DG 201
RAPID PROTOTYPING
OR
MATERIAL INCRESS
MANUFACTURING

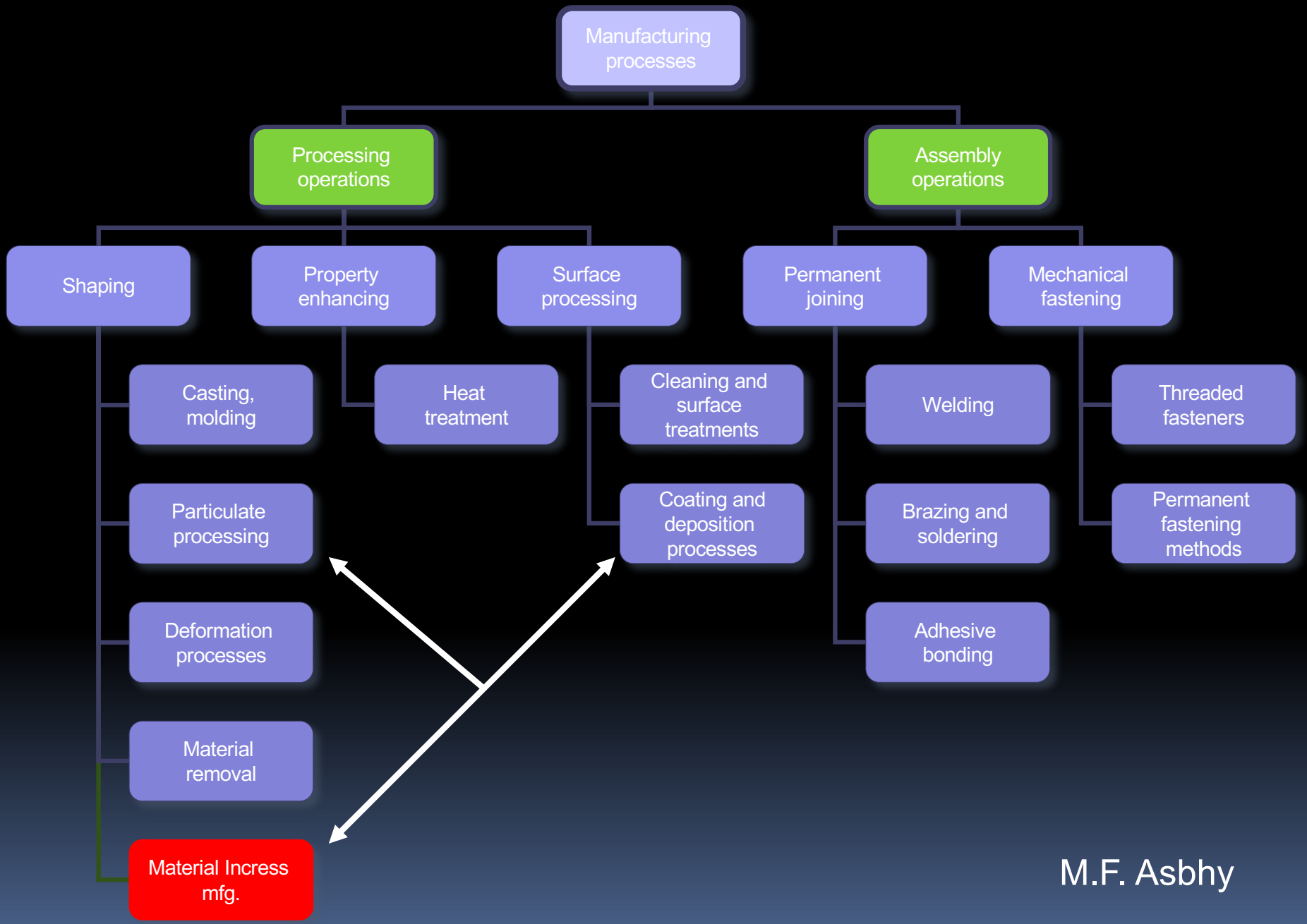
F.L.M. Delbressine & C. Bangaru
TU/e Industrial Design

Literature

1. G.N. Levy, R. Schindel, J.P. Kruth,

   Rapid Manufacturing and Rapid Tooling with Layer Manufacturing Technologies. State of the Art and Future Perspectives, Annals of the CIRP, Vol.52/2, 2003
2. J.P. Kruth,

   Material Incress Manufacturing by Rapid Prototyping Techniques, Annals of the CIRP, Vol. 40/2, 1991
3. M.F. Ashby et all,
   1. CES EduPack, 2010
   2. Materials. Engineering, science, processing and design, Butterworth-Heinemann, 2007


Manufacturing processes
Processing operations
Assembly operations
Shaping
Property enhancing
Surface processing
Permanent joining
Mechanical fastening
Casting, molding
Particulate processing
Deformation processes
Material removal
Material Incress mfg.
Heat treatment
Cleaning and surface treatments
Coating and deposition processes
Welding
Brazing and soldering
Adhesive bonding
Threaded fasteners
Permanent fastening methods

M.F. Asbhy

Classification of Material Incress Manufacturing

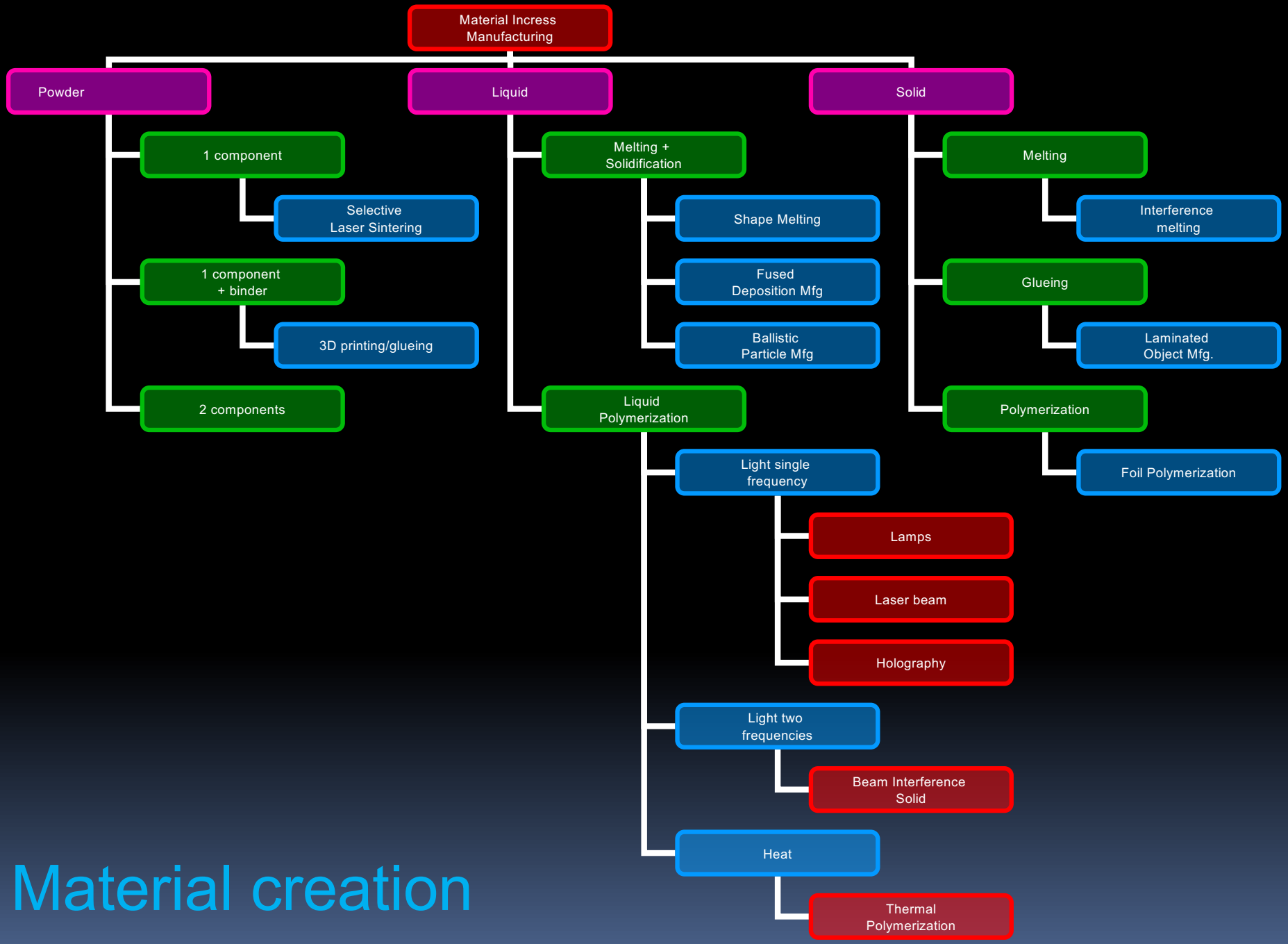
Better name for rapid prototyping is:

