Manufacturing Using “Light” and “Dust”

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Manufacturing Using "Light" and "Dust"

Contents:

- Introduction to the University
- Engineering Department

- Additive Layer Manufacture (The Process)
- Rapid Prototyping
- Rapid Manufacture
- Rapid Parts
- Rapid Tools

- Materials Research
- Development

- The Future

The University of Wolverhampton

UNIVERSITY OF WOLVERHAMPTON

Vital Statistics:

Students and Staff

24,000 Students

3,800 Overseas Students

2,500 Staff

14th out of 111 in the UK for investment per student

Employment and Research

'Best' in the region for employer engagement

Research Assessment Exercise (RAE) 2008 - world class research

The Department of Engineering (DOE)

The Department of Engineering (DOE)

Department : 11 Academics
9 Support Staff
5 Business Engagement Staff

Activities : Teaching
Research
Business Support
- Caparo Innovation Centre
- Manufacturing Club
- Rapid PD

Consultancy

Courses

MSc :

- Rapid Product Development and Advanced Manufacturing
- Polymer Engineering Design

BEng – MEng :

- Mechanical
- Automotive
- Mechatronics
- Electronics and Communications
- Engineering Design Management

Foundation Year

Foundation Degree

- Engineering

Taught Postgraduate

MSc Polymer Engineering Design

MSc Rapid Product Development and Advanced Manufacturing

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The Department of Engineering (DOE)

Facts :

Have won £15M of Grant in last 12 yrs
Assisted approx 5500 SME,s
Safeguarded over 800 Jobs and generated 300 new jobs
Currently have £5M of capital equipment
Currently have £1M of industrial software

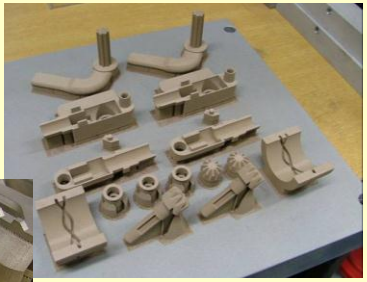
1st UK University to run EOS M250 DMLS
1st UK University to run EOS M270 DMLS
1st University (World Wide) to run Ti Alloys on EOS M270
1st University (World Wide) to run Al Alloys on EOS M270

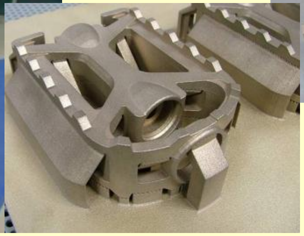
The Department of Engineering (DOE)

Facilities:

Direct Metal Laser Sintering and Laser melting
Fused Deposition Modelling
Selective Laser Sintering
4 and 5 Axis Machining and CAM solutions
Reverse Engineering
EDM and Wire EDM
Powder Metallurgy and Mechanical Alloying
Materials Testing
SEM and Optical / Laser Microscopy
CAD, FEA, CFD and simulation

Telford





Why Additive Layer Manufacture?

- To address an expanding market (1 to $15 billion last 5 years ----- 15 to $50 billion over next 8 years) (Wholers report 2010)
- A need to fulfil existing and future skills shortage within the Additive Layer Technology sector (Wholers report 2010)
- Rapid prototyping sector is shrinking as Rapid manufacture is expanding (Econolyst AWM report 2009)
- Based on the ability to exploit RM based technologies;

"Move from Design led Manufacture to Manufacture led Design" (EOS GmbH 2010)

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What Is Additive Layer Manufacture?

Manufacture of 3D artefacts from a succession of 2D cross-sections stacked in one principal build direction.

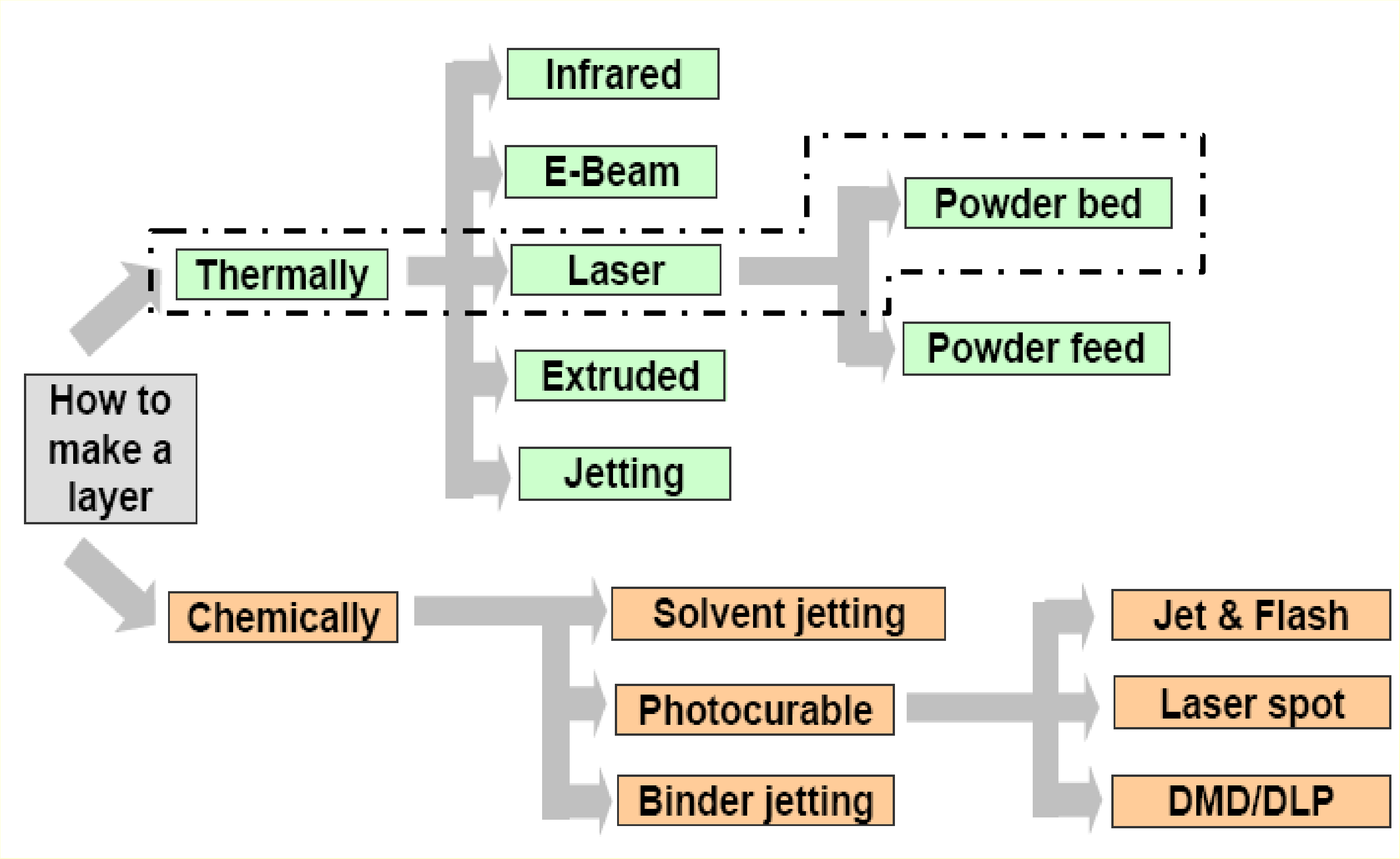
Additive Layer Manufacture

Requires:

- A 3D CAD File
- Slicing Software
- Method of Layer Generation
- Method of Fusing layers

Additive Layer Manufacture

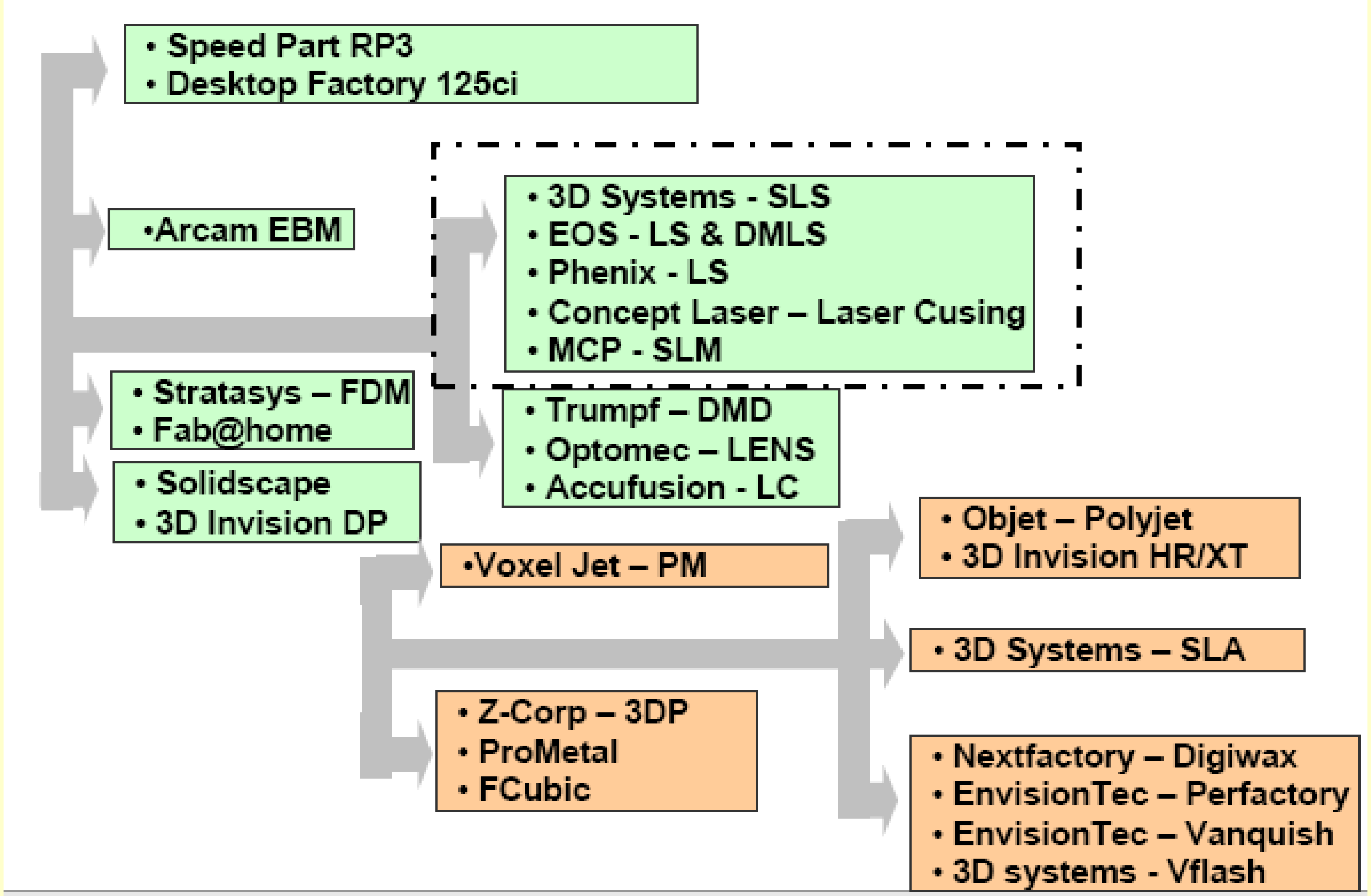
Layer Generation and Fusion :



