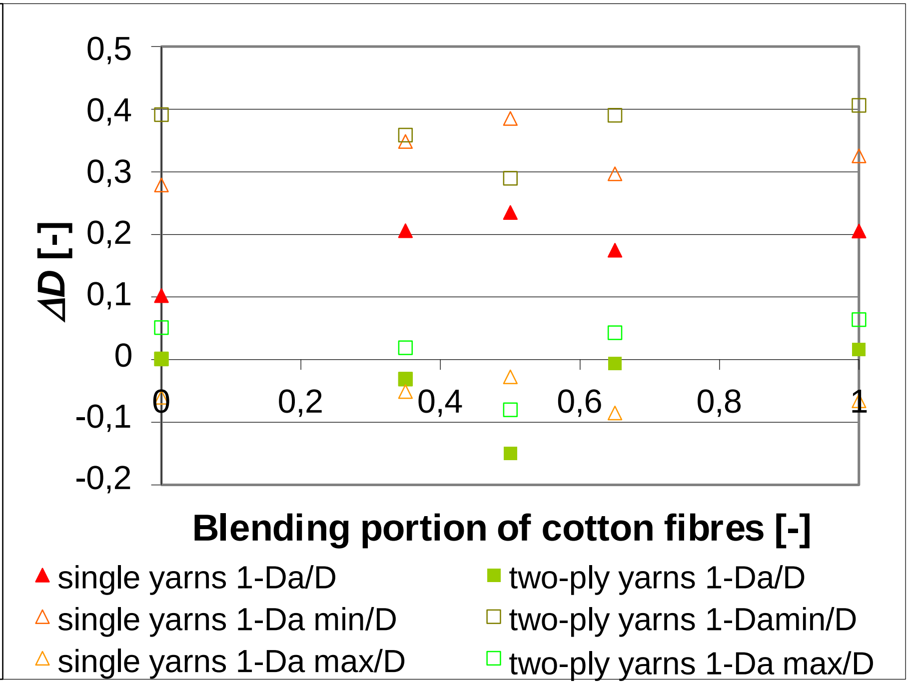


F yarn relative strength, ε yarn elongation.

Krupincová G., Hatipoglu Y. Testing of yarn abrasion. *Autex Research Journal*, 13(1), 2013.

Discussion and conclusions – an example of results





*a** relative number of cycles need for yarn failure

Krupincová G., Hatipoglu Y. Testing of yarn abrasion. *Autex Research Journal*, 13(1), 2013.

Discussion and conclusions – an example of results

Yarns:

✓100% CO single combed compact yarns of 8,4 tex a 10 tex designed for damasks;

✓100% CO single carded ring yarns 25 tex, 38 tex and 100% CO two-ply yarns 25x2 tex design for terry cloths.

✓Yarns were sampled from bobbins (1), warp beam before sizing (2) and warp bean after sizing (3). Sizing was realized by using standard sizing agent based on natural starch.

