Subsequent operations on the model after printing

Petr Keller – post processing for FDM and PolyJet technologies

2020

Post-processing – finishing the model in general

- This is the last part of the production parts using AM, each step depends on the technology used
- removing parts from the device, some methods need to wait a longer time than it can be made part accessible to operator
- removal of the surrounding material, in particular technologies based powders or photopolymers
- subsequent processing - tempering, hardening part by UV, impregnation part with other substance to increase its strength, etc.
- removal support (if used)
- finish part - cutting, sanding, staining, painting, electroplating, etc.

Post-processing – finishing the model for FDM

Printer Dimension sst 768, after printing:

- removing parts from the device can immediately after printing
- removal of support structures
- final finish

Post-processing – finishing the model for FDM

Removal of support structures

For older systems had to be removed support mechanically.

The machine Dimension SST 768 can used soluble support. After building the model and with supports immersed in a bath of sodium hydroxide heated at 70°C. Support is dissolved to leave a clear model.

This way you can build a permanent and movable assemblies – parts must be modelled with appropriate clearances (min. 0,25 mm both side). These gaps are filled during printing by support material, which is then dissolved and left movable model.

Post-processing – finishing the model for FDM

Final finish

Due to the relatively rough layers of FDM technology is finish part required, particularly as regards the prototypes used to assess the appearance or when parts are used as a master model for the technology of casting in a vacuum.

Depending on the building material can be machined parts, grind, stain, etch ("homogenize") surface …

Post-processing – finishing the model for FDM

Example finishing parts filler, sanding, painting

filling and painting part after printing at Dimension SST 768 - ABS material

final finishing
(filling -> grind -> painting)

Post-processing – finishing the model for FDM

Finishing parts filler, sanding, painting

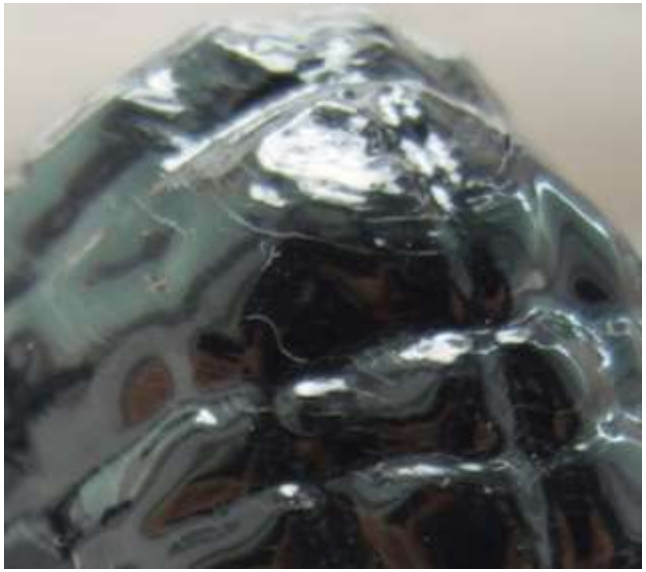
This way the final finishing is rather laborious, it is possible thus to finalize a relatively complicated shape parts.

A certain disadvantage is the loss of dimensional accuracy of the parts. It is very dependent on the human factor. the outer dimensions are usually larger of approximately 0.1 mm on each side, the internal dimensions of the same size smaller. With this to be reckoned with assemblies parts, preferably prior to printing and parts modelled with appropriate clearances.

Post-processing – finishing the model for FDM

Example finishing parts surface etching with acetone

original part surface printed on the machine Dimension SST 768 from ABS material



part of that surface after etching with acetone - there coalescence layers

Post-processing – finishing the model for FDM

Finishing parts surface etching with acetone

This is a relatively simple way of final modification parts made of ABS (this material is dissolved in acetone). Parts were allowed some time to operate vapor acetone in a closed container. Vapor concentration can be influenced by temperature, affecting the skin term exposure to vapors.

It is quite essential provisions of both parameters correctly, otherwise the loss of precision part or to destroy it!

This procedure also has a major disadvantage in the solvent - problems of ecology, labor and the environment!

Post-processing – finishing a model for PolyJet

Printer Objet Connex 500, after printing:

- removing parts from the device can immediately after printing
- removal of support structures
- subsequent processing of certain materials
  (e.g. Vero Clear – hardening part by UV radiation for better optical properties, ABS like – temperation etc.)

Post-processing – finishing a model for PolyJet

Removal of support structures

Washing (blasting) supporting material by pressure water with a special equipment, then it is usually necessary part cleaned from the remnants of supports by mechanical way, eventually, in sodium hydroxide solution in the ultrasonic bath and washed with water.

Post-processing – finishing a model for PolyJet

Sample surface quality from printer Objet Connex 500

Due to the small thickness of the layers of the technology (0.016 to 0.032 mm) is usually not necessary to further parts of surface treated.

Post-processing – finishing a model for PolyJet

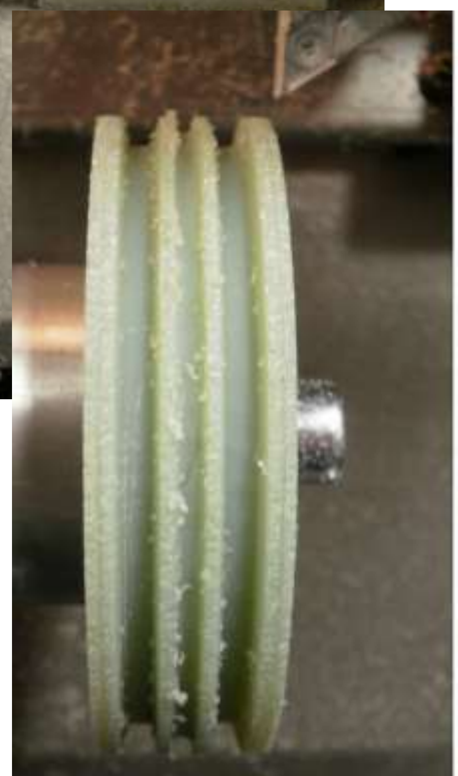
Any other surface treatments of parts

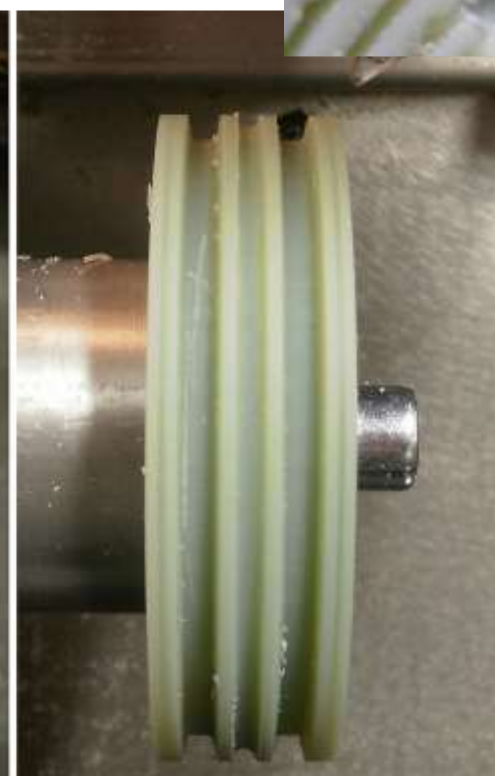
Range of materials (materials of Vero, ABS Like etc.), if necessary may further grind and polish or machined.