Source : Econolyst

Additive Layer Manufacture

ALM Systems:



Source : Econolyst

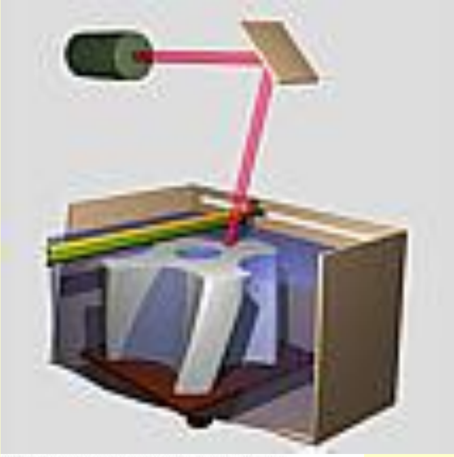
Fundamentals Of Additive Layer Manufacture

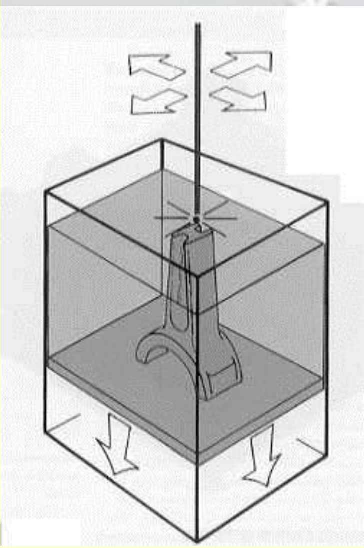
Two Main Categories :

- **Polymeric Materials**
- **Metallic Materials**

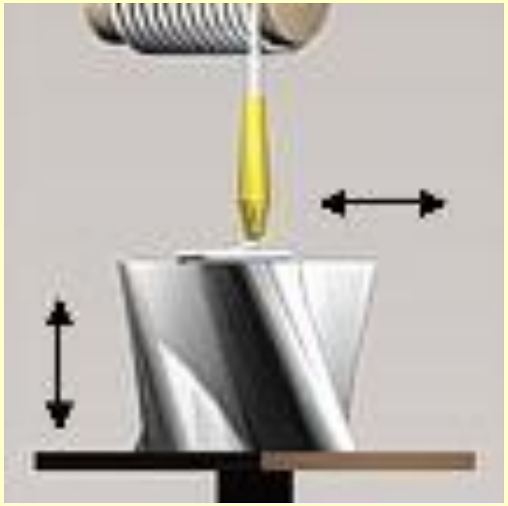
Polymer Based ALM

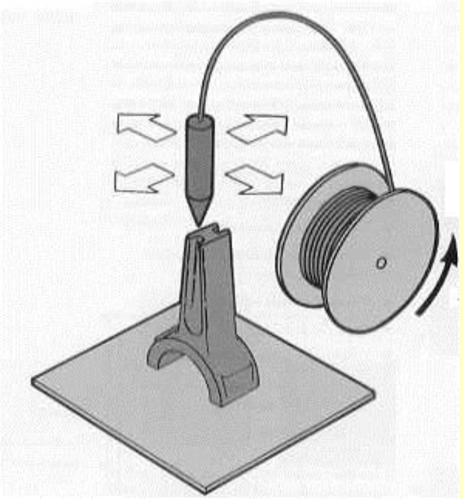
Stereo Lithography



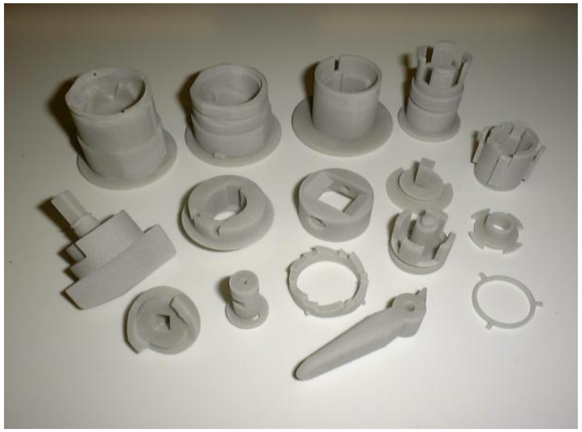


Fused Deposition Modeling





Selective Laser Sintering

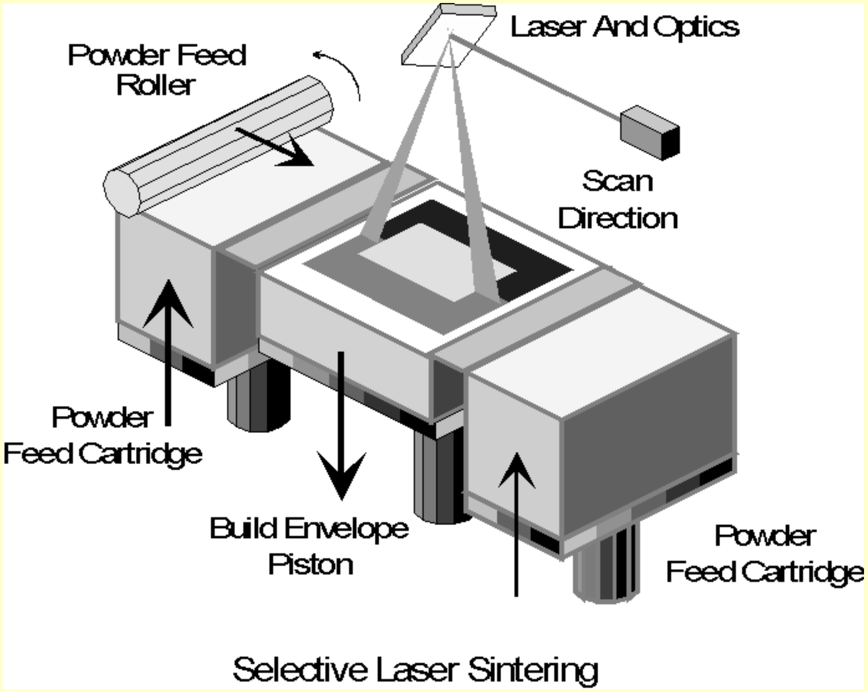


Selective Laser Sintering - Process

- Laser beam is traced over the surface of this lightly compacted powder to selectively melt and bond it to form a layer of the object

- Build envelop is maintained at a temperature just below the melting point of the powder

- After the object is fully formed, the piston is raised to elevate it.



- Excess powder is simply brushed away and final manual finishing may be carried out.

Selective Laser Sintering - Process

- No supports are required since overhangs and undercuts are supported by the powder bed.

- A considerable length of cool-down time is needed before the part can be removed from the machine.

- SLS creates accurate and durable parts but finish out of machine is relatively poor

Selective Laser Sintering - Process

- Build accuracy +/- 0.2 mm
- Build part in 100 or 150 micron layers
- Each layer of powder is selectively melted only where you are forming the final part
- Complexity and internal forms can be made at no extra cost
- Can form complex, detailed parts and combined assemblies
- Refresh rates of between 30 and 100% depending on material choice

3D Systems :

550 x 550 x 750 mm (Pro230) 550 x 550 x 460 mm (Pro140) 0.1 – 0.15mm layer 10 m/sec scan speed 70 watt CO_2 laser	381x 330 x 457 mm 0.1mm layer HiQ - 30 watt CO_2 laser – 5m/sec scan HS - 50 watt CO_2 laser – 10m/sec scan

Sinterstation Pro

Sinterstation HiQ & HiQ + HS

EOSINT P :

700 x 380 x 580 mm	700 x 380 x 580 mm	340 x 340 x 620 mm
0.12 mm layer	0.1 – 0.15 mm layer	0.1 – 0.15mm layer
2 x 50W CO2 laser	2 x 50W CO2 laser	1 x 50W Co2 laser
2 x 6m/s scan speed	5m/s scan speed	6m/s scan speed
35mm build/h	10 - 25mm build/h	35mm build/h
 EOS P730	 EOS P730	 EOS P390

Selective Laser Sintering :Materials

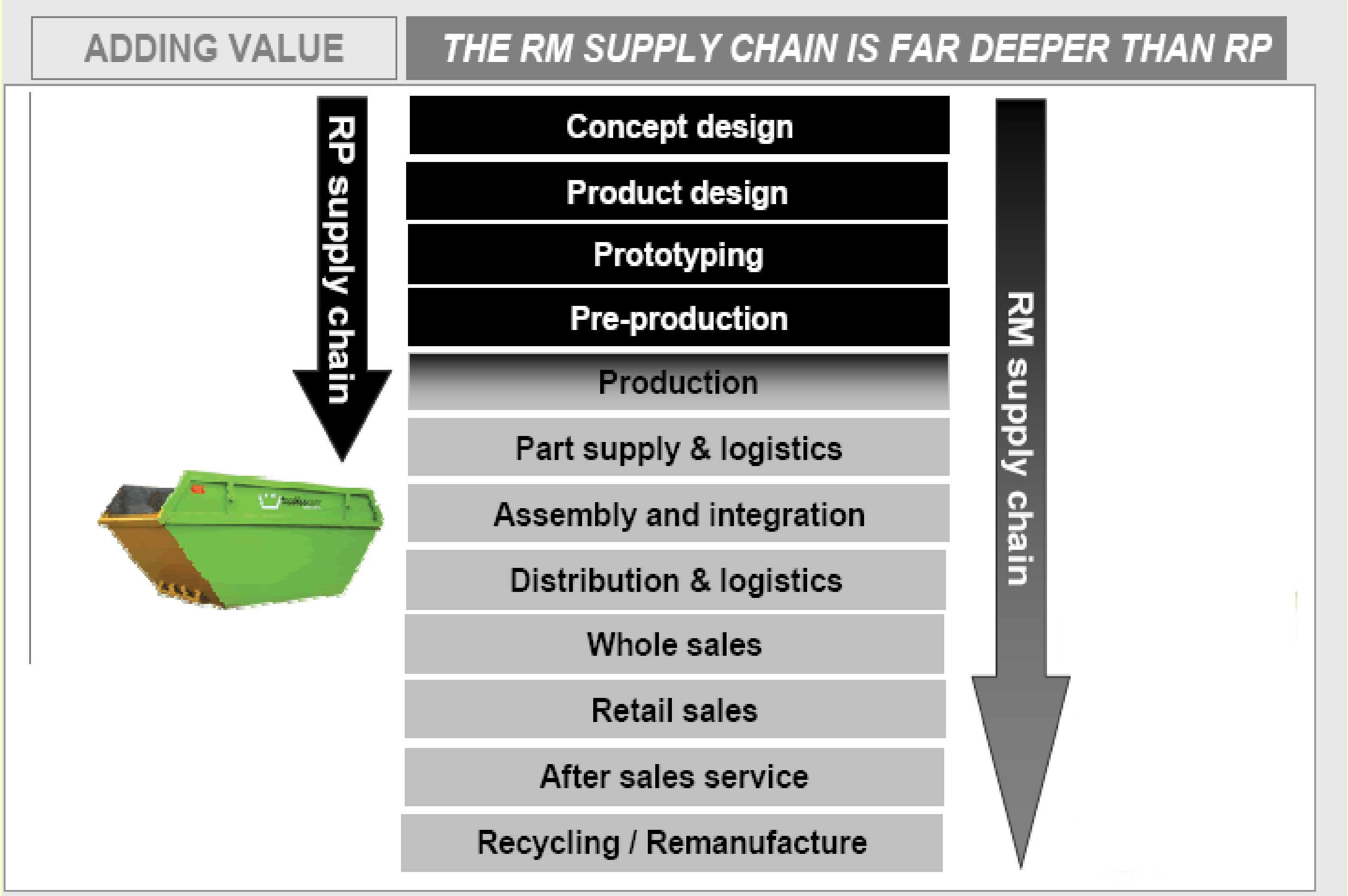
- Polyamides (Nylon 12)
- Glass Filled Nylon
- Carbon Filled Nylon
- Aluminium Filled Nylon
- Peek
- Fire Retardant Polyamide