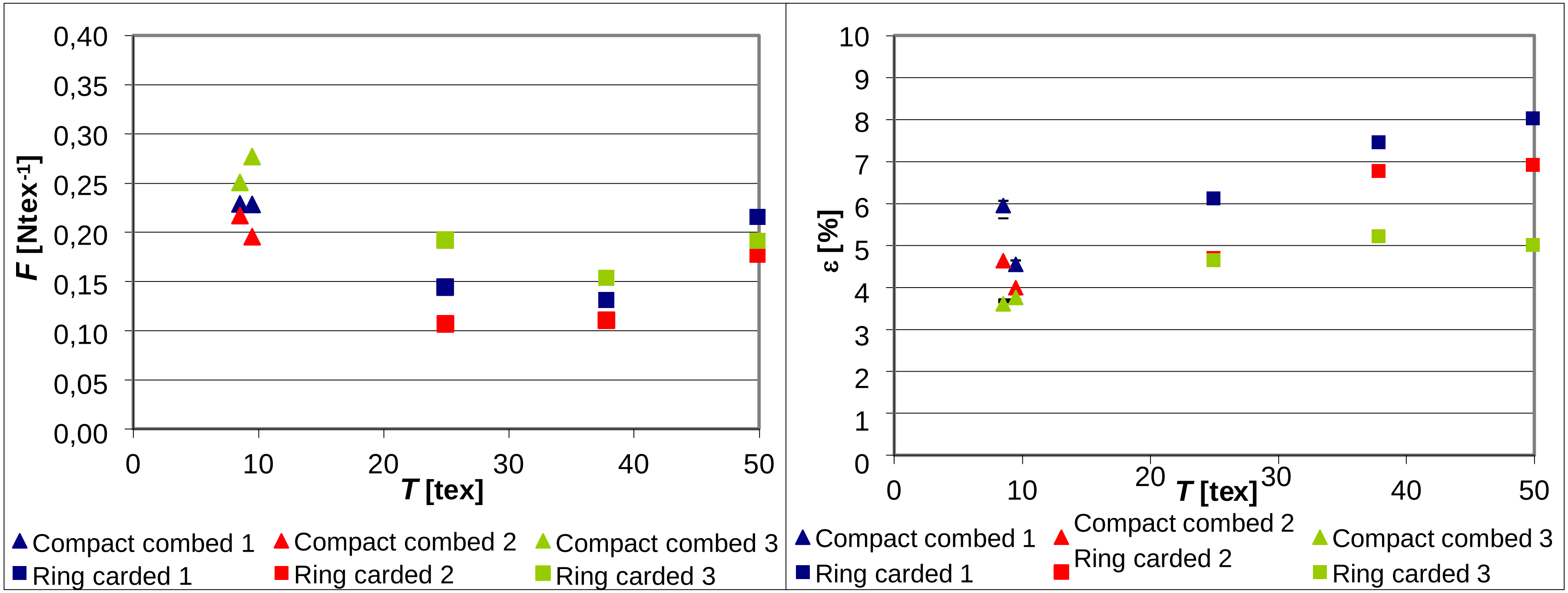
Assumptions:

✓Yarns with higher count will be more easily damaged (influence of the number of fibers in the cross section).

✓Sized yarns will show a higher resistance to frictional stress.

Krupincová G., Hatipoglu Y. Testing of yarn abrasion. *Autex Research Journal*, 13(1), 2013.

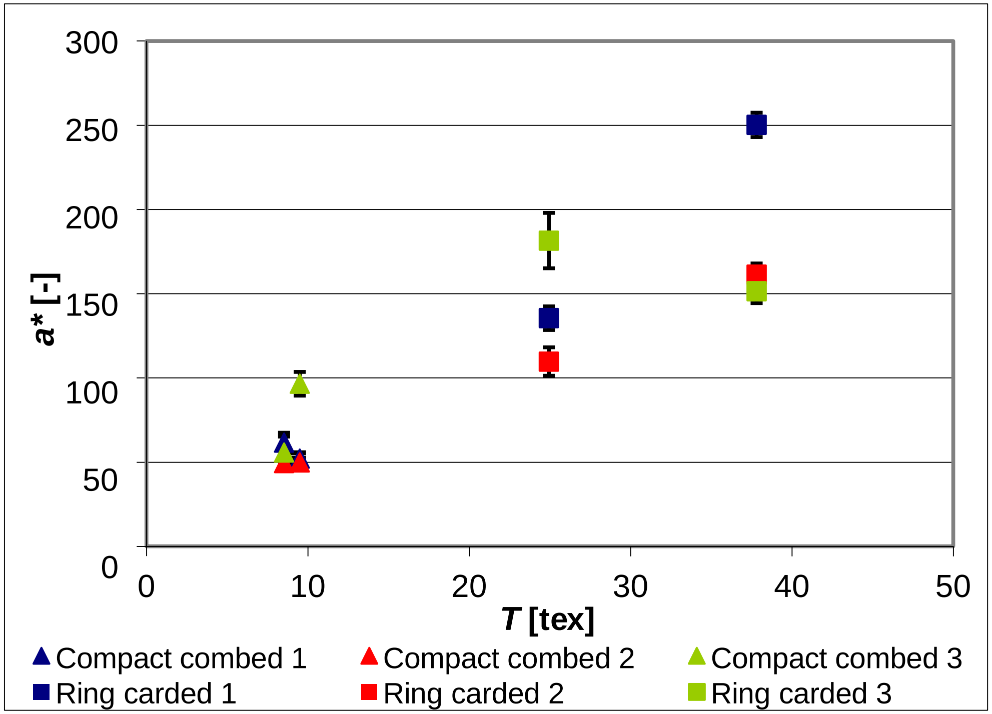
Discussion and conclusions – an example of results



F yarn relative strength, ε yarn elongation.