During these operations it is necessary to comply with certain conditions so that the cutting force was relatively small - photopolymers after curing are generally brittle and tend to break out, especially at the edges.

Post-processing – finishing a model for PolyJet

Machining of ABS Like





Optimal cutting conditions:

f_n = 0,1 [mm/rev]

a_p = 0,2 [mm]

v_c = 150 [m/min]

Vacuum casting technology

Petr Keller – complementary technologies for additive manufacturing

2020

Introduction of technology

Vacuum chamber MK-Mini

- chamber control is manual
- accessories include a pair of tempering furnaces MKT-1
- the maximum mould dimensions for this system are 450x470x400 mm and the maximum casting weight is 1.4 kg
- the volume of tempering furnaces is 108 l and the temperature range is +30 to +220°C,

  serves for preheating of casting resins and moulds before casting and subsequently for hardening and tempering of castings and also for storage of open containers with casting resins

The vacuum casting system offers a simple method of producing plastic prototypes without the need to produce expensive metal tools. A physical model, or a model made by the AM method, is used to create a soft mould.

Prototyping using vacuum casting technology

- designed for the production of a small series of prototype components

- the so-called Master model is needed – an existing component, manufactured in a different way, often using AM technologies

- the first step is the production of a silicone mold based on the Master model

- followed by the production of castings from this mold, it is possible to use polyurethane and other resins, wax and other materials

- the final phase is the cleaning of castings and molds and preparation for the next casting

Manufacturing of the silicone moulds

1. Orientation of the model and production of the mould half from modelling clay:

A more complicated procedure is shown here – with the help of modelling clay is prepared half of the future mould. Then is necessary repeat the whole process of mould manufacturing again for the second half.

Manufacturing of the silicone moulds

2. Manufacturing of the mould frame and completion of the inlet system:

Manufacturing of the silicone moulds

3. Preparation of silicone resin:

For polyurethane resins, the so-called addition silicone (two-components) is used, for waxes, condensation silicone (one-component, solidifies on the basis of air humidity) is more suitable.

Manufacturing of the silicone moulds

4. Silicone vacuuming – removing of air bubbles:

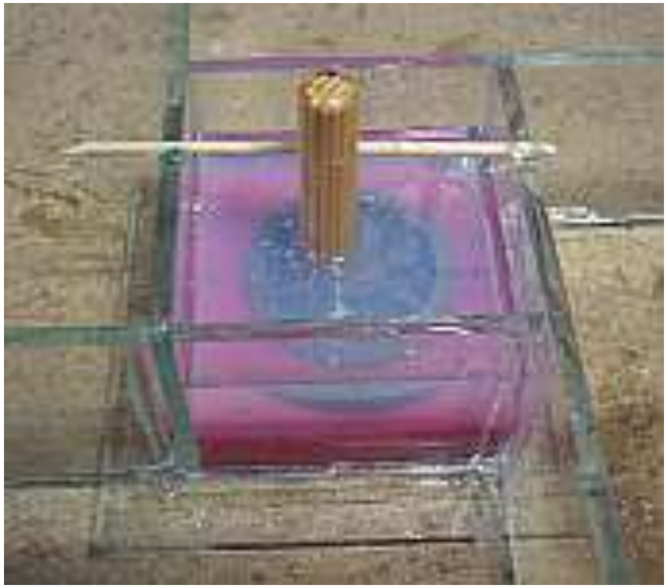
Why is ambient pressure reduction used to remove air bubbles dispersed in the silicone (or later in the casting resin)?

(What law of physics is used here?)

The workability of addition silicones is around 60 - 90 minutes, it also depends very much on the temperature!

Manufacturing of the silicone moulds

5. Casting of the half of the mould with silicone at normal pressure:



The next step can be done only after the silicone has completely solidified, for addition silicones it is about 12 hours, depending on the temperature.

Manufacturing of the silicone moulds

6. Removing the frame and cleaning half of the mould:

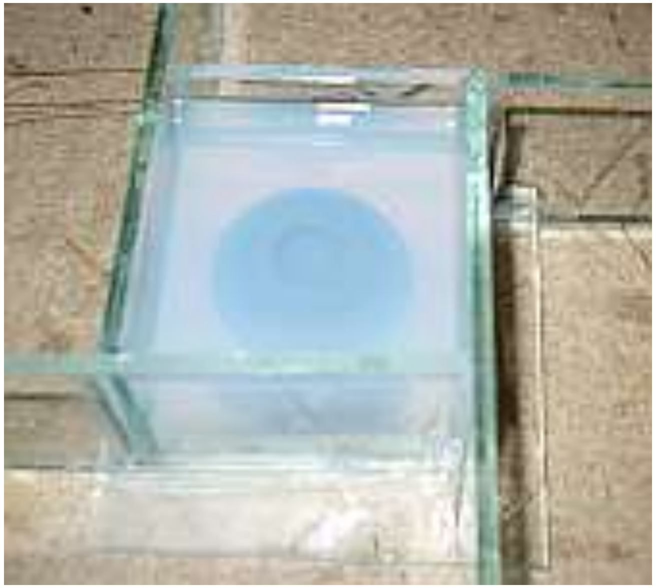
Caution, during the modelling clay removing, the master model must not be released from the silicone, otherwise the mould will be degraded - castings may not be as accurate.

Manufacturing of the silicone moulds

7. Rebuilding the mould frame and separating the silicone:

Manufacturing of the silicone moulds

8. The second half of the mould is formed in the same way as in the previous procedure:



Manufacturing of the silicone moulds

9. Final cleaning of the mould and creation of the exhaust system:

Because the level of vacuum in the chamber during casting into the mould is about 95%, the remaining air must leave the mould - the exhaust system is most often done by punching small holes in the upper edges of the part, for example, using a modified injection needle.

The part casting

1. Preparation and closing of the mould:

To close the mould are used the pins; for larger moulds, it is a good idea to use an auxiliary frame or rigid pad to hold the shape of the mould during casting.

The part casting

2. Weighing and preheating of individual resin and mold components:

The mixing ratios of the components, the temperature and the processing times are given in the material sheets for the individual resins, which vary greatly according to the type of resin.

The part casting

3. Vacuuming of resin, the casting process takes place in a vacuum:

In the evacuation phase, each of the components is in its own cup, in the case of this chamber the cups are manually operated outside the chamber by means of a lever system.

The part casting

4. Mixing of resin components:

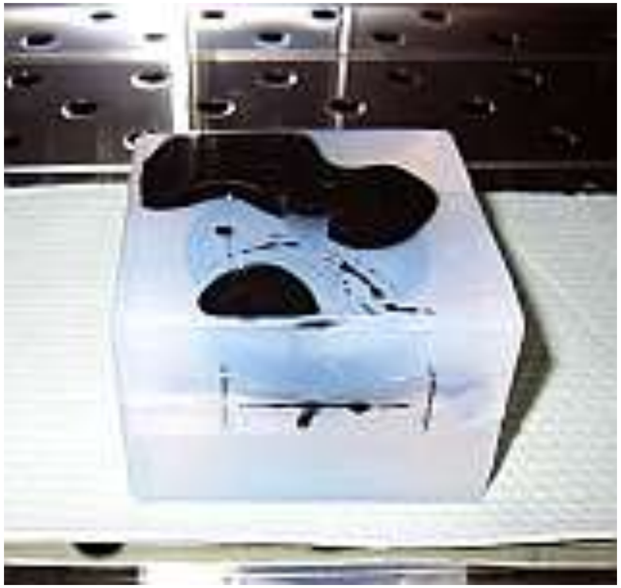
After pouring of both two components into a larger cup, they are mixed for a specified time by the electric mixer.