Applications for Rapid Prototype (RP) and Rapid Manufactured (RM) Components

RM vs RP

RM parts are manufactured using additive technologies with the INTENTION of being used as the final solution

RM vs RP



Source : Econolyst

RM, Opportunities of Adoption

- Enable the economic manufacture of low volume complex geometries and assemblies
- Reduce the need for tooling (moulds / cutters)
- Reduced capital investment
- Simplified supply chains & reduced lead times
- Reduced inventory
- Produces less waste material and recycling
- Just In Time

RM, Opportunities of Adoption

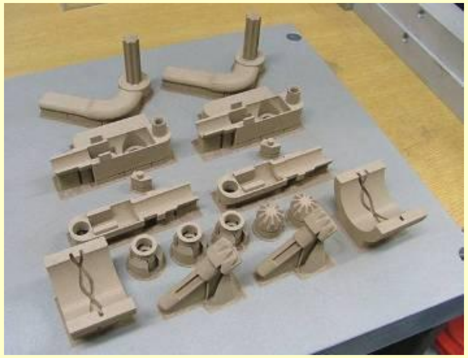
- Affords new design freedoms
- Economic manufacture of topologically optimised components
- Manufacture led design NOT design led manufacture
- Allows for mass customisation
- Enables new business and supply chain models
- Manufacture on Demand
- Flexible design changes with minimal cost

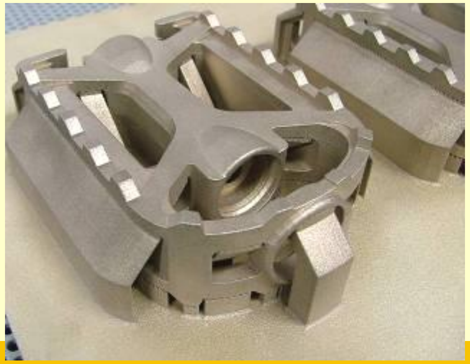
RM, Challenges

- Material Qualification
- Process Qualification
- Compliance with international standards
- Expensive
- Generally restricted to low volume
- Small parts
- Surface finish may need improving

Source : Econolyst

Direct Metal Laser Sintering and Laser Melting





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Direct Metal Laser Sintering and Laser Melting

Metal sintering offers additional functionality over polymer processes:

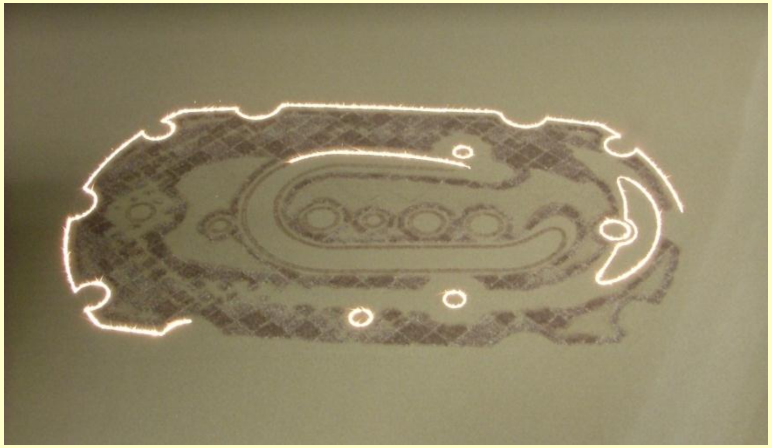
- Larger range of functional materials available
- Parts are able to withstand a larger range of loading scenarios and environments
- Tooling for net-shape processes

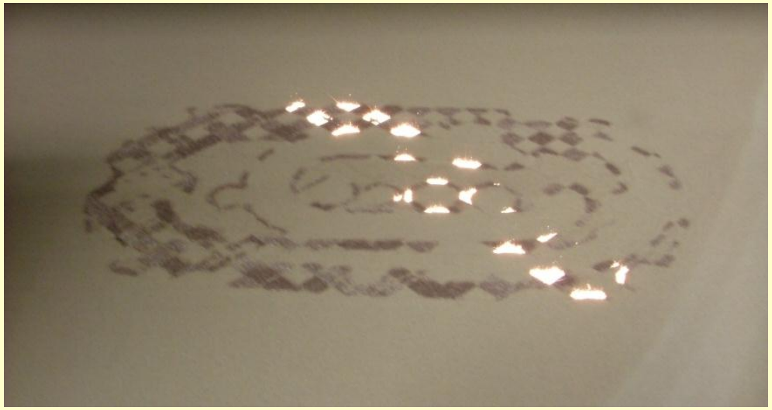
Process is:

- Complex and requires familiarisation
- Parts need to be supported
- Materials need to be qualified.

The Laser Sintering / Melting of Metals (DMLS)

- Start with metal powder (particulate size 10 to 50 microns)
- Build part in 20, 30, or 40 micron layers
- Each layer of powder is selectively melted only where you are forming the final part





The Laser Sintering / Melting of Metals (DMLS)

- Accuracy: +/- 0.05mm
- Surface roughness: 3 – 10 Ra (microns)
- Post machining or EDM may be required
- High volume production possible
- Rapid Manufacture direct from CAD data
- Inserts can be built in 1-4 days

The Laser Sintering / Melting of Metals (DMLS)

- Produces up to 99.9% dense material
- High performance tool inserts
- Can form complex, detailed parts
- Cooling channels can be built into the part at no extra cost
- Cooling channels can conform to the cavity shape "Conformal Cooling"

The Laser Sintering / Melting of Metals (DMLS)

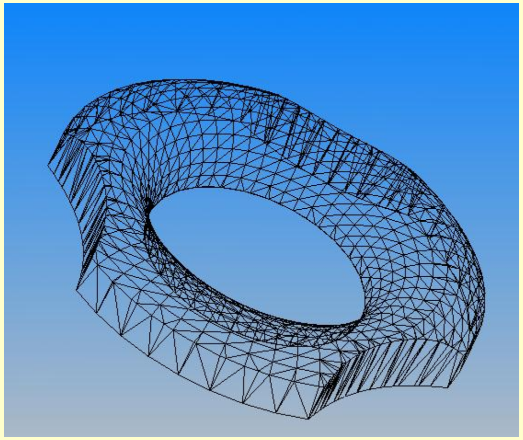
Available metals include:

- Stainless Steel (17-4 PH1)
- Cupro Nickel (DM20)
- Maraging Tool Steel (MS1)
- Cobalt Chrome alloys (MP1)
- Titanium and alloys (Ti64)
- Aluminium Alloys (AlSi10Mg)
- Nickel Based Alloys (Inconel 725, 618)
- Silver Alloys
- Copper Based Alloys

Process Sequence for Manufacture of DMLS Parts:

Data manipulation sequence:

1. Start with a 3D geometry file
2. Generate STL file
3. Orient parts to optimum build direction
4. Generate support structures
5. Slice part & supports horizontally
6. Repair any slice errors
7. Generate slice files
8. Copy slice (.sli) files to the machine



.STL File (Standard Triangulation Language)

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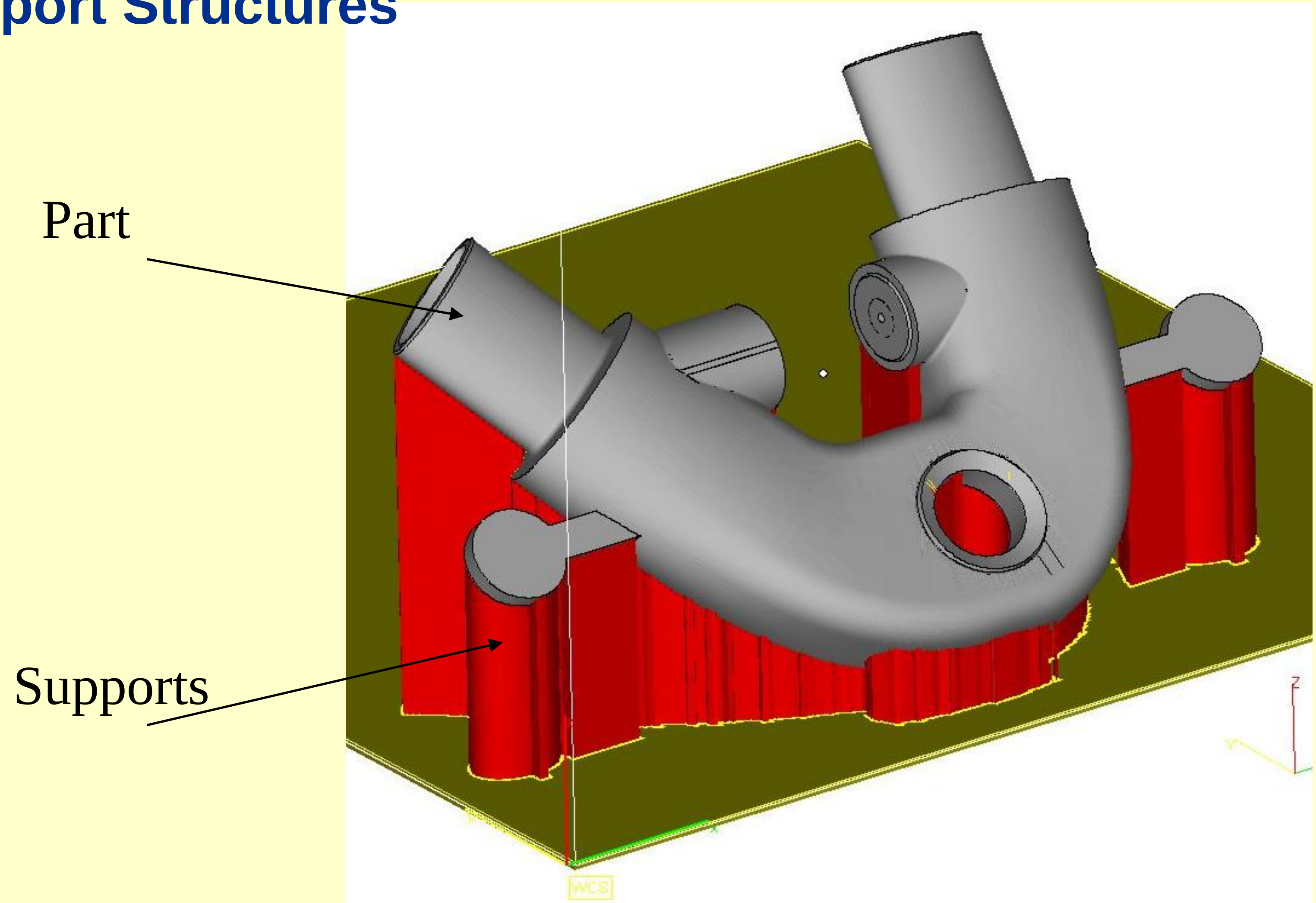
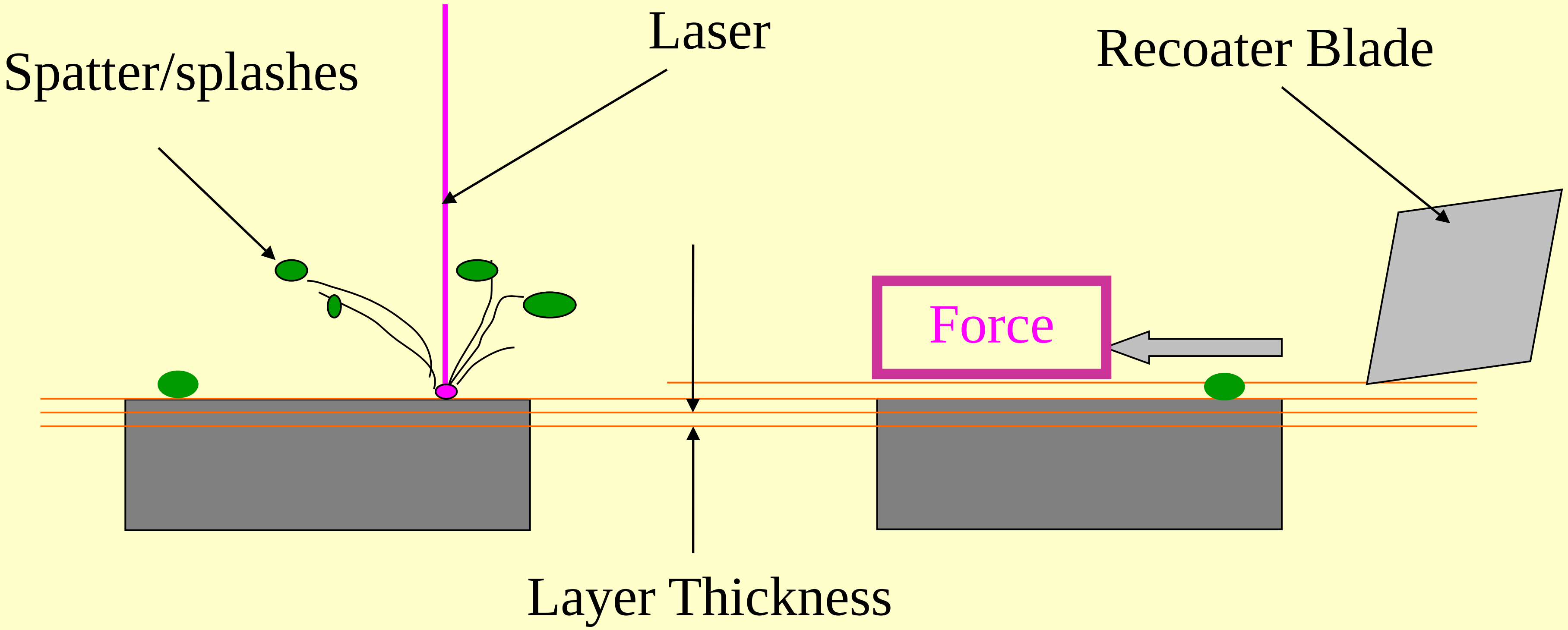
The Laser Sintering / Melting --- Part Manufacture