Krupincová G., Hatipoglu Y. Testing of yarn abrasion. *Autex Research Journal*, 13(1), 2013.

Discussion and conclusions – an example of results



*a** relative number of cycles need for yarn failure.

Krupincová G., Hatipoglu Y. Testing of yarn abrasion. *Autex Research Journal*, 13(1), 2013.

Questions for knowledge verification and repetition

- ✓ What are the basic principles related to friction? Explain the specifics of determining the friction of a length of fabric on a defined surface or fabric.
- ✓ Based on what principles does the fabric wear?
- ✓ How can the degree of wear / abrasion resistance of yarns or multifilamentes be defined and measured?
- ✓ What devices for monitoring the friction and wear resistance of yarns or multifilamentes do you know and on what principle do they work (brief description)?
- ✓ How can image analysis be used to assess the wear resistance of yarns or multifilamentes ?
- ✓ What factors affect the friction and wear resistance of yarns or multifilamentes and why?
- ✓ What are the requirements for yarns or multifilamentes with regard to their subsequent processing? Give examples…

Thank you for your attention…

Exercise 1: Various approaches to evaluation of textile.

Task assignment:

1. During the excursion, get acquainted with available laboratory equipment, the safety of working in the laboratory of KTT FT TUL and the available standards and internal methodologies.
2. Select the yarn to be analysed during the exercises and evaluate its yarn count.
3. Become familiar with the possibilities of image acquisition by NIS elements using microscope and macroscope.
4. Take longitudinal images with appropriate resolution, magnification (calibration) and recommended number of images for further processing.

What is practiced?

- ✓ Characterization of yarn structure: determination of yarn count, ev. twist.
- ✓ IA: Method of setting up NIS elements to capture magnified longitudinal views of yarn using a microscope and macroscope.

Workflow for a task:

Work in the laboratory, selection of yarn for experiments, partial data evaluation and preparation of longitudinal views of yarn in 1.5 hours.

Exercise 3: Relationship between yarn fineness, twist, twist coefficient, yarn diameter, mass non-uniformity, hairiness and yarn production technology, Uster®Statistic

Task assignment:

1. Refresh how the important parameters used for yarn quality description is defined and how can be measured via using testing equipment Uster®Technologies (T [tex], Z [m^{-1}], D [mm], CV [-], faults [km^{-1}], H [-], S_{12} [100 m^{-1}], S_3 [100 m^{-1}], F [$Ntex^{-1}$], ε [%]). Concentrate mostly on parameters measured by Uster®Tester.
2. Familiar yourself with Uster®Statistic. The information available at www.uster.com as well as in study material for this course.
3. Try to find, what kind of quality level is relevant for staple yarn characteristics – partial qualitative indicators and for whole staple yarn. (Evaluate it in respect to earlier measured data available in Uster®Tester 4 SX protocol on disk set to student individually.)
4. Try to find the 5 % a 95 % percentiles of Uster®Statistic for selected yarn characteristics measured by Uster®Tester, which will have the yarn produced from the same fibrous material, technology and final application purpose.
5. How will the quality of the yarn change in terms of the monitored parameters using the Uster®Tester, if the compared yarn has a lower fineness (from the same material composition, production technology and purpose of use)? Comment the results.
6. How will the quality of the yarn change in terms of the monitored parameters using the Uster®Tester, if the compared yarn is produced by a different technology (from the same material composition, fineness and purpose of use)? Discuss.
7. Evaluate the qualitative indicators for „Your“ yarn sample. Realize the measurement of yarn count T [tex], yarn twist Z [m^{-1}] via standard international methodology. Evaluate the quality of yarn from the point of view of yarn unevenness CV [%], number of faults, hairiness index H [-] and yarn diameter $2D\phi$ [mm] and realize the qualitative comparison via Uster®Statistic.

