Geometric Characteristics of Fibers

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Fiber Properties

- Chemical Composition
- Technology of production

Geometric properties	• Length, Fineness, Shape of cross section
Mechanical properties	• Strength, Elongation at break, Modulus, Stiffness, Recovery
Thermal and Thermomechanical properties	• Melting point, Thermal resistance, Transition temperatures, Loss angle, Loss modulus
Electrical properties	• Static charge, Dielectric behavior, Tribology, Insulation, Conductivity
Surface properties	• Roughness, Adhesion, Wetting, Wicking, Abrasion, Aging

Chemical Resistance, Weather resistance, Flame resistance……

Geometrical properties

- Fiber flexibility is dependent on the tensile modulus E and inertia moment I. For circular fiber having diameter d is

$$I = \pi * d^4 / 64$$

- Measure of flexibility is parameter

$$F_e = 1/(M*R),$$

where M is bending moment and R is fiber radius of curvature. For beam bending is $M*R = E*I$. For circular fibers with diameter d is

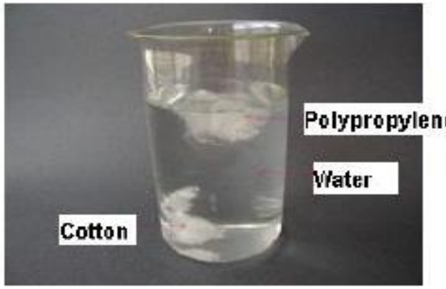
$$F_e = \frac{64}{E * \pi * d^4}$$

Geometrical properties

- Fiber having higher modulus E will have the same flexibility if the diameter will be smaller. For chosen flexibility fiber diameter is indirectly proportional to the fourth root of modulus i.e. $1/E^4$.
- Flexibility is indirectly proportional to fourth power of thickness(diameter). For thickness higher than 40 µm, fibers are too stiff (rigid) and are not suitable for staple yarn formation.

Natural fibers thickness is around 10 – 40 µm
Synthetic fibers thickness is around 10 – 25 µm

Fineness



Fineness (linear density) *T* [tex] is defined as weight *m* [g] of fiber having length *l*=1km.

$$T = \frac{m}{l} = \frac{l * S * \rho}{l} = S * \rho$$

S – Area of cross section
ρ – Fiber (volume) density

For the same fineness *T* is lower fiber diameter for materials having higher density *ρ.*

Fiber density of ;
Classic fibers - 900 – 1600 kg/m^3
Ceramic fibers – 2000 – 4000 kg/m^3
Metal fibers – 2000 – 10000 kg/m^3

Finer fibers lead to:

- More even yarns
- More cohesion within the yarns due to greater surface area
  - Achieve more strength with less twist
- Less fiber stiffness
  - Better drape and softness of fabrics (e.g.: cashmere and silk)

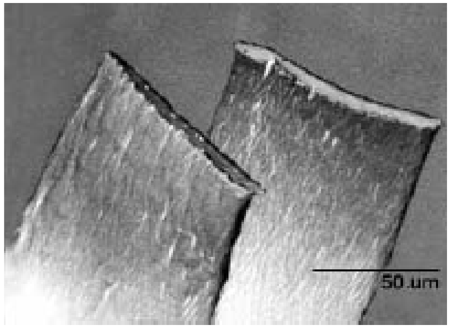
Fineness

Fine – 1 dtex
Extra fine – 0.5 dtex
Super fine – 0.1 dtex

Chemical fibers around 1 – 5 dtex

Fiber	Thickness *d* [μm]	Fineness standard *T* [dtex]
cotton (S.I.)	10	1
cotton (India)	18	3
wool (merino)	22	5
wool (Asia)	43	19
Natural silk	12	1,6
flax (fine)	10	1
flax (coarse)	27	7

Surface area



- **Surface area** S_p, is defined as are per fiber mass. For circular fibers having radius r is

$$S_p = \frac{2\pi * r * l}{\pi * r^2 * l * \rho} = \frac{2}{r * \rho} = \sqrt{\frac{4 * \pi}{T * \rho}}$$

- For non circular fibers is possible to use information about perimeter O_v and cross section area S_v

$$S_p = \frac{O_v * l}{S_v * l * \rho} = \frac{O_v}{S_v * \rho} = \frac{4 * \pi}{O_v * c * \rho} = \frac{4 * \pi(q+1)^2}{O_v * \rho}$$

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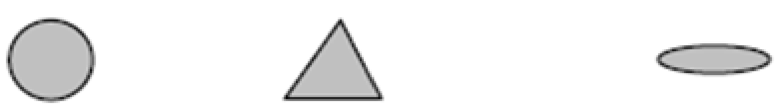
$$c = \frac{S_v}{S_e} = \frac{S_v * 4 * \pi}{O_v^{\ 2}} = \frac{1}{(q+1)^2}$$