Support Structures



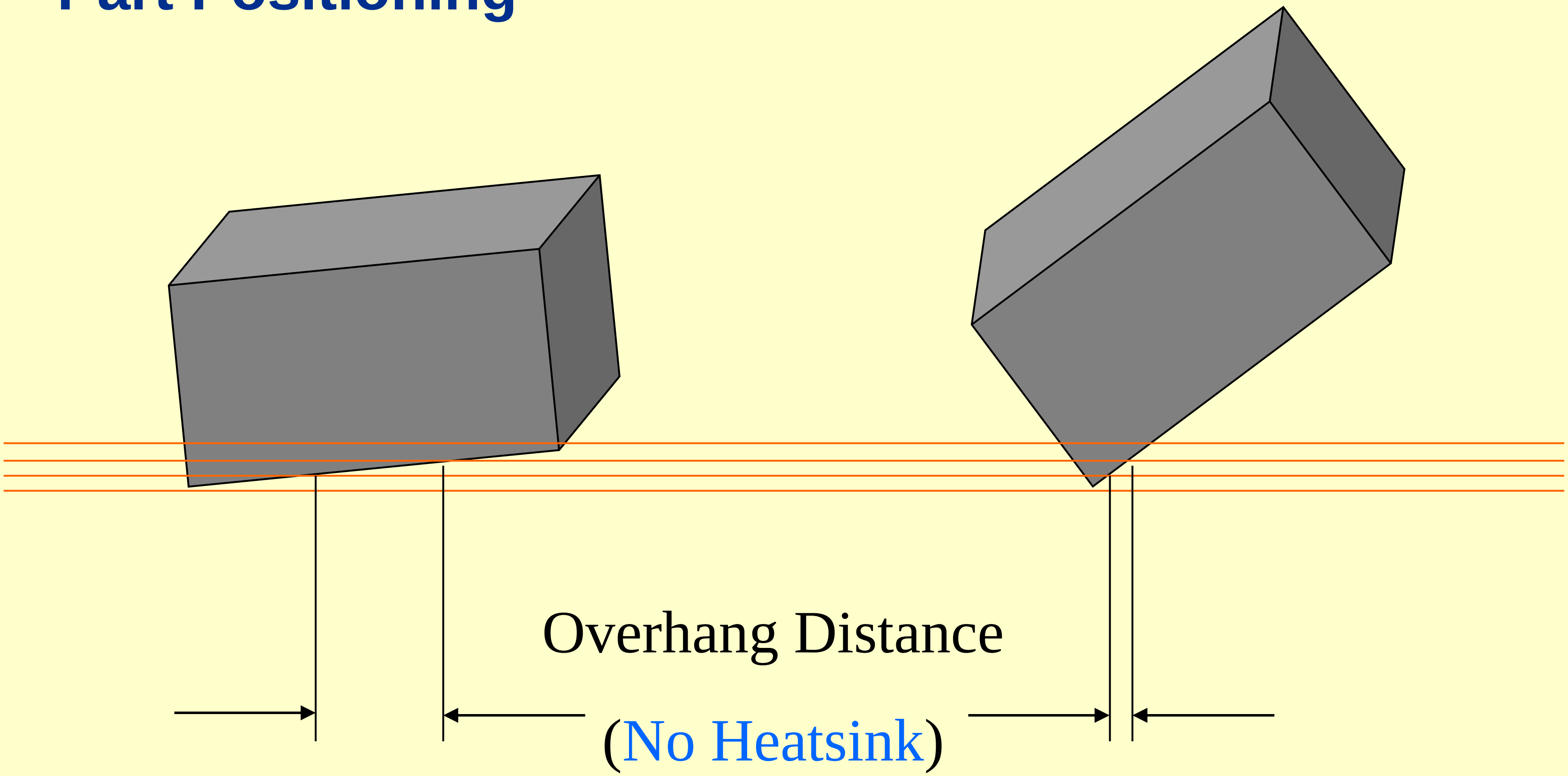
The Laser Sintering / Melting Part Manufacture

Part Restraint



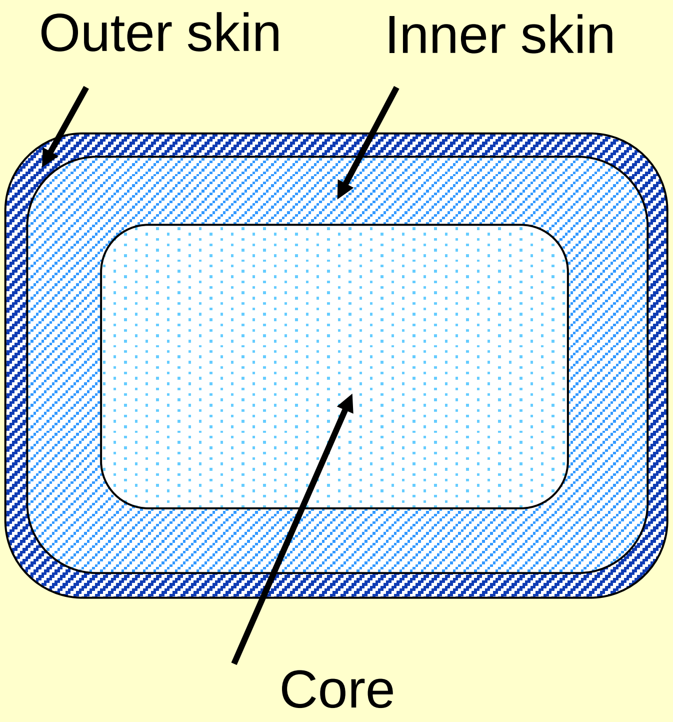
The Laser Sintering / Melting Part Manufacture

Part Positioning



Building Strategies - Skin & Core (Direct Metal20)

- Skin regions require best surface quality and highest density
  - every 20µm layer is exposed for high resolution
  - parameters are used for max. strength and density



- Core regions only require sufficient strength:
  - exposure every 3rd layer (60µm thickness) for high speed
  - fast parameters are used

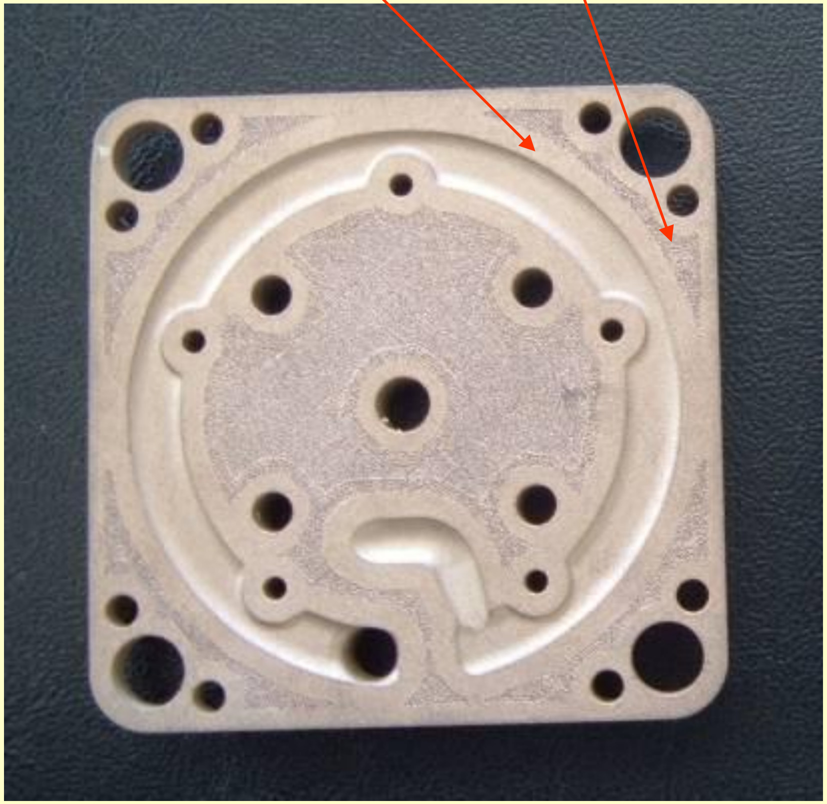
Building Strategies - Skin & Core (Direct Metal20)