The part casting

5. Casting of the mould in vacuum:

The part casting

6. Curing of the casted part:



Immediately after casting, the vacuum is removed from the chamber. The mould with the casting is transferred to a tempering furnace set to the temperature according to the material sheet of the resin. Furthermore, the cups and mixer have to be cleaned of resin residues.

The part casting

7. Opening of the mould, possible tempering and cleaning of the part:

Some resins need to go through the so-called tempering - to achieve the final properties – heating the part to the prescribed course of temperature over time. The mould can be prepared for casting another part.

It is also possible faster - see next

- usually a more laborious division of the mould

- there is a risk of damage to the mould and the master model

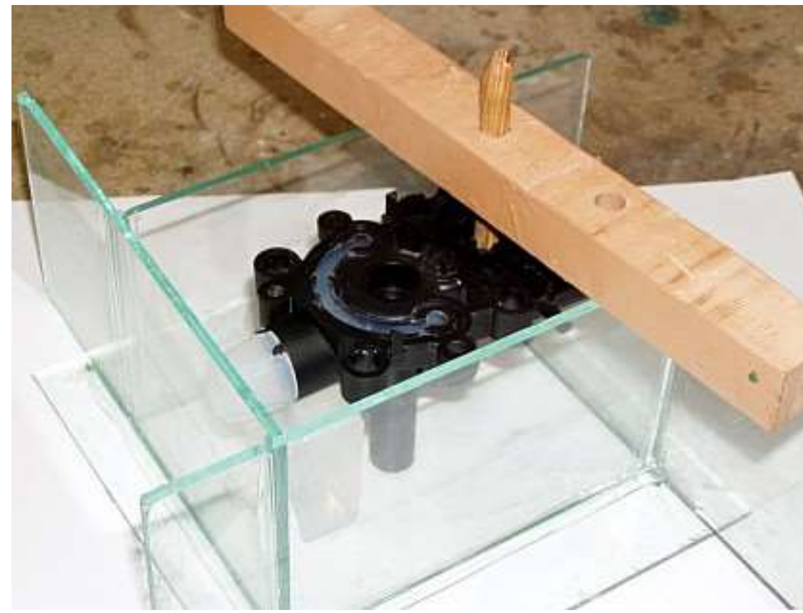
- but less time consuming - the whole mould is cast at once and then "surgically" cut

- due to the less time consuming, we will use the following procedure in the practical exercise

- we will need a master model for this exercise - do you have anything relatively small to create a homogeneous copy? (e.g. a broken plastic part that no longer has the required strength after gluing)

Manufacturing of the silicone moulds – 2nd way

Prepared master model



the mould frame

Now a faster procedure is shown – the master model is filled with silicone all at once, after the silicone has solidified, the mould is then cut with a scalpel.

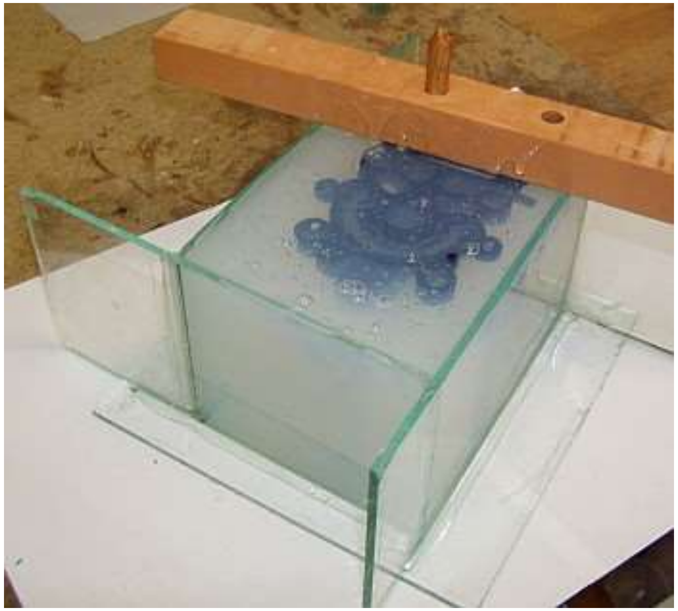
Manufacturing of the silicone moulds – 2nd way