Cross section characterization

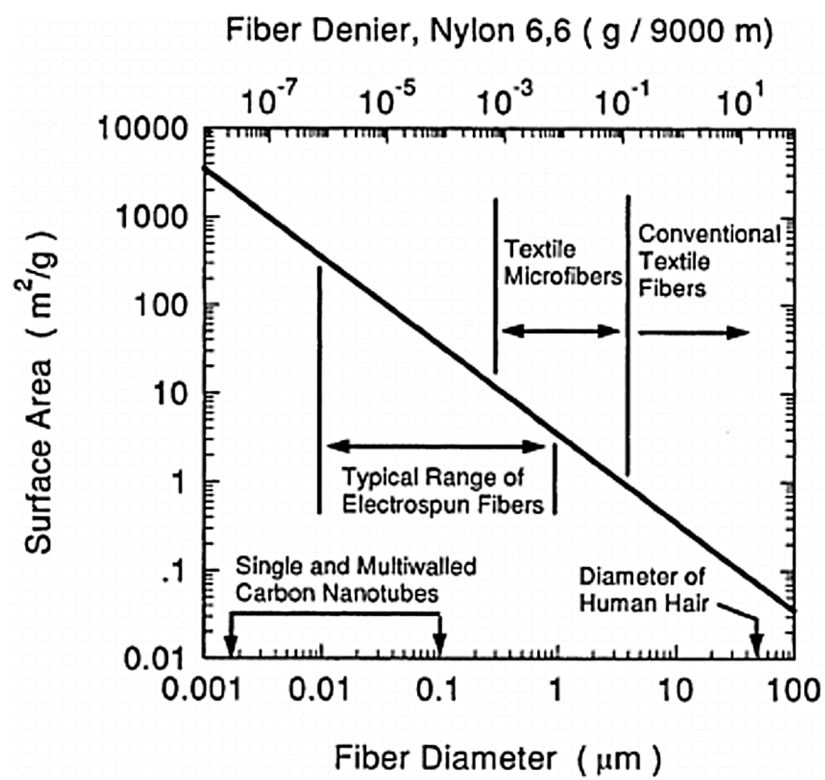
- **circularity** c is ratio of fiber cross section area S_v and cross section area of equivalent circular fiber S_e with the same perimeter
- For square cross section

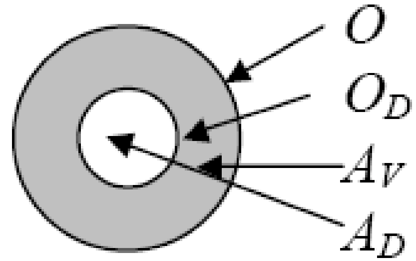
  $c = \pi/4 = 0{,}785.$
- For rectangular cross section

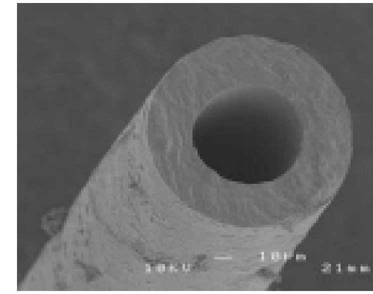
$b=2*a$ is $c=0{,}698.$



$q = 0$ $q = 0{,}09–0{,}12$ $q = 0{,}45–0{,}5$







Hollow Fiber

O outer fiber perimeter, O_D hole perimeter, A_D hole area, A_V fiber area and $A = A_V + A_D$ total area. For hollow fibers the fullness coefficient F_p is defined as

$$F_p = \frac{A - A_D}{A}$$

<u>For circular fiber</u>

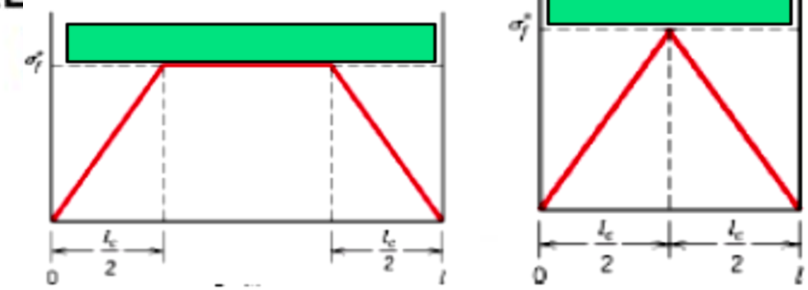
$$F_p = \frac{4 * \pi (A - A_D)}{O^2} = \frac{4 * \pi * A_V}{O^2}$$

Maturity coefficient

$$Z = \frac{A_V}{A}$$

$$Z = \frac{A_V 4}{\pi d^2} = F_p$$

critical length

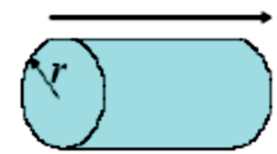


Fiber Length

- According to spinnability, the critical length is around 10mm.
- Critical length L_c is the fiber length in matrix for which the force required to retain fiber on matrix F_s is equal to fiber strength $F_{v.}$

$F_s = A_i * \tau$ $\qquad$ $F_v = A_v * \sigma_v$

$$\sigma_f = \int_0^{\frac{l_c}{2}} \frac{\tau \cdot 2\pi r dx}{\pi r^2} = \int_0^{\frac{l_c}{2}} \frac{2\tau}{r} dx$$



A_i is interface area between fiber and matrix

A_v is fiber cross section area

τ is shear stress between fiber and matrix

$$L_c = \frac{r * \sigma_v}{2 * \tau}$$

- Fibers with length higher than Lc have tendency to break and their strength is fully exploited.
- Fiber with length lower than Lc have the tendency to be removed from matrix.