Skin : 20µm layer

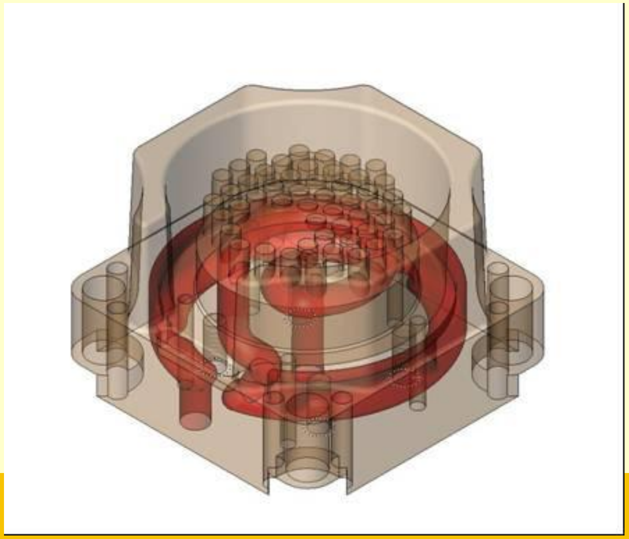
(98% density)

Core : 60µm layer

(94% density)



- Skin 20 – 40 µm layers :
  - best surface finish
  - highest density
  - max. strength
- Core 60 – 80 µm layers :
  - high build speed



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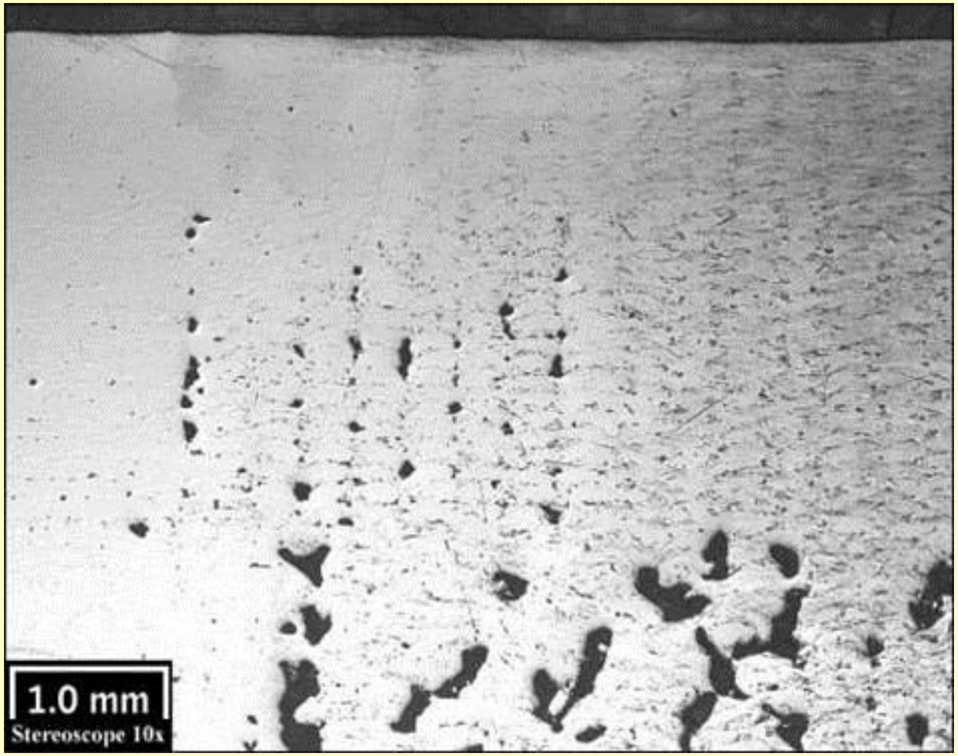
Building Strategies - Skin & Core (Direct Metal20)



Vertical cross-section through directmetal 20 part built on EOSINT M 250 Xt with standard parameters, shot-peened

← Upskin

Outer skin approx. 99.5%

Inner skin approx. 97%

Core approx. 94%

Exposure speed (mm^3/s) of Core can be up to 8x faster than for Outer Skin

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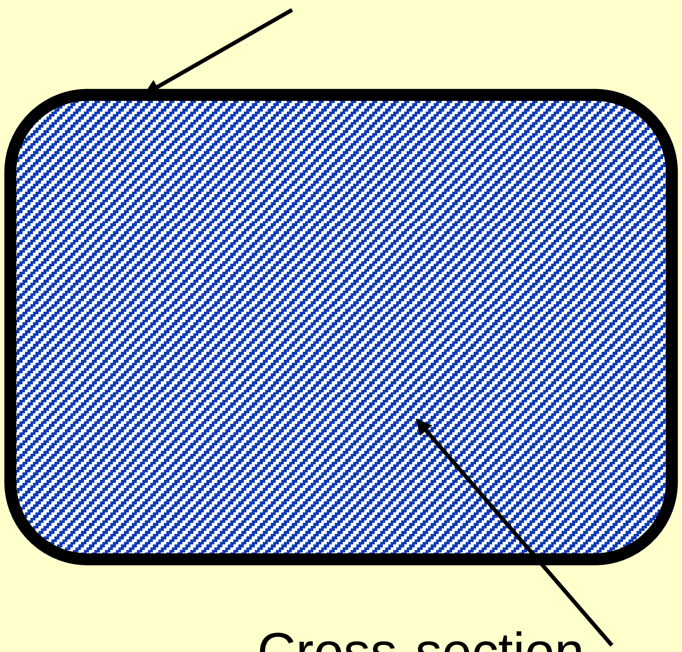
Building Strategies – In Fill (All other metals used)

- No Skin and Core internal section raster scanned in stripes with a set stepover to suit material and diameter of the laser spot.

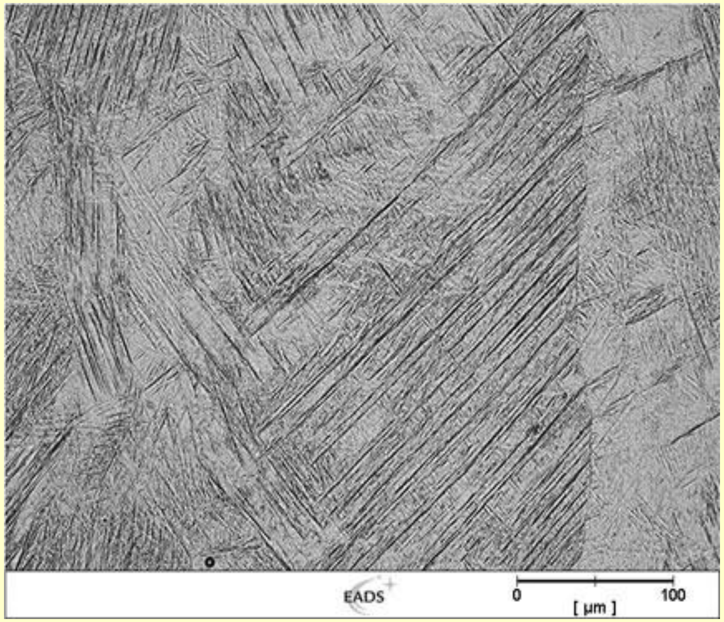
- Pre contours used to define section to melt and post contours used to impart final size of component.



Building Strategies – In Fill (All other metals used)

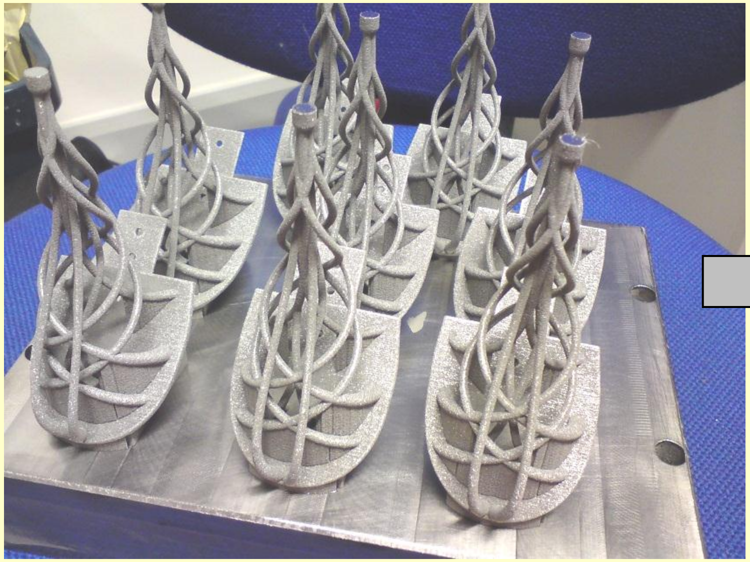
Eg. EOS Titanium Ti64

- Mechanical properties
  - UTS: approx. 1100 MPa
  - yield strength: approx. 1000 MPa
  - Young's Modulus: approx. 117 GPa
  - elongation: approx. 8%
- Physical / chemical properties
  - laser-sintered density: ~ 100 %
  - fulfils ASTM F136 and ASTM F1472 regarding maximum concentration of impurities
    - oxygen <1500ppm or 2000ppm
    - nitrogen < 700ppm
  - Bioadhesion cell growth tested with good results

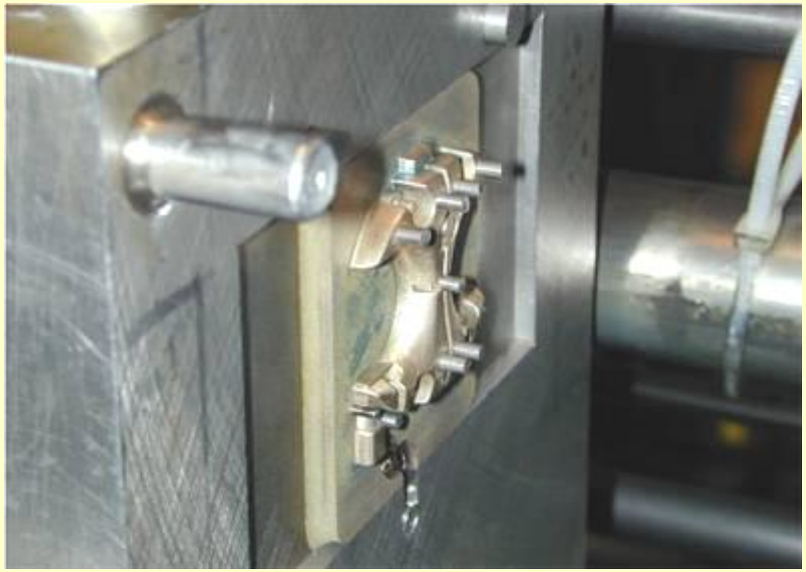


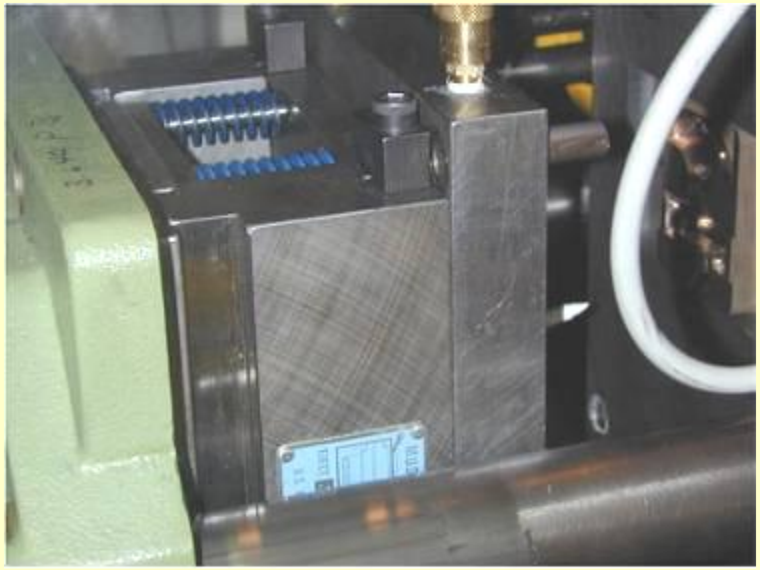
Micrograph of laser-sintered EOS Titanium Ti64, showing fully dense structure (only single pores) and martensitic structure with preferential orientation (picture: EADS)