weighing the amount of silicone

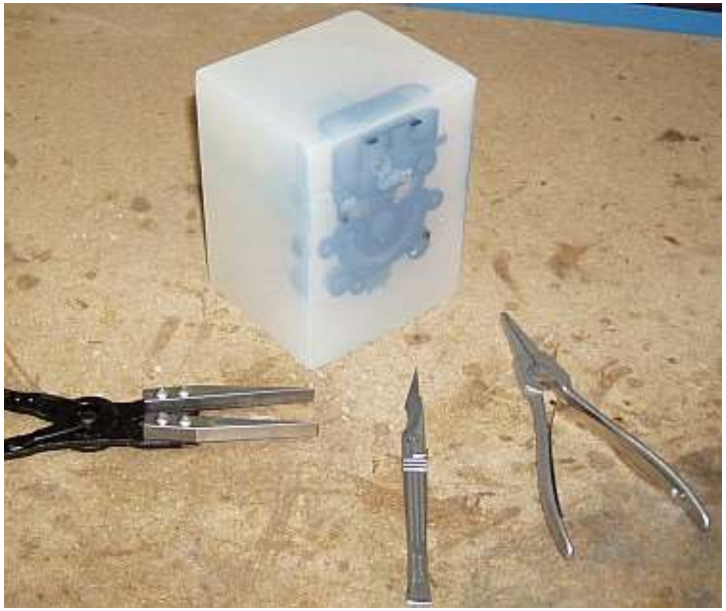
mixing the silicone resin components

vacuuming

Manufacturing of the silicone moulds – 2nd way



casting silicone into the mould
12 hours solidification



silicone mould with master
model inside as one block

Manufacturing of the silicone moulds – 2nd way

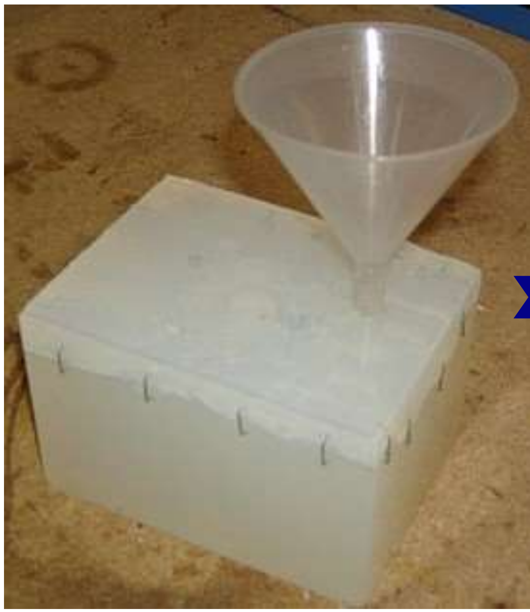
cutting moulds

Manufacturing of the silicone moulds – 2nd way

divided mould

creating exhausts

For completeness - the process of casting a part again

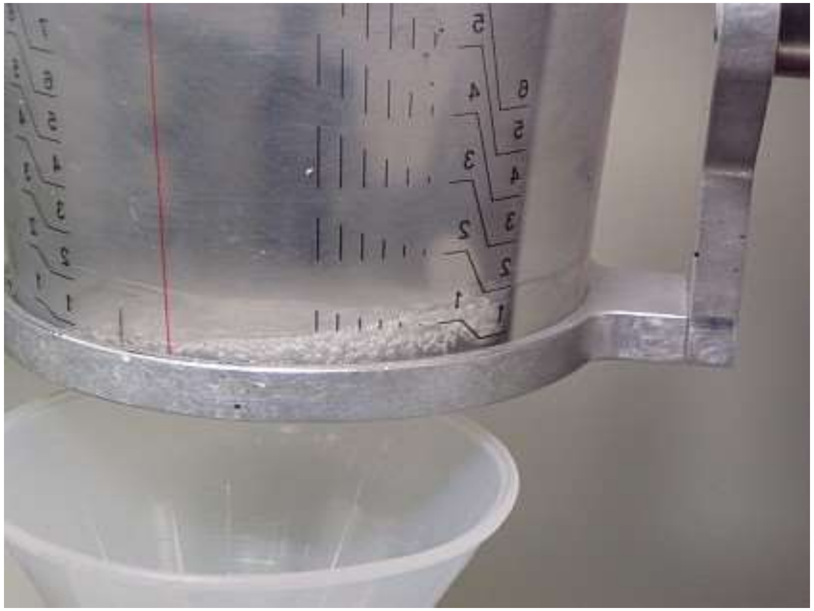


closed mould

weighing of casting resin components

vacuuming in the chamber

The part casting

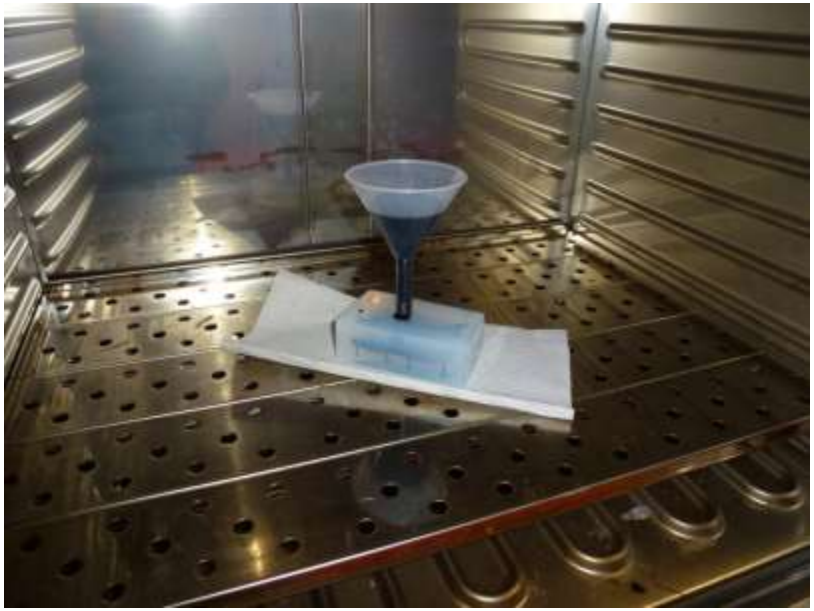


air bubbles

mixing the two resin components in vacuum

The part casting

casting resin into the mould



curing in oven

The part casting

demoulding

raw casted part

The part casting

finished casted part

Advantages of vacuum casting into silicone moulds

- easy and relatively fast reproducibility of prototype parts of any shapes and partly also colours
- ability to reproduce in detail even the smallest details and textures multiple use of silicone mould - cheaper production of prototype series of parts
- using a "soft" silicone mould, parts with negative shapes can be formed, or the mould can be additionally divided by cutting
- using various materials of casting resins, it is possible to imitate various conventional materials (from soft rubber to various hard and tough plastics, or it is possible to use and powdered metal fillers)

Disadvantages of vacuum casting into silicone moulds

- difficult and time consuming work
- some components of resins are harmful to health or have a negative effect on the environment

News, near and distant future in the field of additive technologies

Petr Keller

2020

Injection Moulding Application

Injection moulding is the most commonly used manufacturing process for producing high precision, complex plastic parts.

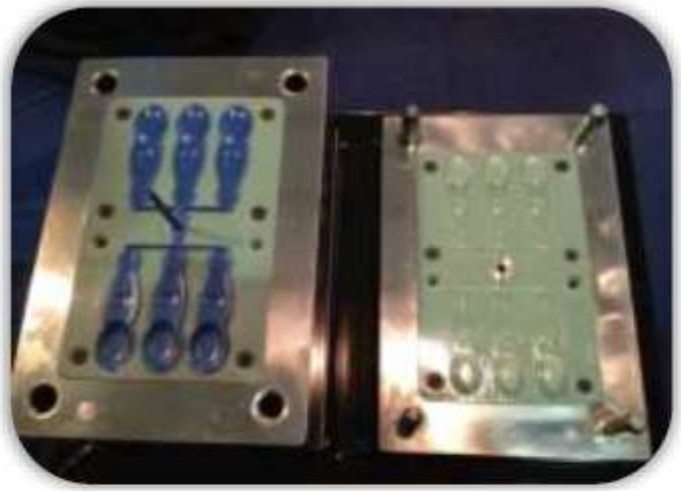
Traditionally… tooling for injection moulding is a slow and expensive process

Printing the mould with PolyJet technology using ABS-like material allows:

- Short series production
- Drastically reduced time and costs

Injection Moulding Application

Material injected: PP (Polypropylene) at 220-230°C

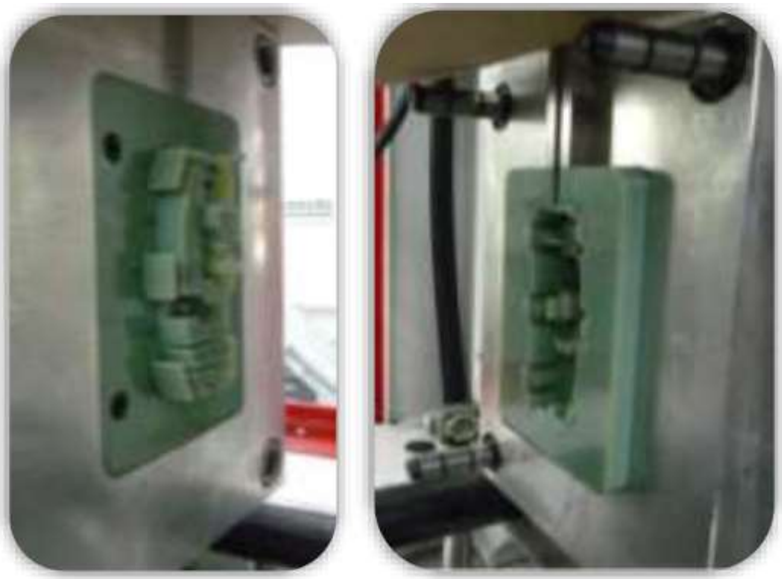


600 parts (100 injection cycles) were successfully injected

No degradation to the mould, still totally functional

Injection Moulding Application

Material injected: PE (Polyethylene) at 190°C

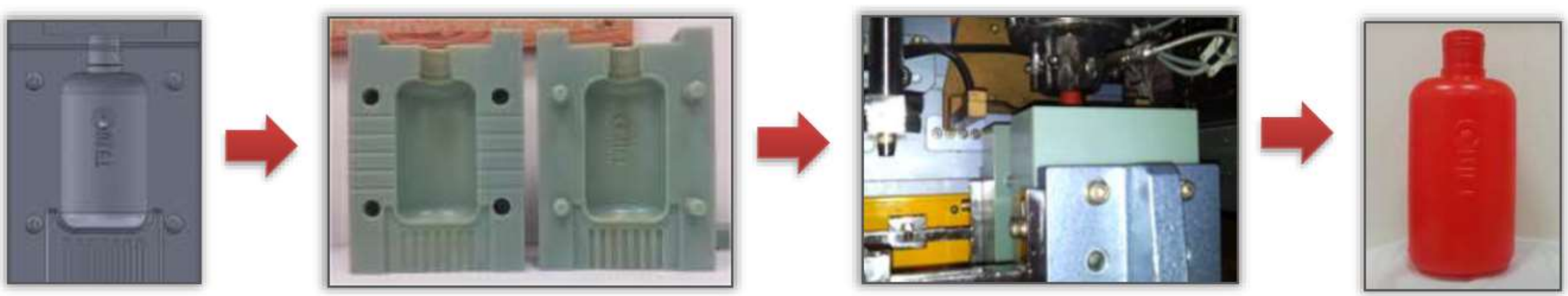


Number of parts: 10, Mould is available for additional use

Blow Moulding Application

What is Blow Moulding?

- Blow moulding is a process that produces hollow plastic parts, mainly bottles and containers.
- It is based on inflating preheated plastic against a mould in the desired shape.
- Many of the products that we use in our day-to-day life are blow moulded, such as drink bottles, containers, toys, even the fuel tanks in our cars.



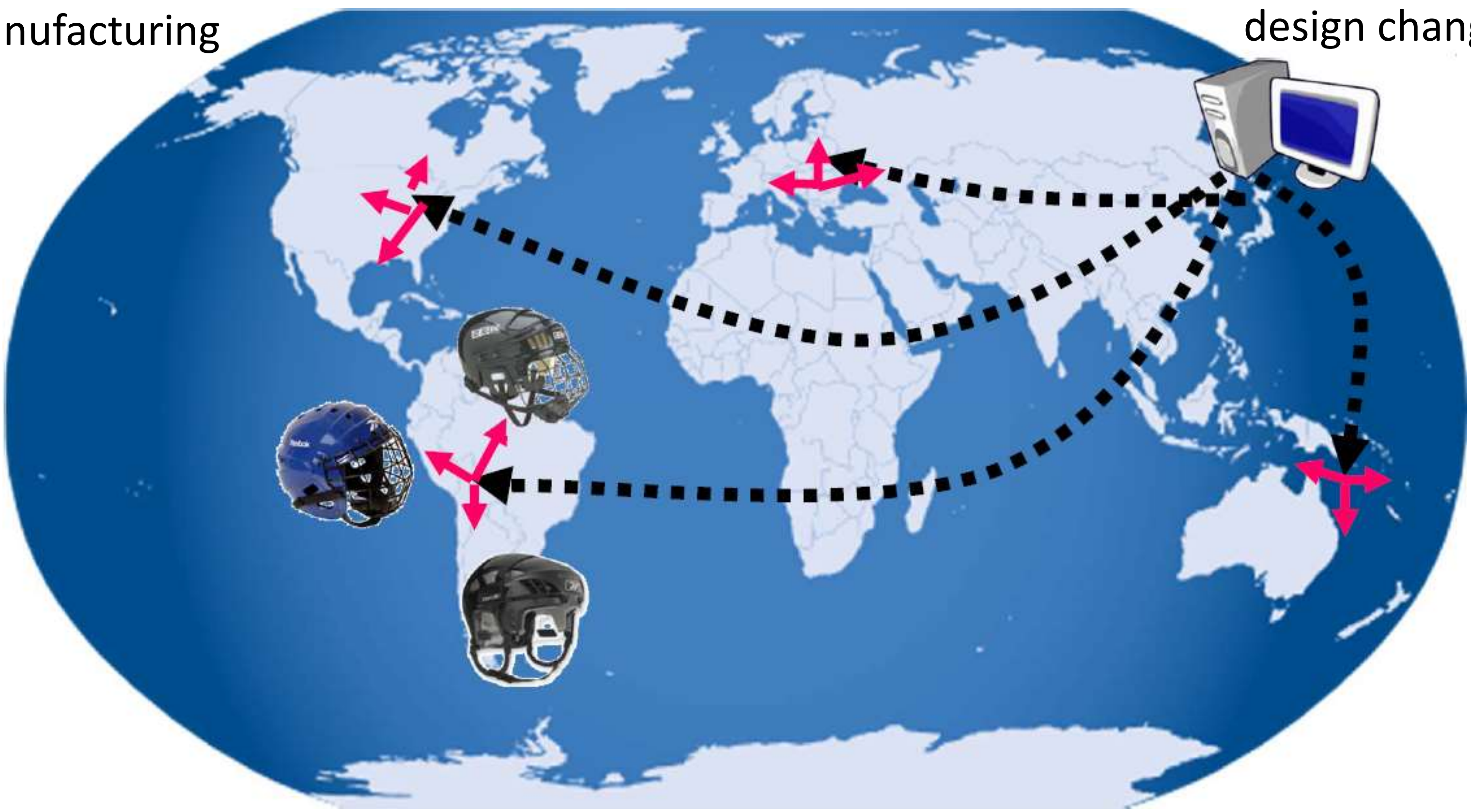
3D-Printing can change the world:

3D-Printing as Production Concept

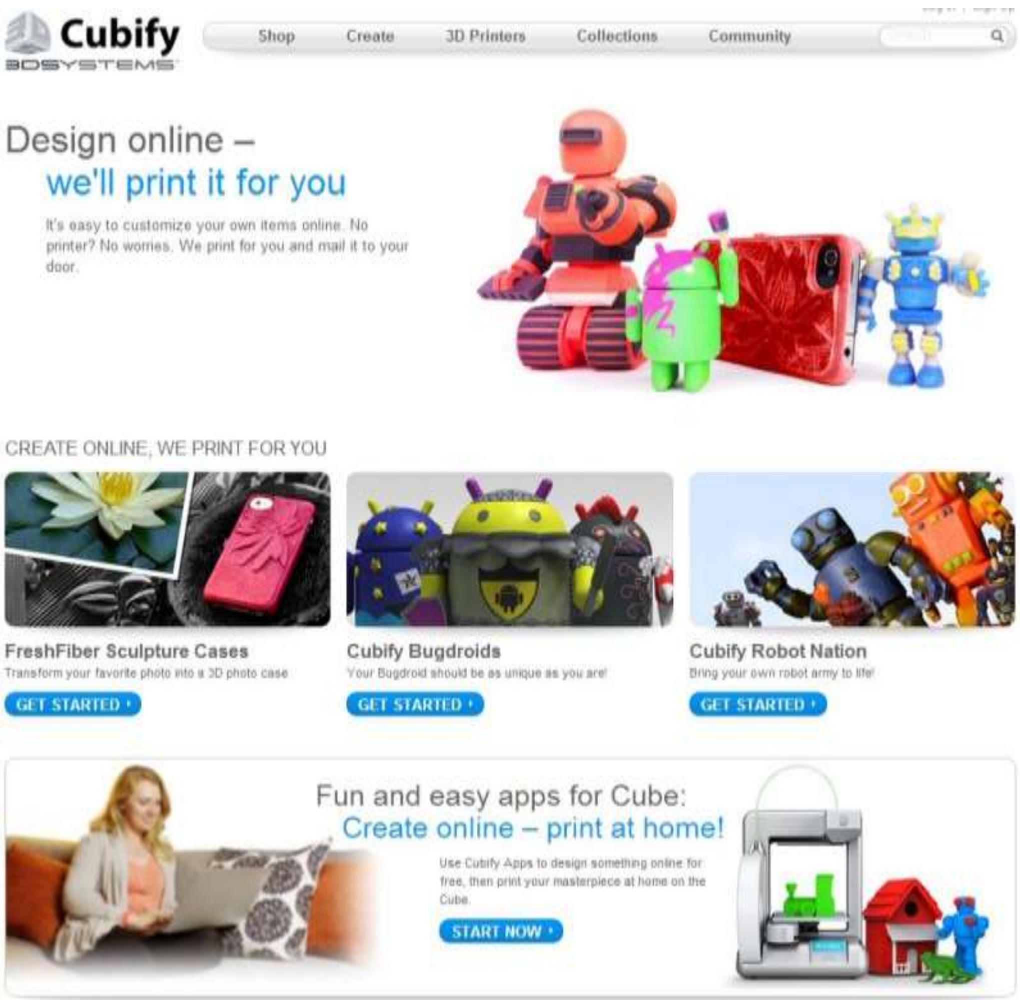
(10 – 20 year horizon)
Currently 3D-Printing is minute fraction of total production