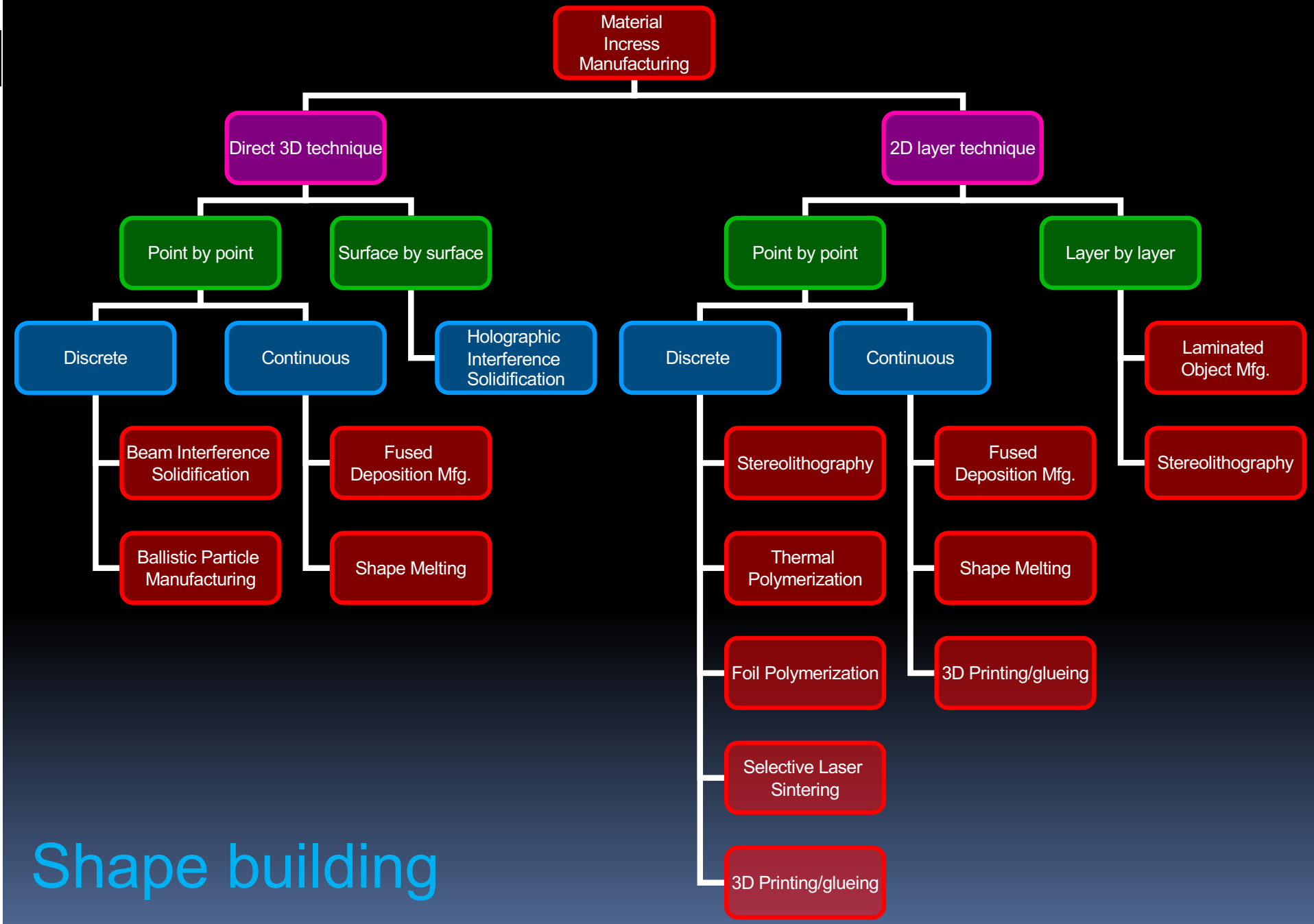
- Material Incress Manufacturing
  - Really slow manufacturing processes!
    - Why called rapid prototyping?

Classification according to:

- Material creation
- Shape building

Material creation





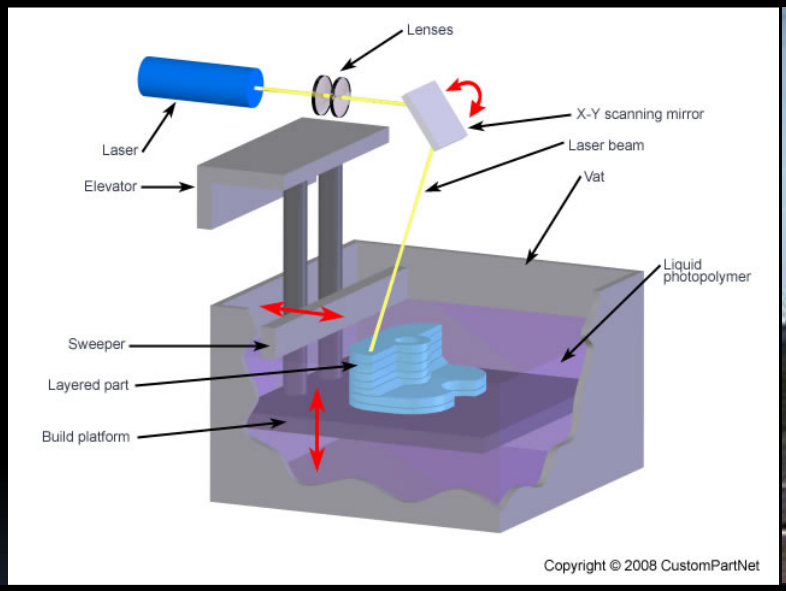
Shape building

What is Material Incress Mfg?