What is practiced?

- ✓ Character of a yarn structure: the relationship between yarn count, twist, diameter, yarn unevenness and hairiness.
- ✓ The way of evaluation of a yarn count T [tex] and a twist Z [m^{-1}]. The using of the Uster®Tester 4 SX for evaluation of yarn quality.
- ✓ Application of the Uster®Statistic.

Workflow for a task:

Individual data are at disposal in the form of the Uster®Tester 4 SX protocol and data from evaluation of "Your" yarn. Estimated processing time up to 1.5 hours including repetition.

Note:

For processing, use the yarn that you choose for experiments in the laboratory. For a possible extension of the work, there are protocols of yarns made of different material composition (100% CO, 100% VS, 100% PAN, 100% PES), different fineness (16.5 tex, 20 tex, 29.5 tex, 42 tex), produced by ring spinning, which are intended for weaving. Protocols can be downloaded from the shared google drive of the KVD course.

Exercise 3: Relationship between yarn fineness, twist, twist coefficient, yarn diameter, mass non-uniformity, hairiness and yarn production technology, Uster®Statistic

Task assignment:

1. Familiarize yourself with the definition of yarn diameter and estimate its value for the selected yarn (substance diameter D_s).
2. Familiarize yourself with the possibilities of yarn diameter evaluation using NIS Elements and internal methodologies.
3. Try working in NIS Elements for already taken and prepared images or longitudinal views of yarns processed by you.
   A. Subjective determination of yarn diameter using the length measurement function in the NIS Elements environment
   B. Determination of yarn diameter using subjective thresholding, morphological operations and determination of selected features of objects in the NIS Elements environment.
4. Compare obtained results of yarn diameter obtained by various ways and discus it.

What is practiced?

- ✓ Character of yarn structure: the relationship between yarn count, twist, diameter and hairiness.
- ✓ IA: image capturing, calibration, thresholding, conversion to binary form, use of morphological operations, work with image sequences, work with objects and fields, data export.

Workflow for a task:

Individual assignment for processing previously prepared images and yarn chosen for experiments. Scanning and partial evaluation including preparation within 1.5 hours.

Note: For processing, use the yarn you select for experiments in the laboratory. For possible expansion of the work, data of previously scanned yarns are available on the shared google drive of the KVD subject.

Tab. 1 Yarn data - prepared microscopic views 100% CO.

$T_{jm.}$ [tex]	**14,5**	**14,5**	**14,5**	**20**	**20**	**20**	**35,5**	**35,5**	**35,5**
a [ktex$^{2/3}$m^{-1}]	**70**	**85**	**100**	**70**	**85**	**100**	**70**	**85**	**100**
T_{exp} [tex].	14,61	14,78	14,60	19,66	19,71	19,99	35,38	35,82	35,79
	(13,79; 16,93)	(14,57; 14,99)	(14,39; 14,81)	(19,22; 20,1)	(19,37; 20,04)	(19,6; 20,38)	(34,99; 35,76)	(35,29; 36,34)	(35,37; 36,2)
$D_{ef.}$ [mm][1]	0,144	0,148	0,146	0,176	0,168	0,172	0,238	0,234	0,244
	(0,137; 0,151)	(0,140; 0,156)	(0,137; 0,155)	(0,169; 0,183)	(0,165; 0,179)	(0,153; 0,183)	(0,218; 0,258)	(0,218; 0,250)	(0,230; 0,256)
D_{UT4}[2][mm]	0,217	0,208	0,202	0,251	0,244	0,234	0,333	0,327	0,313
D_{dens}[3][mm]	0,1557	0,1508	0,1390	0,1764	0,1671	0,1612	0,2306	0,2280	0,2202
D_{cover}[mm][3]	0,1889	0,1838	0,1599	0,2109	0,1985	0,1920	0,2654	0,2751	0,2652

[1] effective diameter D_{ef} evaluated in accordance with Internal standard IS 22-103-01/01 Yarn packing density. Direct method and method Secant. Textile Research Centre, FT TUL 2004; [2] two-dimensional yarn diameter D_{UT4} measured by Uster Tester 4 SX; [3] cover and dense yarn diameter D_{dens}, D_{cover} evaluated in respect to the internal standard IS 22-102-01/01 Yarn diameter and yarn hairiness. Textile Research Centre, FT TUL 2004.