Global network
Local manufacturing

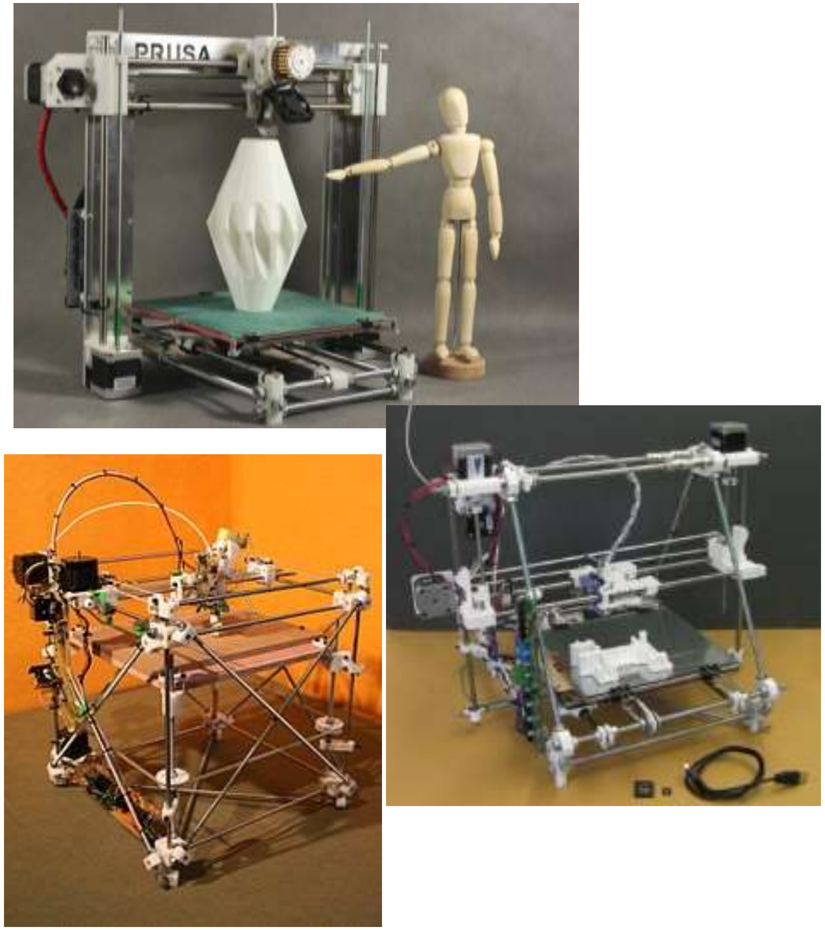
Fast, cost effective
design change



Present and future of 3D printing



Hobby 3D printers



Present and future of 3D printing

Dentistry Applications - Invisible teeth aligners

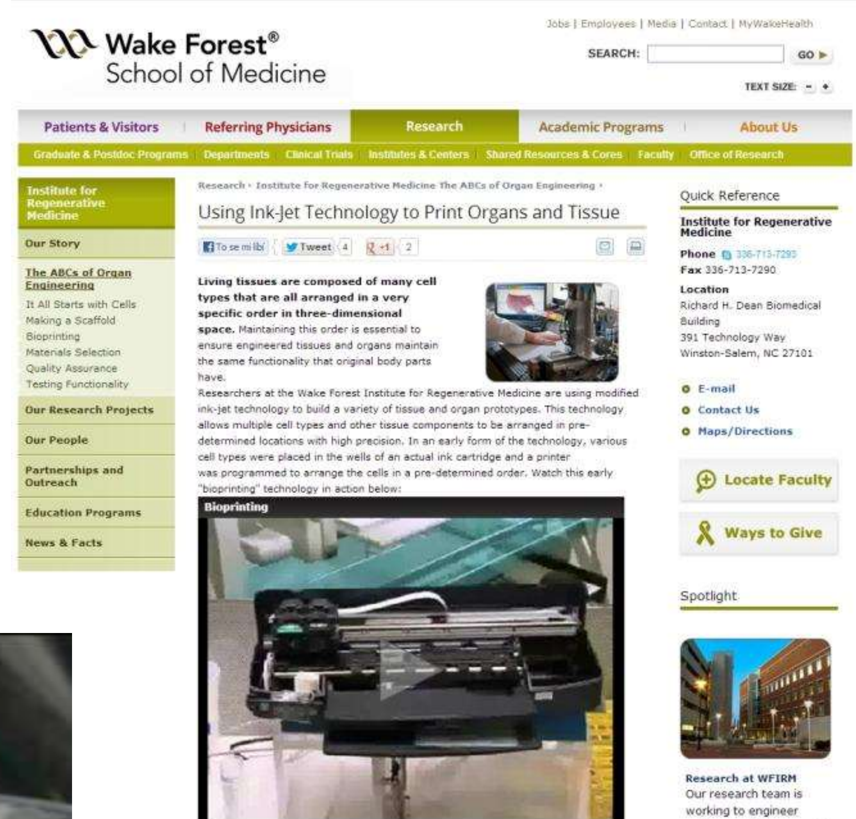
source: www.invisalign.com

Present and future of 3D printing

Individual hearing aid shells
Manufacturing from 1 week to 1 day

Present and future of 3D printing

Biomedicine



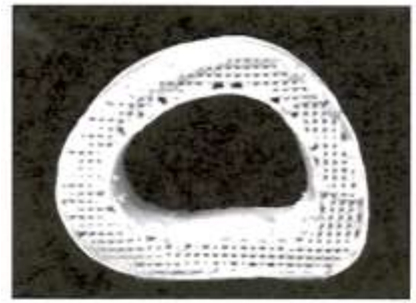
Present and future of 3D printing

Biomedicine

Sorry, article about 3D printing of artificial bones only in Czech.