Example Part builds:



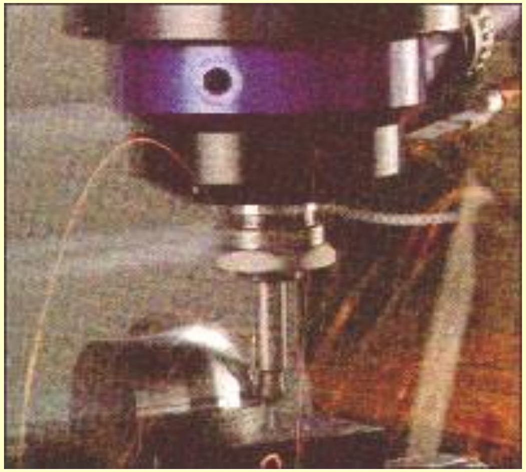
The Laser Sintering / Tooling Manufacture



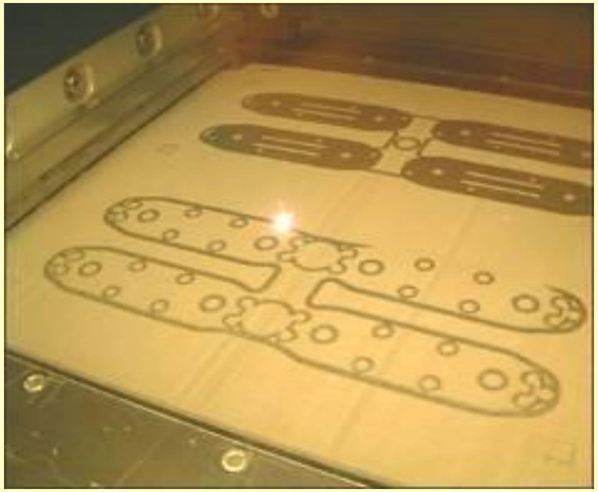


The Laser Sintering / Tooling Manufacture

CNC machining?



Laser sintering ?

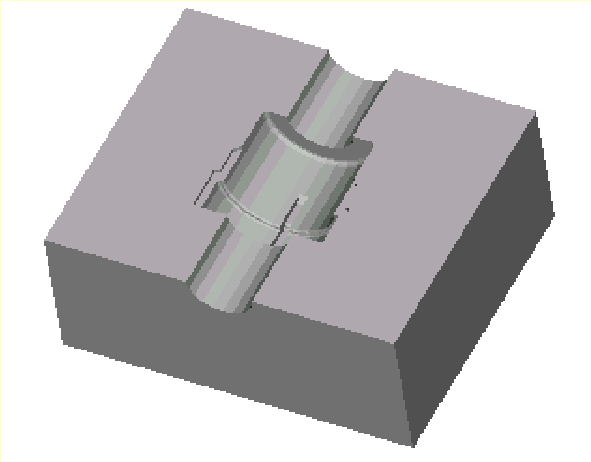


Probably both ?

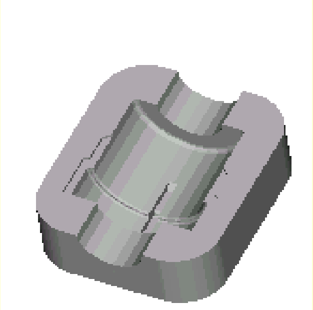
The Laser Sintering / Tooling Manufacture

Design for Manufacturing Method:

- Efficient machining means minimise volume of material to be removed and number of tool or clamping changes
- Efficient laser sintering means minimise volume of material to be laser-sintered



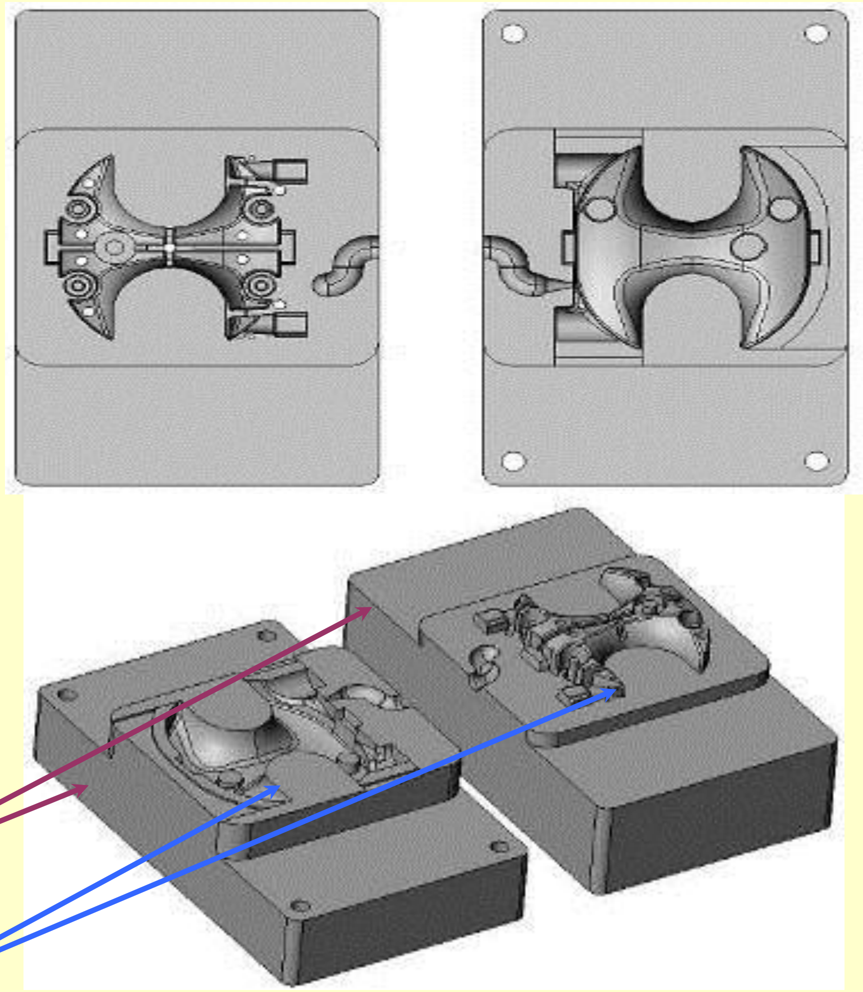
Example of insert designed for machining



Same cavity geometry optimized for DMLS

The Laser Sintering / Tooling Manufacture

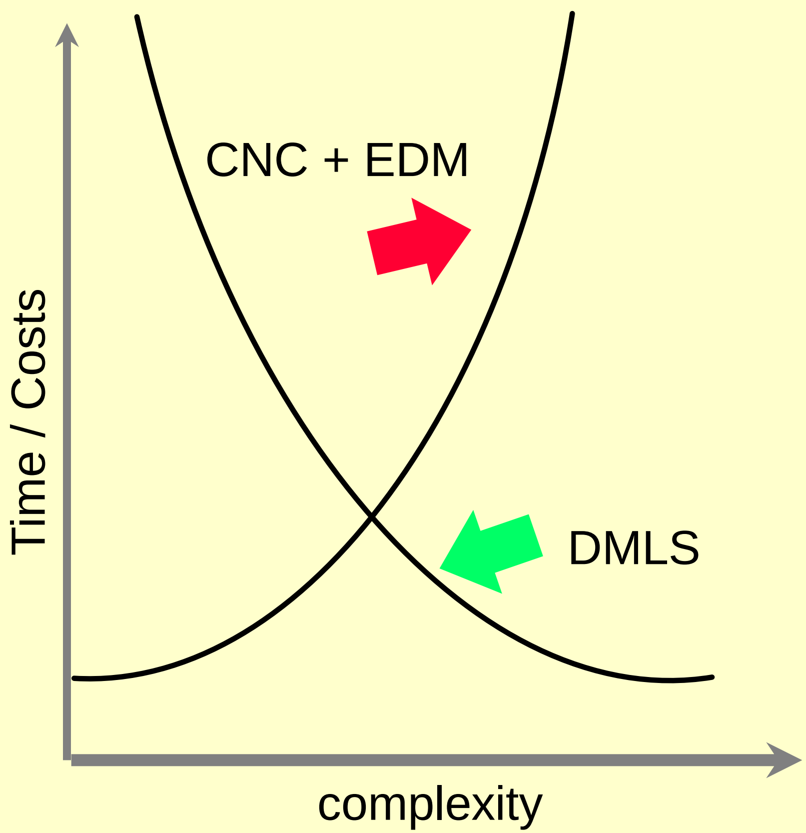
- Build All Features Into CAD Model
- Undersize Ejector Holes by ~ 0.5 mm
- Minimum Standing Feature Size is ~ 0.3 mm”
- 0.5° Min. Draft Angle
- Standing Ribs Max Height/Width is ~ 4:1 Max