Exercise 7: Character of yarn structure – yarn diameter and yarn hairiness (longitudinal views)

Task assignment:

1. Familiarize yourself with the principle and definition of yarn hairiness detected with the Uster®Tester SX4.
2. Get to know the options for yarn hairiness assessment using NIS Elements and internal methodologies.
3. Try working in NIS Elements for already taken and prepared images. Perform an objective determination of yarn hairiness using subjective thresholding, morphological operations, and determination of selected object features in the NIS Elements environment.
4. Familiarize yourself with the measurement methodology using the Uster Tester 4SX device and possibly measure the selected yarn sample.
5. Compare the yarn diameter and hairiness results obtained in different ways.

What is practiced?

- ✓ Character of yarn structure: a different approach to the definition of yarn diameter and yarn hairiness.
- ✓ IA: image capturing, calibration, thresholding, conversion to binary form, use of morphological operations, work with image sequence, work with objects and fields, work with binary layers, data export, definition of own variable.

Workflow for a task:

Individual assignment for processing previously prepared images and yarn chosen for experiments. Scanning and partial evaluation including preparation within 1.5 hours.

Note: For processing, use the yarn you select for experiments in the laboratory. For possible expansion of the work, data of previously scanned yarns are available on the shared google drive of the KVD subject.

Tab. 1 Data of 100% CO yarn samples

$T_{jm.}$ [tex]	**14,5**	**14,5**	**14,5**	**20**	**20**	**20**	**35,5**	**35,5**	**35,5**
a [ktex$^{2/3}$m^{-1}]	**70**	**85**	**100**	**70**	**85**	**100**	**70**	**85**	**100**
$T_{exp.}$ [tex]	14,61	14,78	14,60	19,66	19,71	19,99	35,38	35,82	35,79
	(13,79; 16,93)	(14,57; 14,99)	(14,39; 14,81)	(19,22; 20,1)	(19,37; 20,04)	(19,6; 20,38)	(34,99; 35,76)	(35,29; 36,34)	(35,37; 36,2)
D_{UT4} [1][mm]	0,217	0,208	0,202	0,251	0,244	0,234	0,333	0,327	0,313
D_{dens}[2][mm]	0,1557	0,1508	0,1390	0,1764	0,1671	0,1612	0,2306	0,2280	0,2202
D_{cover}[2] [mm]	0,1889	0,1838	0,1599	0,2109	0,1985	0,1920	0,2654	0,2751	0,2652
H[1][-]	4,04	3,75	3,78	4,26	4,12	4,06	4,89	4,68	4,66
$l_{1\,dens}$ [2] [mm]	0,0099	0,0081	0,0087	0,0058	0,0086	0,0061	0,0024	0,0023	0,0089
$l_{2\,dens}$ [2][mm]	0,0181	0,0183	0,0141	0,0164	0,0278	0,0156	0,0147	0,0177	0,0245
$l_{c\,dens}$ [2][mm]	0,0207	0,0222	0,0137	0,0229	0,0323	0,0207	0,0238	0,0313	0,0303
$l_{1\,covers}$ [2][mm]	0,0076	0,0065	0,0066	0,0044	0,0067	0,0044	0,0021	0,0020	0,0089
$l_{2\,cover}$ [2][mm]	0,00004	0,00002	0,00006	0,00003	0,00006	0,00008	0,00004	0,00007	0,00007
$l_{c\,cover}$ [2][mm]	0,0115	0,0127	0,0085	0,0126	0,0232	0,0119	0,0128	0,0158	0,0157
S_{12}[3][-]	943	1201	1575	1725	2236	2183	1646	783	808
	(876; 1010)	(1069; 1333)	(1410; 1740)	(1629; 1820)	(1980; 2493)	(1992; 2374)	(1531; 1761)	(734; 831)	(795; 857)
S_3 [3][-]	41	69	49	158	146	101	234	61	45
	(23; 60)	(47; 90)	(36; 62)	(141; 174)	(116; 176)	(85; 116)	(222; 246)	(48; 73)	(26; 64)