- *Additive* manufacturing processes, generate parts in a layered way (> 1985).

- Main types:
  - Stereo-lithography
  - Fused Deposition Modelling
  - Selective Laser Sintering
  - 3D printing

Stereo-lithography



Stereo lithography

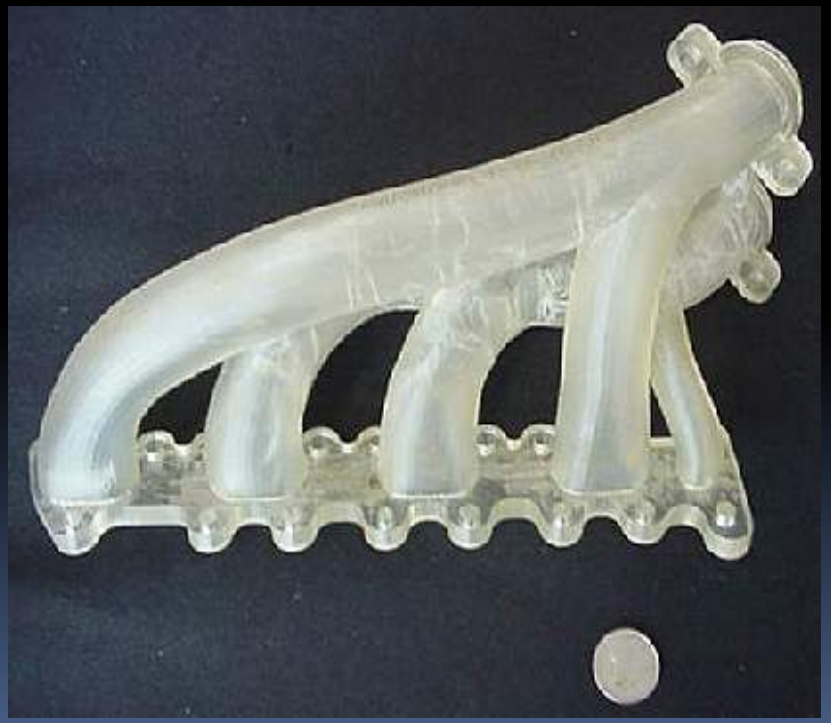
- The machine has four main parts:
- A *tank* filled with a liquid photopolymer. The photopolymer is a clear, liquid resin.
- A perforated *build platform*, immersed in the tank. The platform can move down in the tank as the printing process proceeds.
- An ultraviolet *laser*
- A *computer* that drives the laser and the platform

Stereo lithography

- http://www.youtube.com/watch?v=0P2HHHvHWLI&feature=related
- http://www.youtube.com/watch?v=ky87zxNy1oo&feature=related

SLA applications:

- Functional prototyping
- Concept modelling
- Customer goods
- Rapid Tooling



SLA Material & accuracies:

Material:

- Photopolymer resin (liquid)

Accuracy:

- +/- 0,2%

Layer thickness:

- 0,1 – 0,15 mm

SLA Advantages & disadvantages

Advantages :

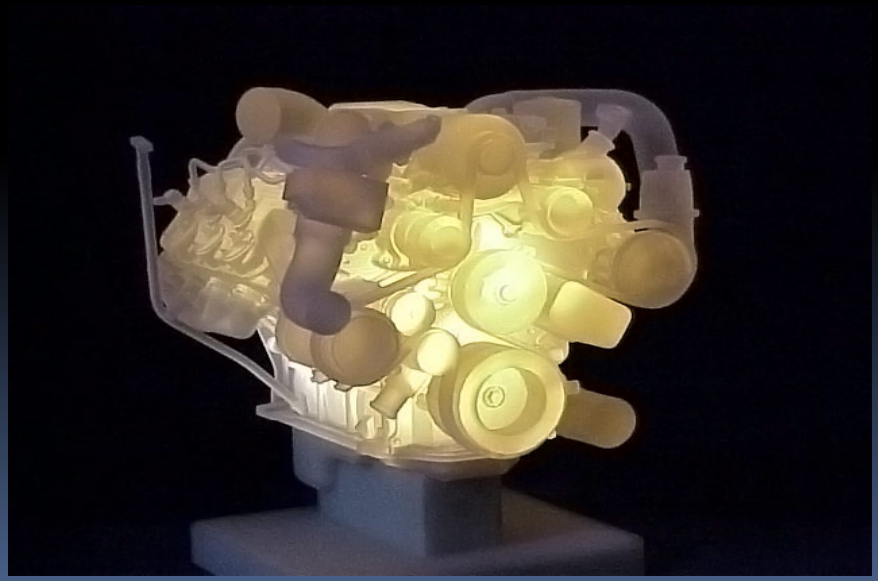
- ✓ The unused resin is re-usable.
- ✓ Good combination of accuracy, speed, and surface quality.
- ✓ Good finishing properties **after sanding**.

Disadvantages:

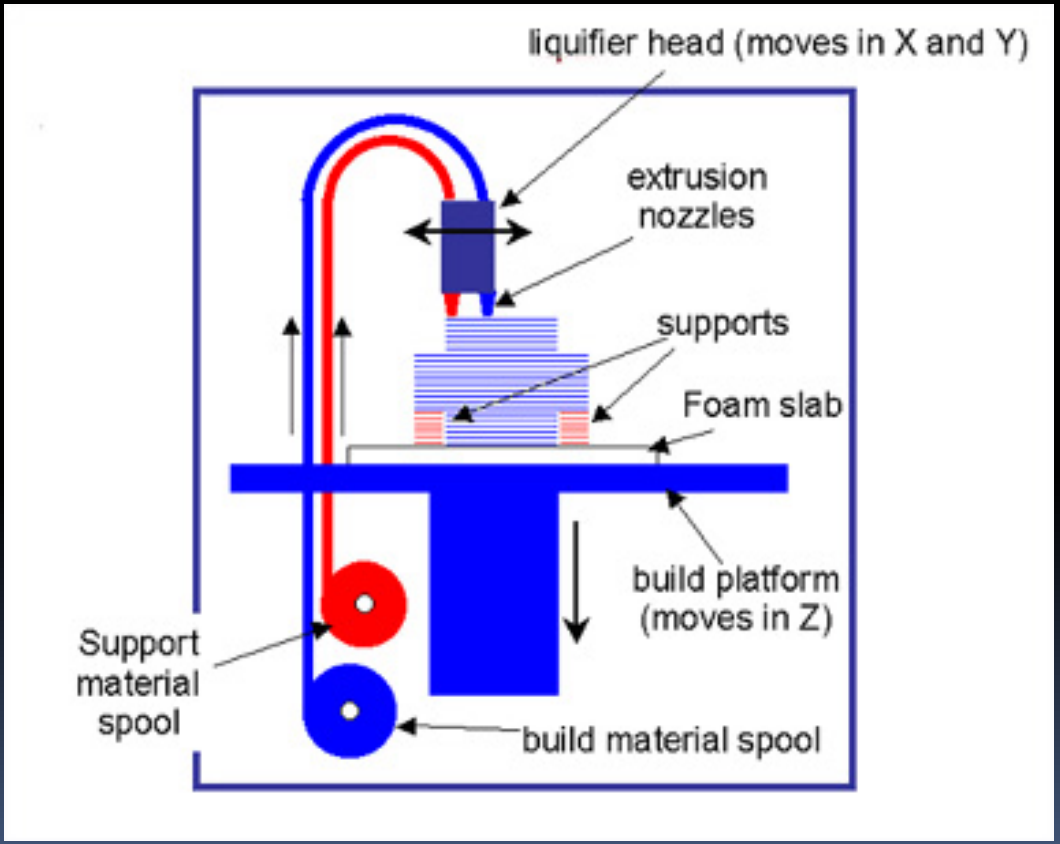
- Models are **too fragile** for mechanical testing.
- Resins are **environmentally unfriendly**.
- Support structure can only be removed by a solvent (aceton).