Steel Base Plate

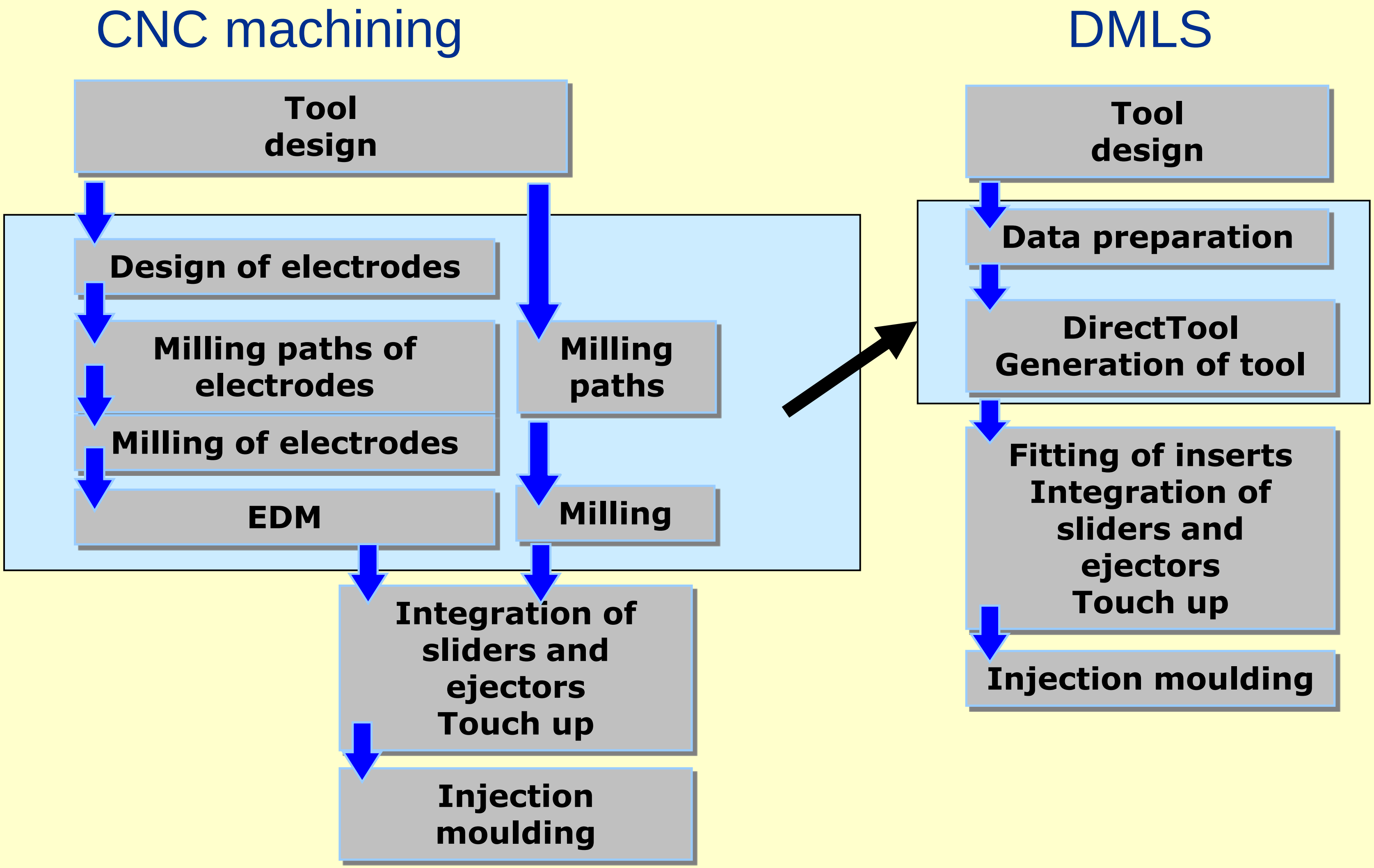
Sintered Volume

When Is DMLS Advantageous?



- No waste material
- No design of electrodes
- No manufacture of electrodes
- No EDM
- No cutter-path generation
- No milling for, or generating complex geometry

Process Route Comparison For Tooling Manufacture



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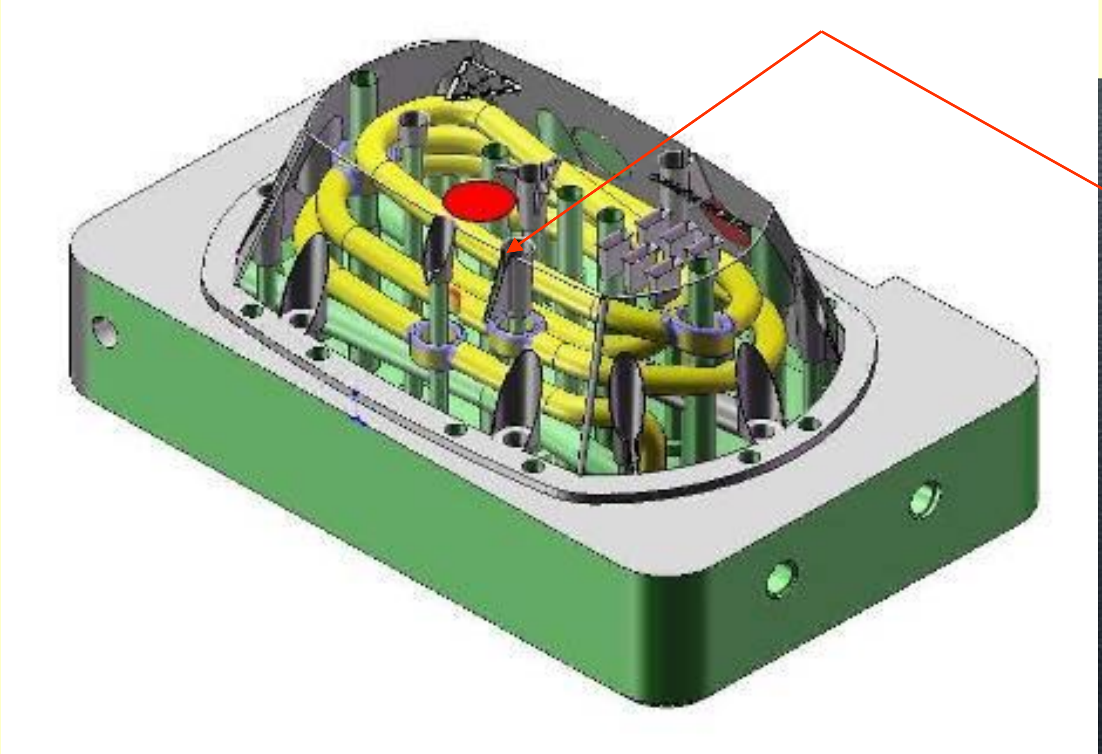
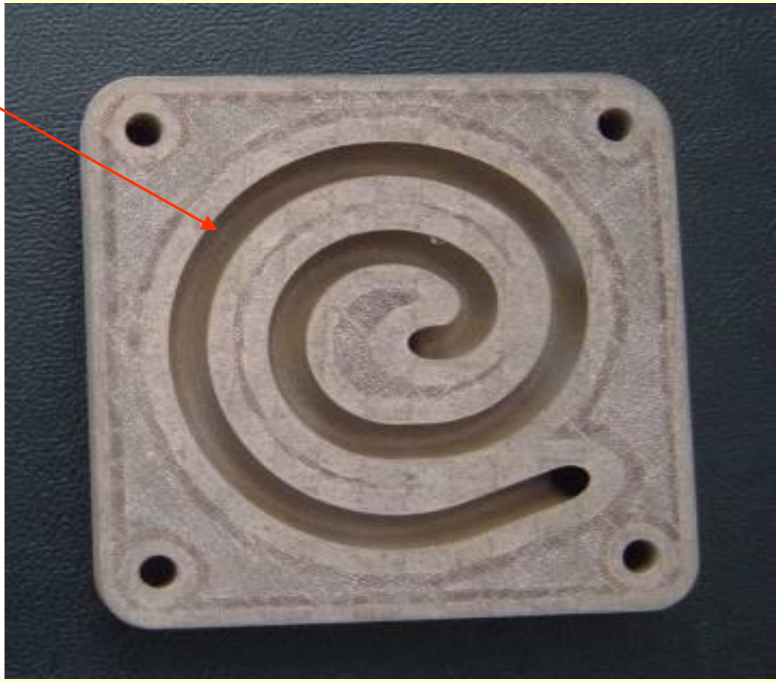
Tooling Manufacture : Why use DMLS?

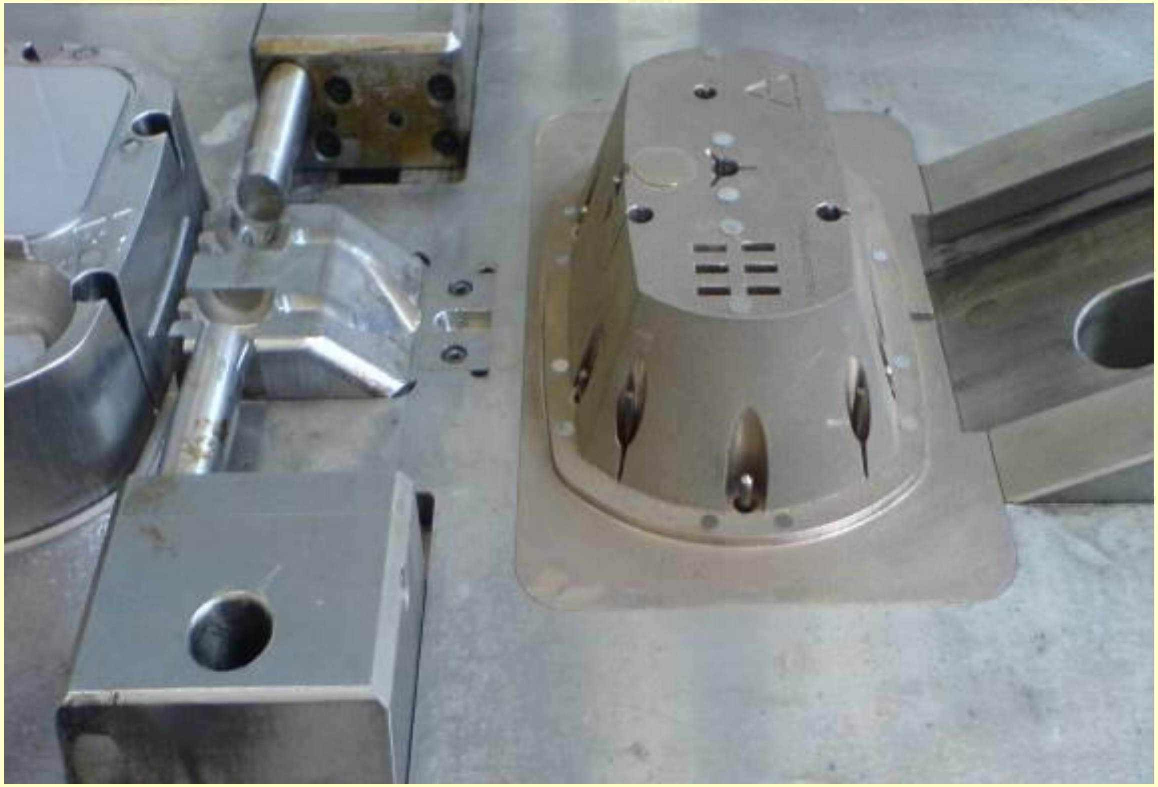
- Conformal cooling capability for improved moulded product quality
- Follows the contours of the tool surface

Conformal cooling channels





- High geometric flexibility
- Injection mould tooling for low and medium volume production using DM20



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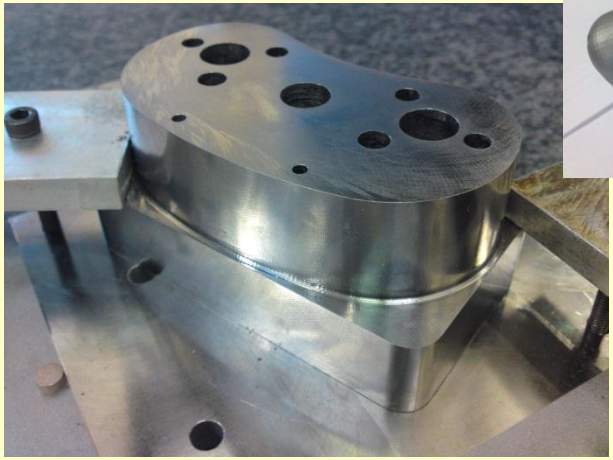
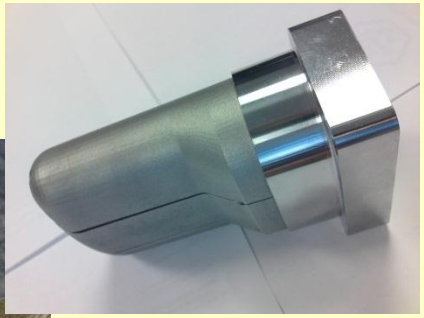
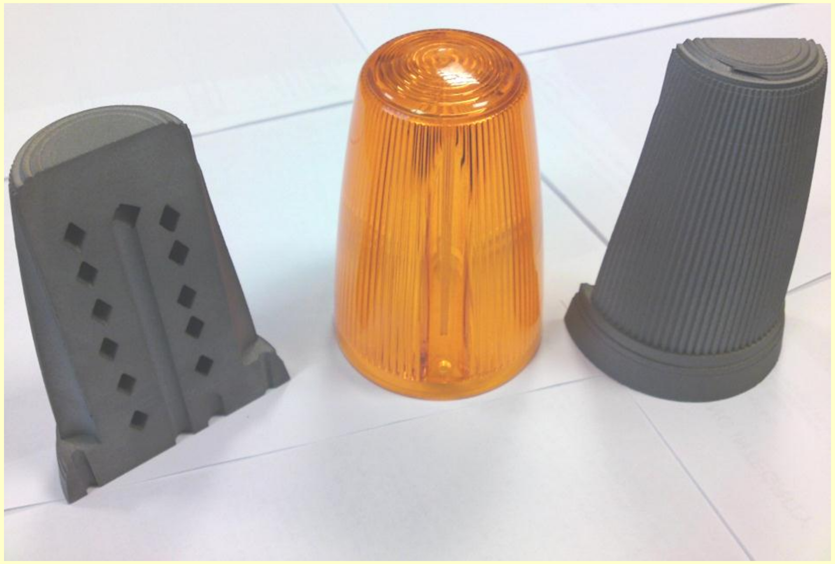
Tooling Manufacture : Why use DMLS?