S novým bionanomateriálem lze 3D tisknout lepší umělé kosti

Vědci americké Severozápadní univerzity vyvinuli speciální inkoust pro 3D tiskárny, kterým lze vytisknout syntetické kostní implantáty, podporující rychlou regeneraci a růst kosti. Jde o velice elastický materiál,



jehož tvar lze snadno přizpůsobit potřebám pacienta. Vzhledem ke své povaze je tento materiál obzvláště vhodný k léčbě defektů kostí u dětských pacientů.

Implantace kosti nebývají nikdy snadné. Nejvíce komplikované a bolestivé jsou ale obvykle pro děti. Nejde jenom o to, že dospělí lépe snášejí pobyt v nemocnici a samotné operace. V podobných případech lékaři často používají kovové kostní implantáty, a když dítě ještě roste, tak mu to přináší značné problémy. V mnoha případech čeká na takové dítě celá série operací, což je pochopitelně velmi zatěžující.

Ramille Shahová a její spolupracovníci proto chtěli vyrobit biomateriál, který by mohl dětským pacientům v tomto směru pomoci. Jejich řešením je biokompatibilní nanomateriál do 3D tiskárny, na který je pak možné tímto inkoustem tisknout rozmanité tvary implantátů. Shahová a spol. vsadili na směs hydroxyapatitu, který je klíčovou součástí kostní tkáně, a biologicky odbouratelného polymeru, běžně používaného v medicínských aplikacích. Experimenty na pokusných zvířatech ukázaly, že 3D tištěné kostní implantáty z tohoto materiálu jsou velice slibné.

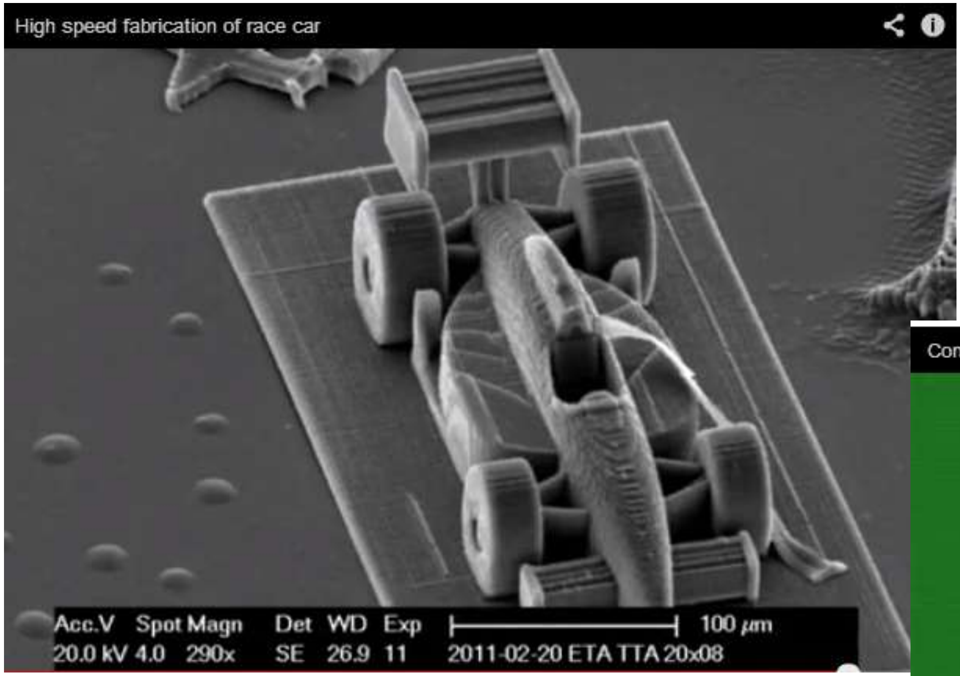
O hydroxyapatitu víme, že podporuje regeneraci kosti. Zároveň se s ním ale velmi špatně pracuje. Medicínské produkty z hydroxyapatitu bývají tvrdé a křehké. V bionanomateriálu týmu Shahové přitom na hydroxyapatit připadá celých 90 procent váhy materiálu. Zmíněný polymer tedy tvoří pouze 10 procent hmoty materiálu, ale díky své sofistikované nanostruktuře a 3D tisku si vzniklý materiál stále udržuje značnou ohebnost. Buňky v okolí takového implantátu dostávají signál, že je přítomno velké množství hydroxyapatitu, a intenzivně regenerují kostní tkáň. Výhodou je i to, že 3D

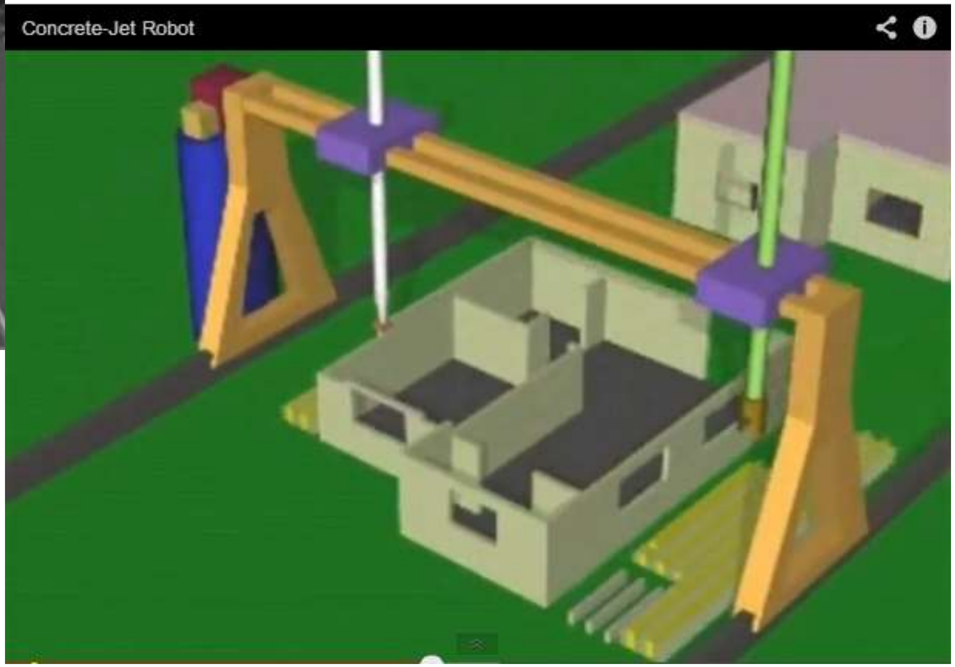
> Výhodou je i to, že 3D tisk kostních implantátů probíhá za pokojové teploty, takže **do inkoustu pro 3D tiskárnu lze přimíchat antibiotika** nebo jiné biologicky aktivní látky.

tisk kostních implantátů probíhá za pokojové teploty, takže do inkoustu pro 3D tiskárnu lze přimíchat antibiotika nebo jiné biologicky aktivní látky, které pak působí v místě vložení implantátu.