Cost of stereolithography:

- Machine cost > $250.000
- Ventilation needed, thus costly
- Polymer is extremely expensive: ~$200/liter



Fused deposition modeling(FDM)



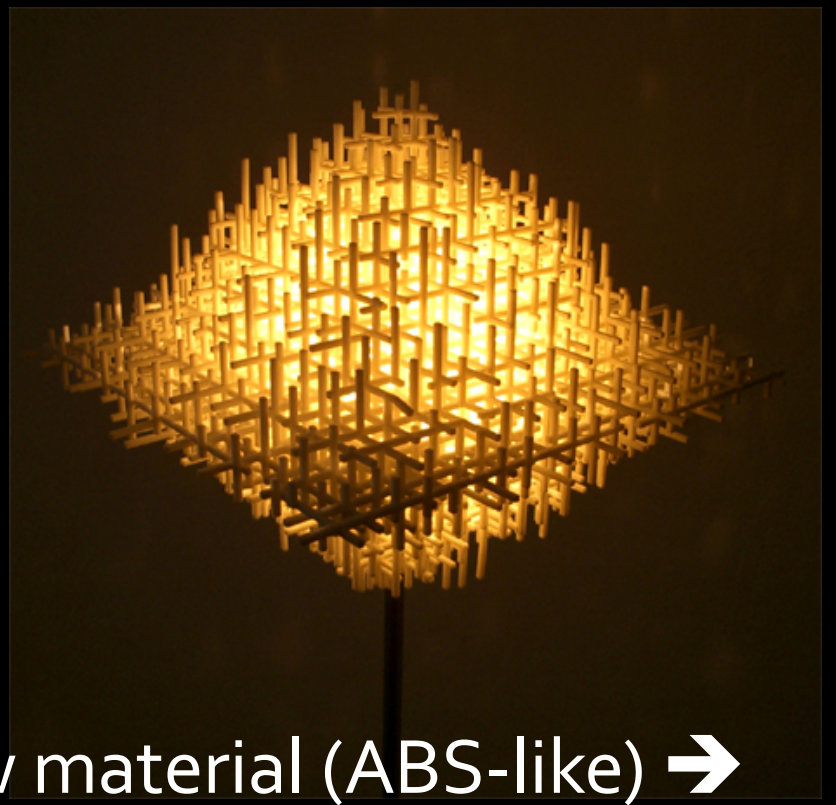
Basic machine components:

1. A *build platform* moving down during building.
2. A "*liquifier head*" that heats up the raw material.
3. *Extrusion nozzles* which deposit molten material on the specific location.
4. A *computer* that drives the head and build platform.

http://www.youtube.com/watch?v=yKHMmKqdI68

http://www.youtube.com/watch?v=Ha1mij5dA8o&feature=related

FDM aplications:



- ✓ Functional models.
- ✓ Concept modelling.
- ✓ Rapid tooling

- Higher strength of the raw material (ABS-like) ➔ suitable for mechanical testing applications.

- Used in: medical, food and automotive, higher T applications (< 130°C).

FDM materials & accuracies

Material used for building:

- ABS, PC, material on a spool (Filament)

Tolerances:

- +/- 0,2mm

Layer thickness:

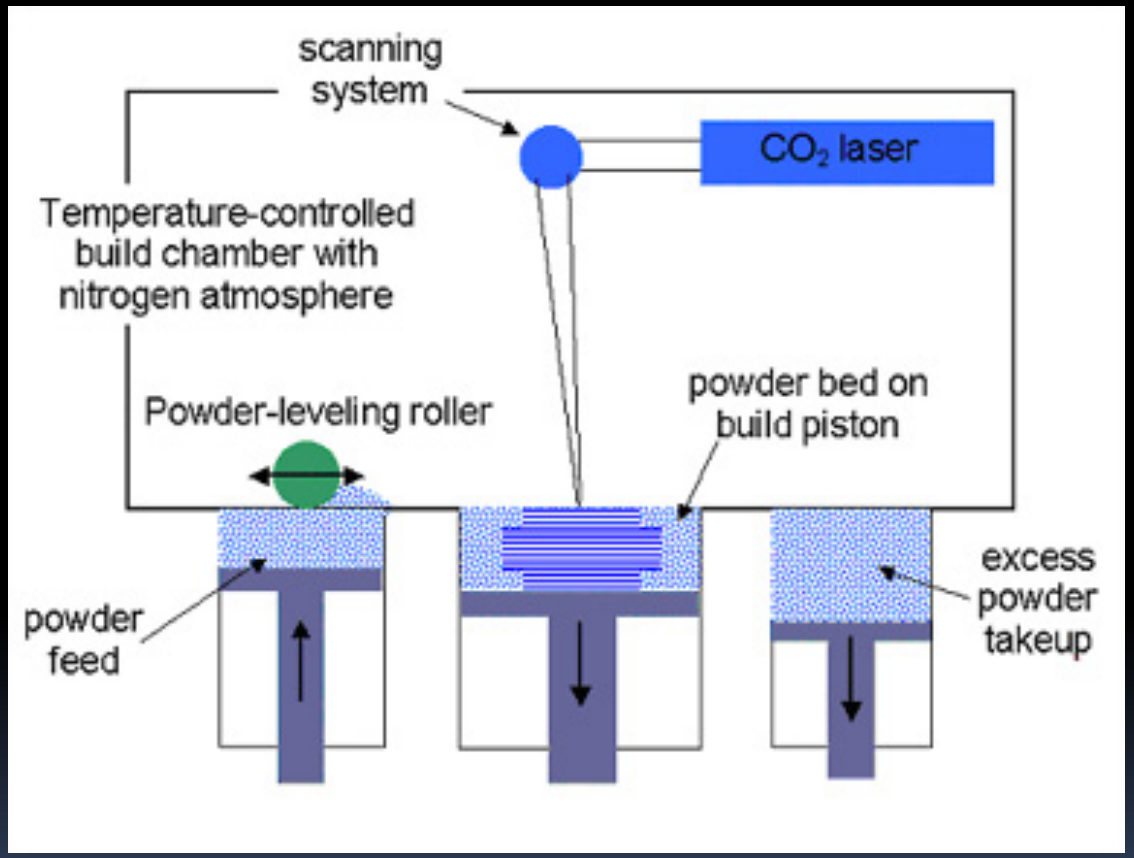
- 0,13 – 0,25 mm

Advantages & disadvantages

- ✓ Wide variety of material possible; close to injection molding
- ✓ Form stability; no distortion due to temperature or UV.
- ✓ Fast building time for small objects; suitable for rapid manufacturing.
- ✓ Material is suitable for mechanical testing