- Hot spots in tool avoided
- Material density can be controlled for natural venting of tool
- Full series production tooling using Maraging Steel (MS1) Hardenable to 55 Rc







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Tooling Manufacture : CASE STUDIES

55% time saving
30% cost saving

- Prototype single cavity tool
- Part material – Polyamide 66 (Zytel ST801)
- Functional parts for testing
- DMLS build time – 43 hrs
- Cycle time reduction 10%

50% time saving
40% cost saving

- Prototype single cavity tool with conformal cooling
- Part material – Acetal POM (Copolymer)
- Functional parts for testing
- DMLS Build time – 70 hrs
- Cycle time reduction 30%

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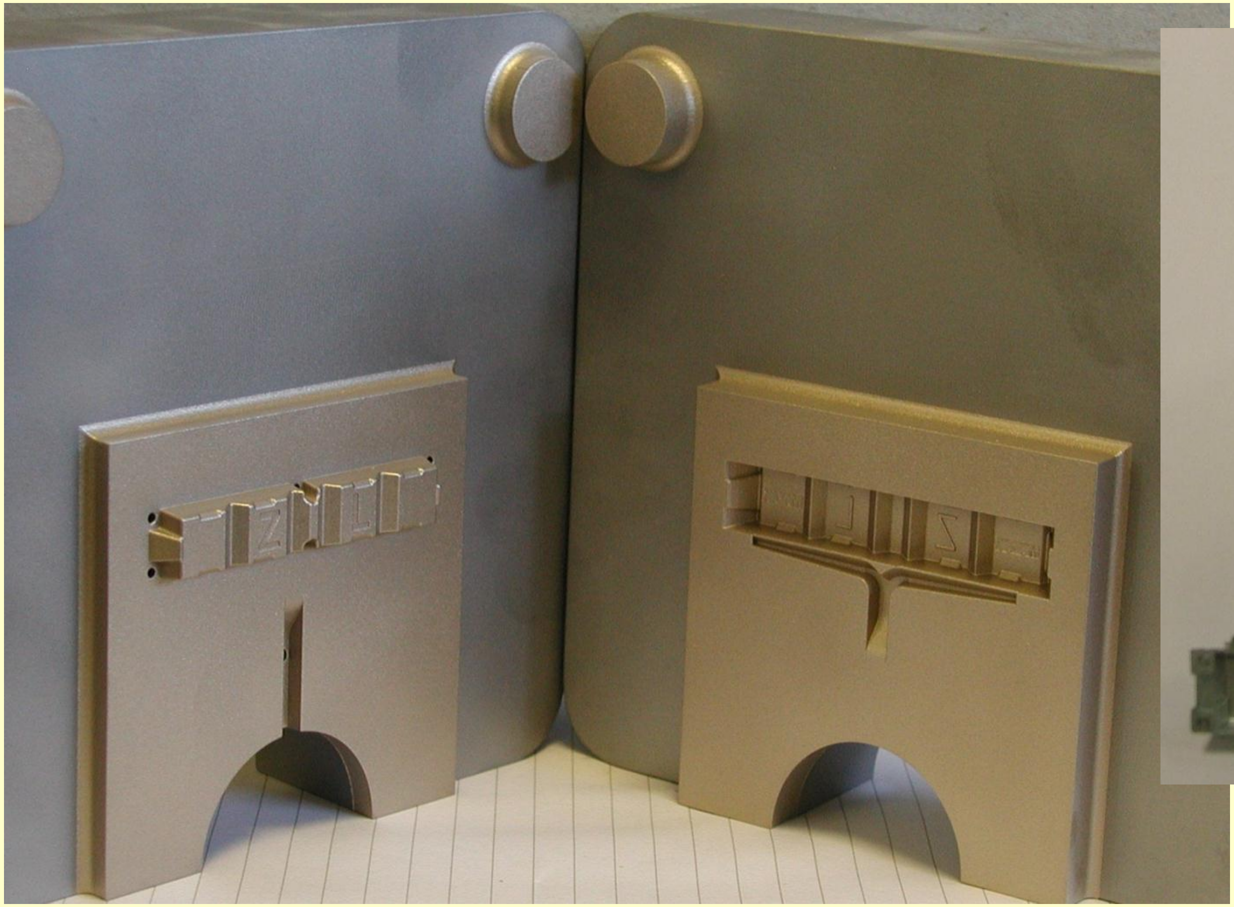
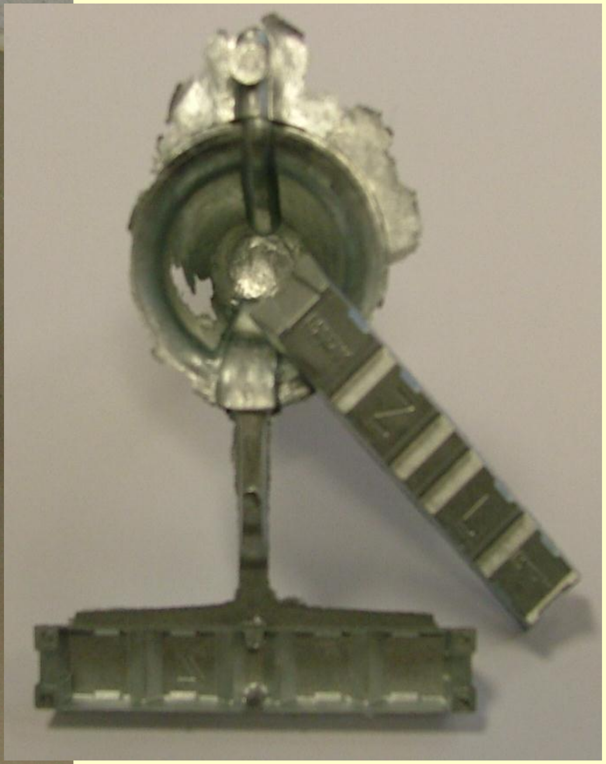
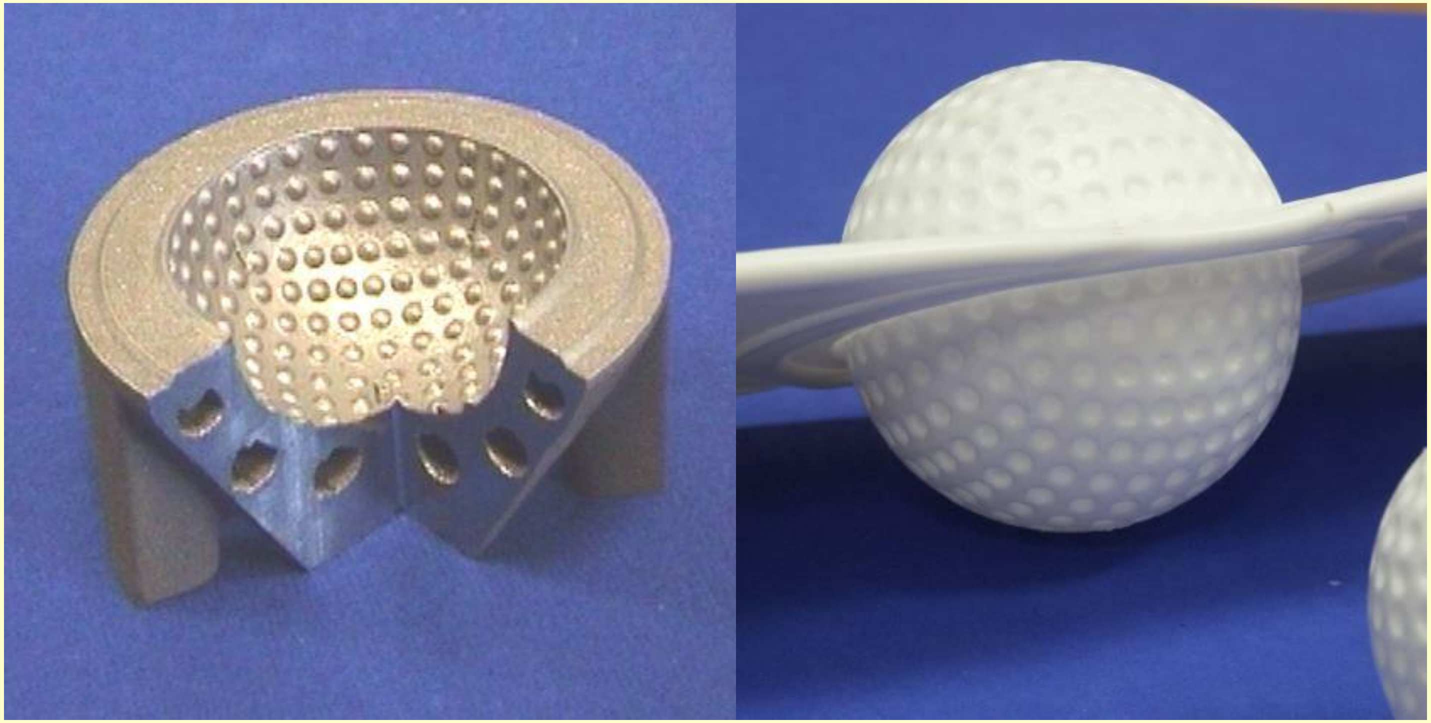




- High Pressure Zinc Die-Casting Tool
- Used to check fluidity of new Mazak ZL5 alloy
- Casting wall thickness 0.12 mm



One sectioned insert from a four-cavity production tool in DirectSteel 20 for blow-moulded golf balls. 20 million balls were produced.

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Core insert from in DirectMetal20 used to form moulten glass 2000 components have been produced.

Laser Sintering / Melting and Research

Scope

- New alloys development
- Tailored materials for specific applications
- Part manufacture to suit downstream processes
- Functionally graded components
- Lightweighting
- etc

DMLS / LM The Future

Three trains of thought

- Machine platform development to meet market demands
- New materials development to meet market demand
- Standardisation and qualification of both platforms and materials

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