Present and future of 3D printing

Size extremes





Present and future of 3D printing


RESEARCH WATCH

3D printer creates objects from NASA moon material

By James Holloway 3 Comments
November 28, 2012

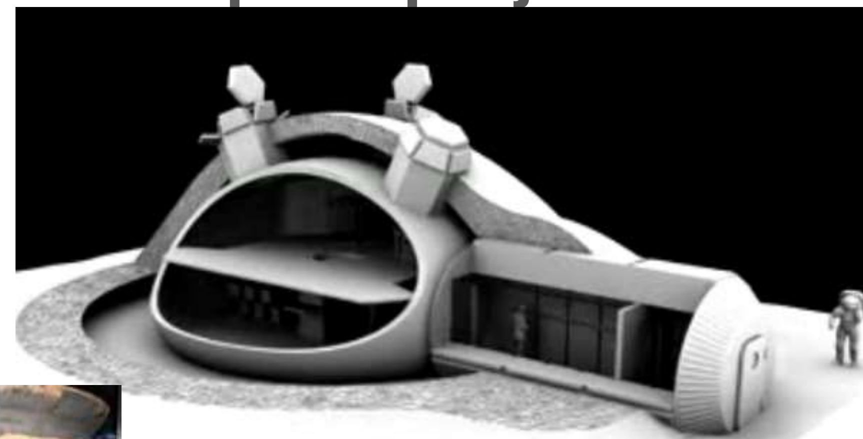
Buzz Aldrin went without the option of 3D printing spare parts out of lunar materials (Photo: NASA)

Researchers at Washington State University have successfully 3D printed basic shapes with simulated moon rock, offering the first glimpse of a future in which off world explorers or colonists may be able to fabricate parts and components composed of lunar or Martian surface matter.

The research came about as a result of an approach in 2010 from NASA to Washington State University's Amit Bandyopadhyay, posing the question of whether 3D fabrication using moon rock was possible.

NASA duly provided Bandyopadhyay and fellow researcher Susmita Bose with 10 pounds (4.5 kg) of simulated raw lunar regolith (or surface material),

Space projects



Present and future of 3D printing

This rover, which has a pressurized cabin to support astronauts, includes about 70 FDM parts, including housings, vents and fixtures.

Space projects

ELECTRONICS › NASA 3D PRINTS ROCKET PARTS — WITH STEEL, NOT PLASTIC

NASA 3D prints rocket parts — with steel, not plastic

By John Hewitt on November 15, 2012 at 10:47 am | 11 Comments

Share This Article

NASA's Marshall Space Flight Center in Huntsville, Alabama, has 3D printed nickel alloy rocket engine parts using a fabrication technique called selective laser melting, or SLM. The part will be used on the J-2x engine for the largest rocket ever built, known simply as the Space Launch System. 3D printing (see: What is 3D printing?) has become popular for fabricating parts from plastic, but using the technique with metals requires equipment that is a bit more *extreme*. Will 3D printing of hard materials become part of a general, growing trend, or will these exotic fabrication technologies be viable only for elite, niche markets?

SLM evolved from an older method known as selective laser sintering, or SLS. In the traditional sintering process, a part is first molded from ceramic or metal powder and pressed into the desired shape. The "green," as it is called at this point, is then fired in a oven to bond it. The oven was later replaced with a laser which provides greater precision

Present and future of 3D printing

Space projects

Made in space: Nasa tests 3D printers that will let Mars-bound astronauts craft their own equipment as they travel

By ROB WAUGH

PUBLISHED: 11:08 GMT, 23 July 2012 | UPDATED: 11:23 GMT, 23 July 2012

Comments (6) | Share | Tweet

Future astronauts might 'forget to pack', just like Earthbound holidaymakers - but it won't matter.

Instead, astronauts will use 3D printing machines that can make any object the astronauts need - even metal machine parts.

Nasa is already testing 'additive manufacturing' machines - 3D printers that create objects layer by layer - in low-gravity parabolic flights on Earth.

The space agency already has a (rather bulky) machine that can build metallic objects to order.

Whatever you need, when you need it: Nasa is already testing 'additive manufacturing' machines - 3D printers that create objects layer by layer - in low-gravity parabolic flights on Earth

Almost 10 years ago, engineers at NASA's Langley Research Center developed the Electron Beam Freeform Fabrication, or EBF3, a process that uses an electron beam gun, a dual wire feed and computer controls to manufacture metallic structures for building parts or tools in hours, rather than days or weeks.

Nasa 3D printing expert Karen Taminger said, 'We are working towards demonstrating this capability on ISS.'

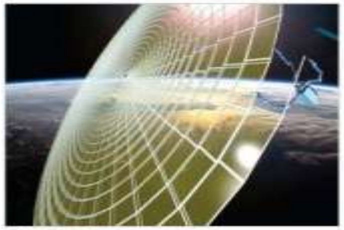
More...

- From statins to sugar: The 'Chemputer' which can give you any drug or organic material using a 3D printer
- It's alive! Scientists create first 100% realistic virtual sex disease bacteria inside a computer - and it could pave the way for artificial life forms

Future Tech

NASA Turns to 3D Printing for Self-Building Spacecraft

Jeremy Hsu, InnovationNewsDaily Senior Writer
September 13 2012 12:58 AM ET



SpiderFab Concept
CREDIT: Unlimited Tethers
View full size image

Spacecraft could build thems
space telescopes someday t
materials from space junk or
wild vision stems from a mod
use 3D printing technology al
satellite to create a much larg
space.

The "SpiderFab" project rece
from NASA's Innovative Adva
Concepts program to hamme
and figure out whether space
construction makes business
Practical planning and additi
could lead to the launch of a 3D-printing test mission within several years.

"We'd like someday to be able to have a spacecraft create itself entirely fro
realistically that's quite a ways out," said Robert Hoyt, CEO and chief scien
Unlimited Inc. "That's still science fiction."

Using 3D printers to build spacecraft parts in orbit would offer an easier wa
huge space antennas or space telescope components 10 or 20 times large
counterparts without having to fold them up and squeeze them inside a rock
could simply launch with the 3D printers and raw materials. [NASA Looks to
for Spare Space-Station Parts]

Future Tech

NASA Looks to 3D Printing for Spare Space-Station Parts

Jeremy Hsu, InnovationNewsDaily Senior Writer
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The International Space Station is featured in this image photographed by an STS-133 crew member on space shuttle Discovery after the station and shuttle began their post-undocking relative separation on March 7, 2011.
CREDIT: NASA
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Launch $1-billion-worth of spare parts to the International Space Station, and you can keep Earth's orbital outpost going for another decade. Send up some 3D-printing devices, and you invest in the ability to build everything on demand in space: space-station parts, astronaut tools, satellites, even spacecraft.

A first step toward space factories may come from NASA's recent selection of a U.S. startup's proposal to build a 3D printer for the space station. Such printing technology could build any number of objects, layer by layer, based on designs uploaded from mission control. Astronauts would only need "feedstock" material, such as plastic or metal, to make new tools or spare parts on the fly.

"When a tool breaks, at the very worst the space-station crew calls Houston and says, 'Send us a CAD (computer-aided design) file of that tool,' and they'll be able to 3D-print it," said Jason Dunn, chief technology officer and cofounder of Made in Space, Inc. "Ideally, one day they'll be able to design it themselves."

Interesting links

- **Prusa 4 materials**
  https://www.youtube.com/watch?v=KpcH74DXyy0
  https://www.youtube.com/watch?v=utWiZZUERkY
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  https://www.youtube.com/watch?v=9rTeyPZDn_0
- **3D print of castle from concrete**
  https://www.youtube.com/watch?v=DQ5Elbvvr1M
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  https://www.youtube.com/watch?v=WzmCnzA7hnE
  https://www.youtube.com/watch?v=bTSakUtxXYY
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- **Printing from glass**
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- **Kovosvit + CTU Prague**
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