- – Not suitable for big parts (too slow)
- – Relatively expensive technique
- – No transparent materials
- – Surface quality is poor (sanding/sandblasting needed)
- – Model strength is depending on the build orientation

Selective Laser Sintering



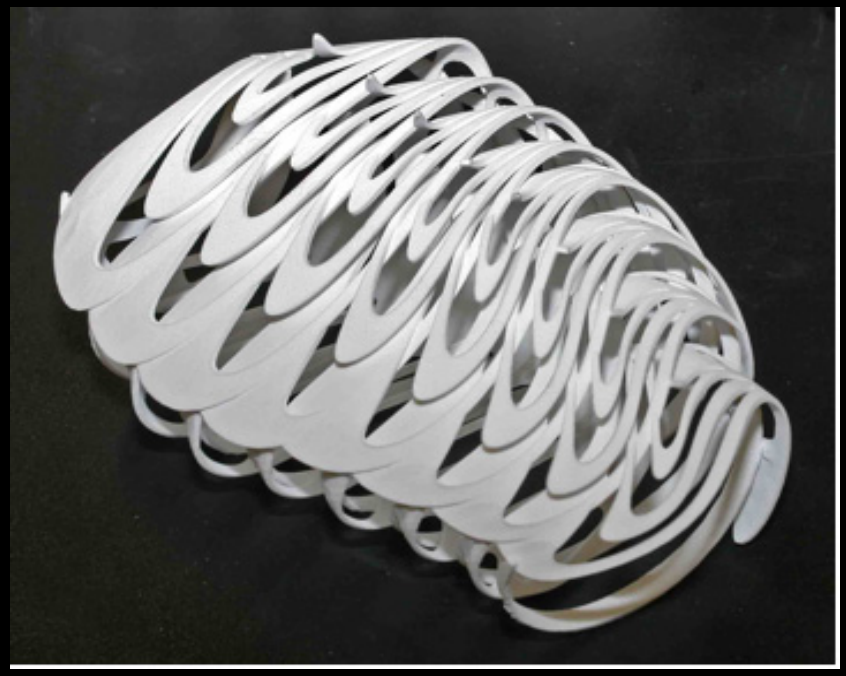
SLS Machine components

1. Build platform that moves in the Z direction.
2. Powder-leveling roller.
3. CO_2 laser with scanning mirrors
4. Computer that drives the laser and build platform

http://www.youtube.com/watch?v=gLxve3ZOmvc

http://www.youtube.com/watch?v=FTPpTmA41fo&feature=related

Selective laser sintering



SLS Applications

- ✓ Functional testing of parts.
- ✓ Mechanical testing of parts.
- ✓ Parts produced for high heat applications.
- ✓ Concept modeling.
- ✓ Consumer goods.
- ✓ Parts with snap-fits & living hinges.

SLS materials & accuracy

Material usable in SLS:

- Polyamide powder (PA)
- Glas filled polyamide powder (PA-GF)
- Alumide: a blend of aluminium - and Polyamide powders.