[1] two-dimensional yarn diameter D_{UT4} and hairiness index H measured by Uster Tester 4 SX; [2] cover and dense yarn diameter D_{dens}, D_{cover} and integral hairiness parameters evaluated in respect to the internal standard IS 22-102-01/01 Yarn diameter and yarn hairiness. Textile Research Centre, FT TUL 2004, summation hairiness criteria S_{12}, S_3 evaluated via Zweigle G 567 in accordance with IS 42-102-01/01 Evaluation of yarn hairiness. Textile Research Centre, FT TUL 2009.

Exercise 8: Character of the surface structure of the yarns –wrapper (belt) fibers of open end rotor yarn.

Task assignment:

1. Familiarize yourself with the possibilities of assessment of wrapper fiber parameters of open end rotor yarn via using NIS Elements and internal methodologies.
2. Get to know the concept of a wrapper fiber subjective evaluation, look at the prepared pictures and try to identify the wrapper fibers.
3. Determine selected characteristics of wrapper fibers of open end rotor yarn using interactive measurement in the NIS Elements environment.
4. Try working in NIS Elements for already captured images and try to sort the identified wrapper fibers into selected groups.

What is practiced?

- ✓ Character of yarn structure: possibilities of describing the surface structure of open end rotor yarn, identification and quantification of wrapper fibers.
- ✓ IA: work with big images, taxonomy, saving of images including annotation layer, data export, possibly scanning of big images.

Workflow for a task:

Work with already prepared images available at the shared disk shared google drive of the KVD subject. Partial evaluation including preparation within 1.5 hours.

Exercise 9: Character of fancy and hybrid yarns - determination of selected quality characteristics

Task assignment:

1. Familiarize yourself with the possibilities of fancy and hybrid yarn via NIS Elements and internal standards.
2. Try working in NIS Elements for already taken and prepared big images.
3. Eventually try to scan the big images for your own sample of fancy or hybrid yarn.

What is practiced?

- ✓ Character of yarn structure: wrap angle of surface fibers, covering ability of wrap fibers.
- ✓ IA: image capturing, thresholding, conversion to binary form, use of morphological operations, work with binary layers, work with fields and ROI, data export.

Workflow for a task:

Work with already prepared images or eventually scan big images of fancy or hybrid yarn in a laboratory. Scanning and partial evaluation including preparation within 1.5 hours.

Exercise 11: Quality of yarns in relation to the processed product – friction and abrasion of yarns.

Task assignment:

1. Familiarize yourself with the possibilities of evaluating yarn friction and abrasion resistance of yarns using internal methodologies and the Zweigle G 522, the Lawson Hemphil and NIS elements.
2. Evaluate the number of cycles necessary for "Your" yarn destruction during abrasion resistance text using Zweigle G 522.
3. Evaluate the coefficient of friction and amount of lint generation for "Your" yarn by Lawson Hemphil.
4. Finally, try to measure the change in yarn diameter during the yarn abrasion test by Zweigle G 522 according to the internal standard IS using NIS elements.

- The method of determining the diameter before and after abrasion is based on the previous exercises. Use your experience... You can do the evaluation for previously taken images or your own longitudinal views of the yarn before and after abrasion.

What is practiced?

- ✓ Characterization of yarn structure: evaluation of yarn abrasion resistance, friction coefficient and lint generation, eventually evaluation of yarn diameter change due to abrasion.
- ✓ IA: image capturing, eventually capturing of big images, thresholding, conversion to binary form, use of morphological operations, work with fields and ROI, data export.

Workflow for a task:

Work at a laboratory with yarn selected for experiments. Potential extension of task with already prepared images of yarn before and after abrasion. Scanning and partial evaluation including preparation within 1.5 hours.