Tolerances: +/- 0,2 mm

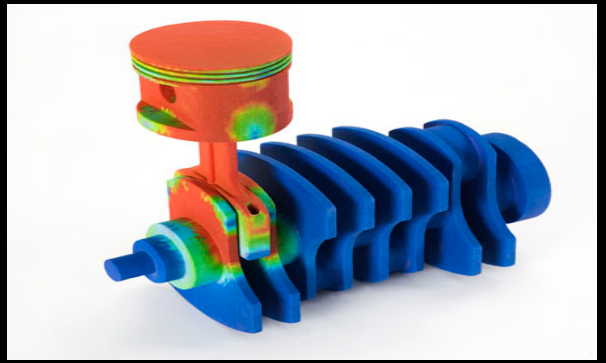
Layer thickness: 0,1- 0,2 mm

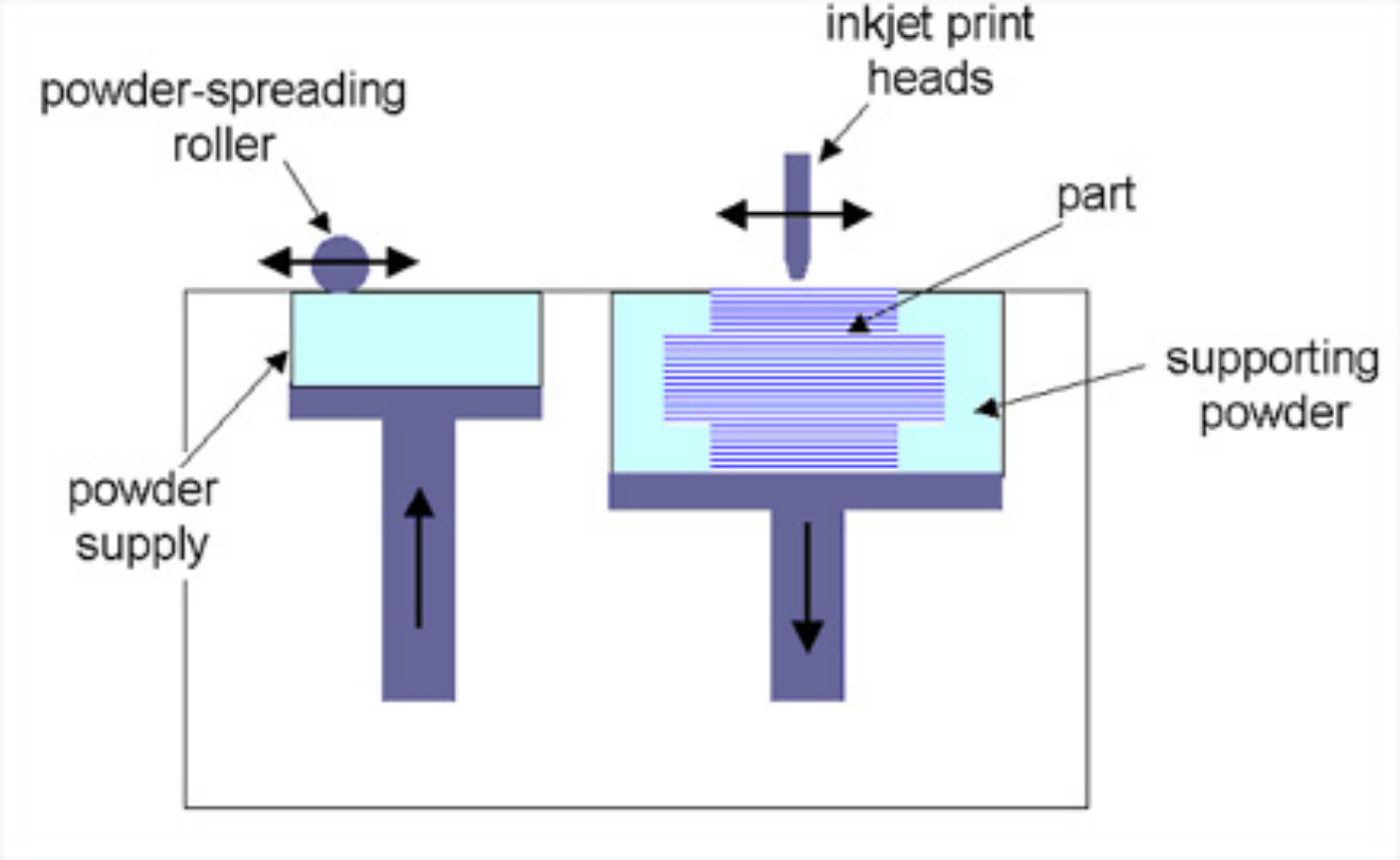
SLS advantages & disadvantages

- ✓ Use of different materials possible; metals & plastics.
- ✓ Mechanically testable products.
- ✓ Large and complex functional parts (700x380x580mm) can be made in one piece
- ✓ Cheap and fast compared to other RP techniques.
- ✓ Models build in SLS have almost the same mechanical properties as injection moulded parts.

- SLS parts have a rough, grainy and porous surface. (sanding , sandblasting, etc.. needed).
- Form stability is not always guaranteed : large shrinkage

3D powder printing



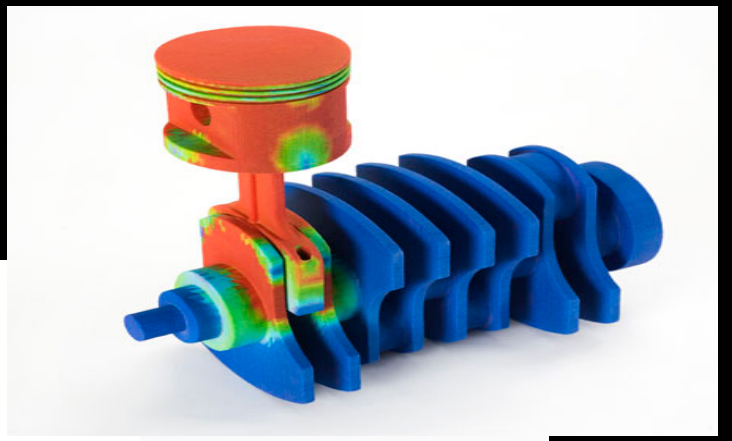


Machine parts

1. Build platform that moves in the Z direction
2. Powder-spreading roller
3. Inkjet print head
4. Computer driving the head and the build platform

http://www.youtube.com/watch?v=OpGrFBHhlsM

Examples:



Applications, materials & accuracies

Applications:

- Concept modelling

Material used:

- High perfomance composite powder

Tolerance: 0,4 mm

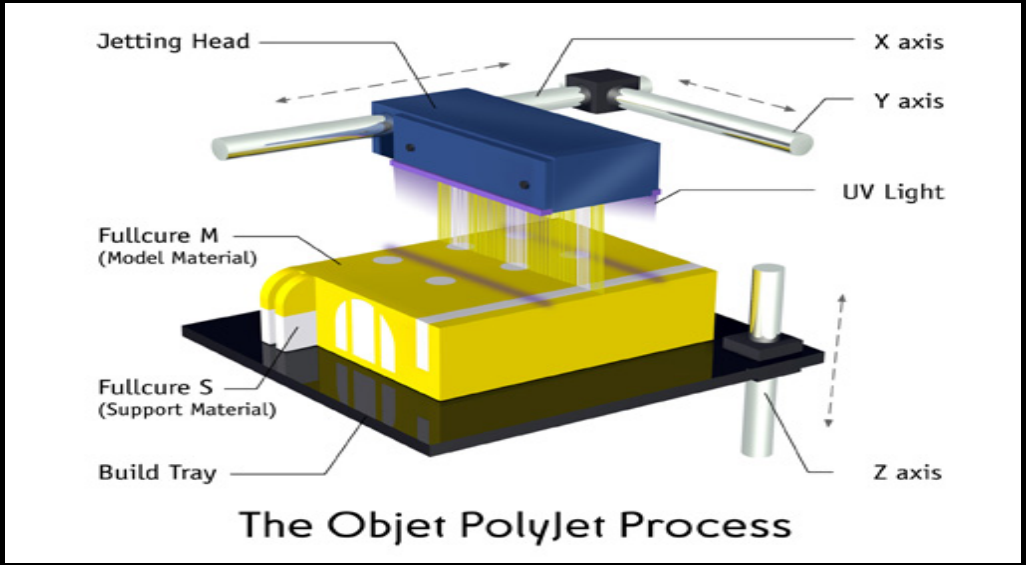
Layer thickness: ~0,1mm

Advantages & disadvantages

- ✓ Relatively cheap and fast
- ✓ Possible to print multiple colors models.
- ✓ Re-use of support powder possible

- ➢ Models are very fragile,
- ➢ Low resolution.

3D Resin printing (Objet)



The Objet PolyJet Process

Similar to Stereolithography except:

- Curing: ultra-violet light (not a laser)
- Resign deposition (not a bath)

http://www.youtube.com/watch v=kMdoH4ZJusw&playnext=1&list=PL3E6F402D7BB489FB

http://www.youtube.com/watch?v=idp_5e_qavE&feature=related

Applications & materials

Applications:

- ✓ Concept modelling.
- ✓ Functional prototyping.
- ✓ Rapid tooling.

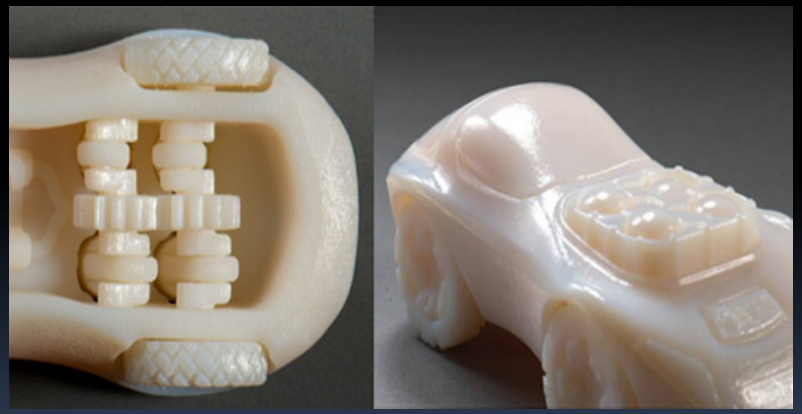
Possible to use stiff and flexible materials in one model!

Materials suitable for resin printing:

- Photopolymer (UV- sensitive) with different mechanical properties.

Advantages & disadvantages

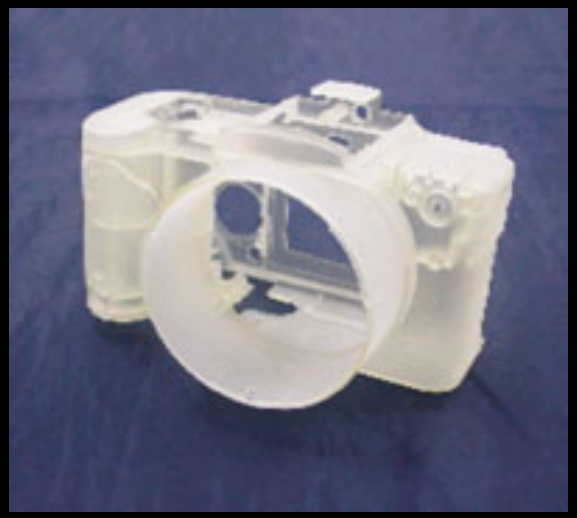
- ✓ Use of multiple colors in models is possible
- ✓ Materials are available with different mechanical properties.
- ✓ High resolution thus high- detailed features possible



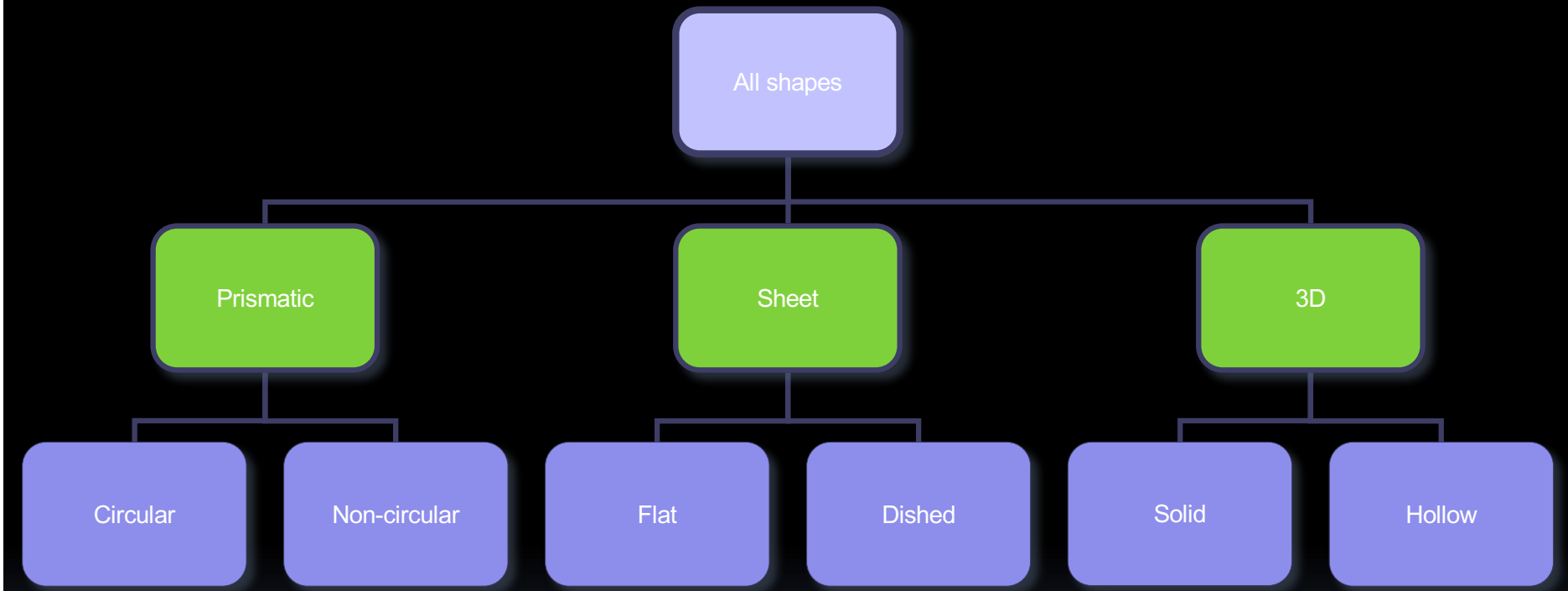
Disadvantages:

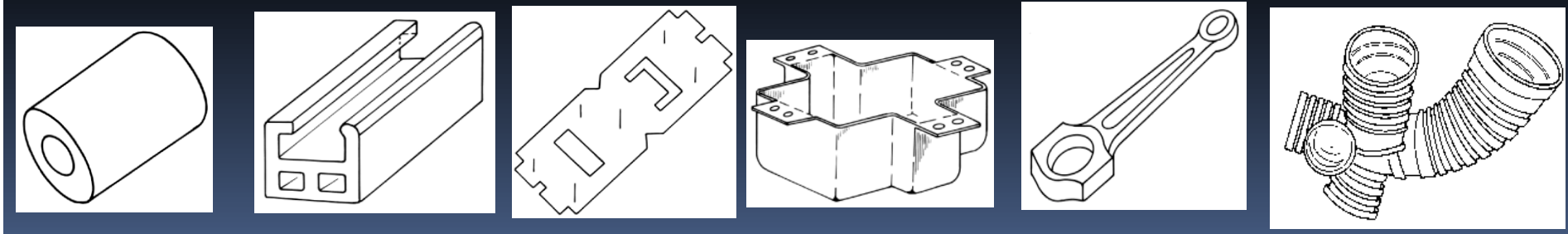
- ➢ Expensive in use.
- ➢ Material with low Heat Distortion Temperature

What can be manufactured with our printer (Objet Eden)



Shape categories:





M.F. Ashby

Typical application areas

- Medical
- Sports
- Industry
- Art & Design
- …

Medical examples

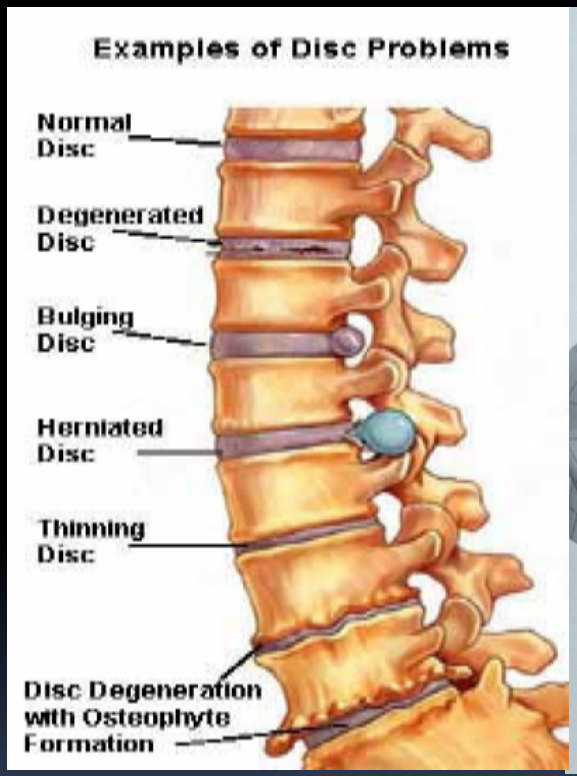
Bone implant

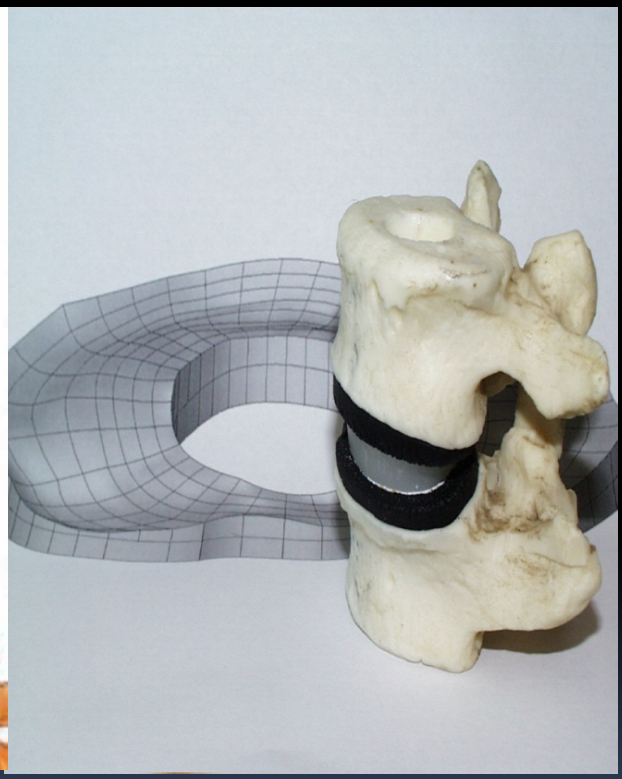
Printing pils

Medical

Hearing aids

Vertebral disc





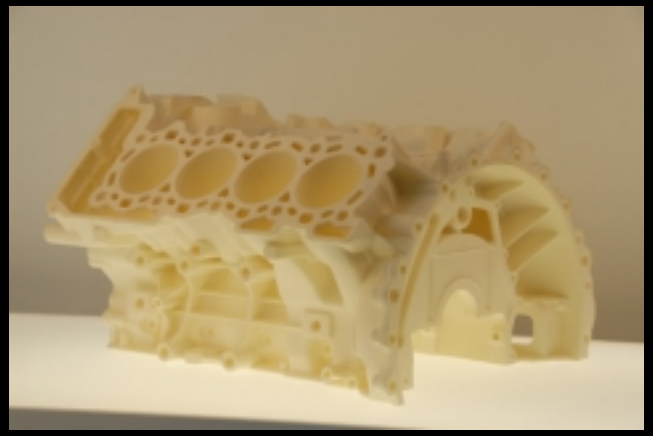
Sports

- Reflect sunlight
- Guide cool air to the head

Formula 1 airducts

Industry

Prototypes in SLS used for form and fit testing



R.I.M. dashboard for Bentley

This Peugeot 807 Rapid Injection Moulding rear bumper was mounted on a test car and used for wind tunnel tests

Visual prototype (Skill)

Prototype used for a professional photoshoot

Materialise

Arts & consumer goods




Furniture, clothing, accessories

Application conclusions

- Small series
- Complex parts possible
- Expensive, economically feasible?

Conclusion

"As for real direct rapid manufacturing of products, its application is still in its infancy, even though very promising.

The real breakthrough of Rapid Manufacturing will mainly depend on cost and productivity improvements, which have to be accompanied with further technical progress in material properties and most of all in accuracy and reliability"

G.N. Levi, R. Schindel, J.P. Kruth,
Annals of the CIRP, Vol. 52/2/2003

From Design to Manufacturing

1. Computer Aided Design file
   - 3D solid and/or solid features
   - No surface models (where is the material?)
2. STL file
   - Facetted triangular volumetric structure. Each triangle has a normal vector. Direction away from material.
3. Layer Manufacturing

Fuksas: triangular facets

STL contents

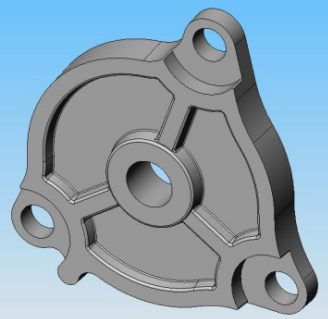
```
solid productname
  facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
    outer loop
      vertex 5.565140e+001 1.007345e+001 1.000000e+000
      vertex 3.866820e+001 5.550859e+000 1.000000e+000
      vertex 4.130585e+001 6.442590e+000 1.000000e+000
    endloop
  endfacet
  facet normal 0.000000e+000 0.000000e+000 -1.000000e+000
    outer loop
      vertex 1.181699e+001 2.954762e+000 1.000000e+000
      vertex 1.170823e+001 3.361983e+000 1.000000e+000
      vertex 1.657872e+001 1.176009e+000 1.000000e+000
    endloop
  endfacet
      …
endsolid
```

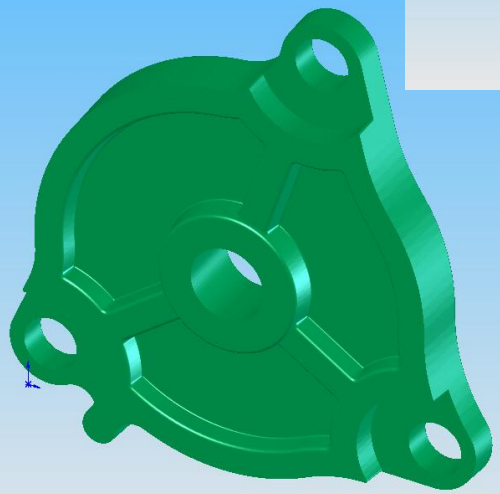
STL output

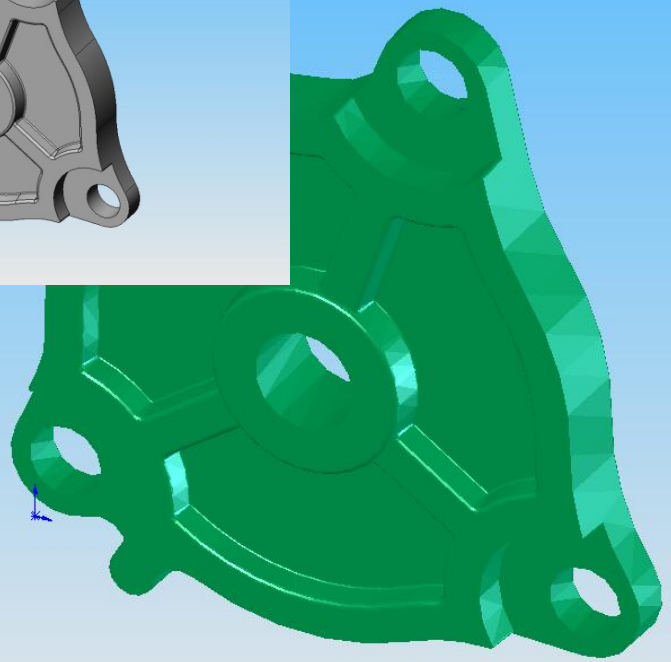
Original

STL Coarse

STL Fine







Fine:
- deviation tolerance 0.01mm
- angle tolerance 5 degrees

Coarse:
- deviation tolerance 0.11mm
- angle tolerance 30 degrees