EOSINT M Technology
for Direct Metal Laser-Sintering (DMLS)

Source: EOS

e-Manufacturing Solutions

EOSINT M
Direct Metal Laser-Sintering (DMLS)

Contents

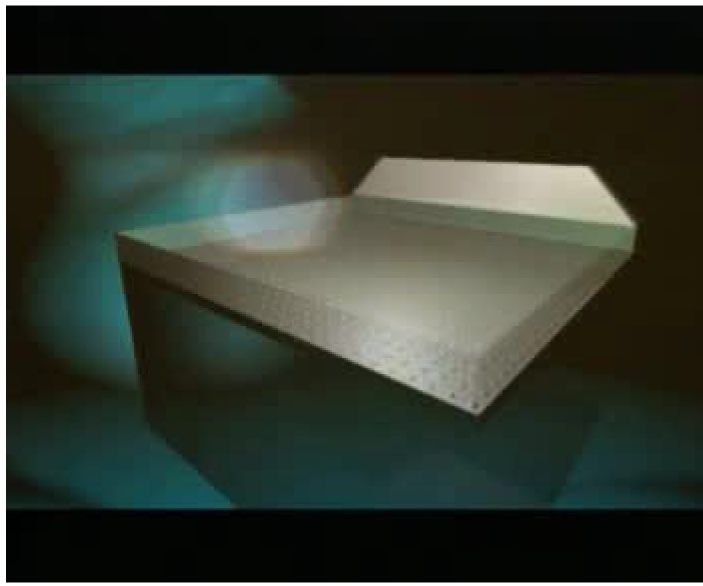
Source: EOS

What is DMLS?

Definition of Laser-Sintering

"A family of methods which manufacture solid parts by solidifying powder-like materials layer-by-layer by exposing the surface of a powder bed with a laser beam"

Powder



Laser-Sintering

Part

Source: EOS

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EOSINT M Technology

Source: EOS

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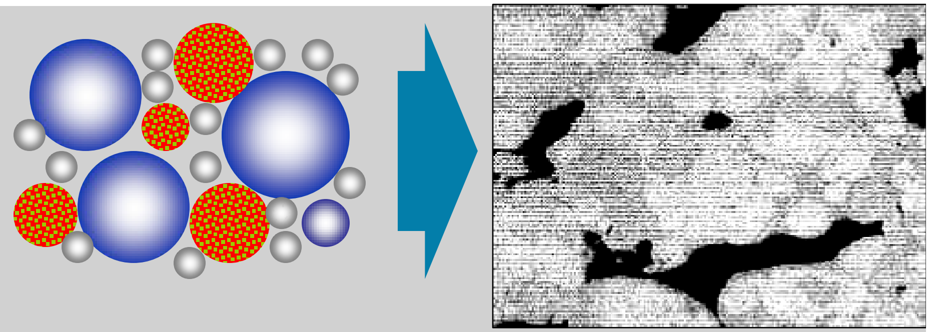
Direct Metal Laser-Sintering (DMLS) Process

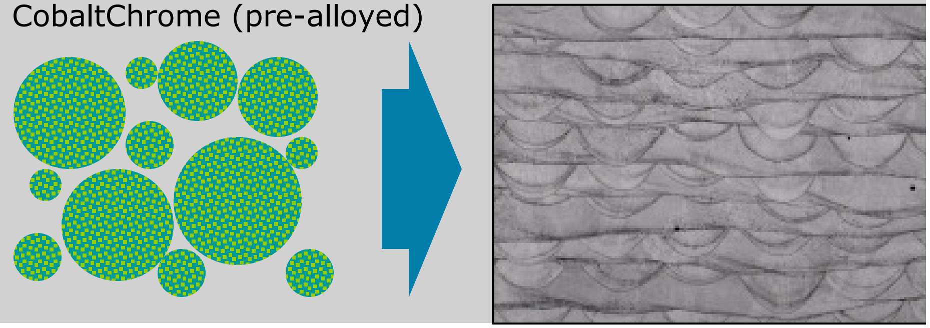
Key characteristics

- Uses only metal powder(s)
  - i.e. no organic binders
- Solid metal part with final properties is created directly in the building process
  - secondary processes can optionally be applied if desired
- Solidification process is:
  - melting or liquid phase sintering of multiple component mixtures (DirectMetal, DirectSteel), or
  - complete melting and resolidification of elemental or pre-alloyed powders (CobaltChrome, Stainless Steel, Titanium etc.)



Above: schematic example DirectMetal (multi-component mixture)

Below: schematic example CobaltChrome (pre-alloyed)



Source: EOS

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EOS offers State-of-the-Art EOSINT M system

EOSINT M 270

- 250 x 250 x 215 mm
- solid state Yb-fibre laser
- 200 Watt
- dual focus
- integrated nitrogen generator
- 20 – 60 micron layer thickness
- 20 – 50 micron tolerances

Source: EOS

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EOSINT M Technology

Real time processing of maraging steel powder

Source: EOS

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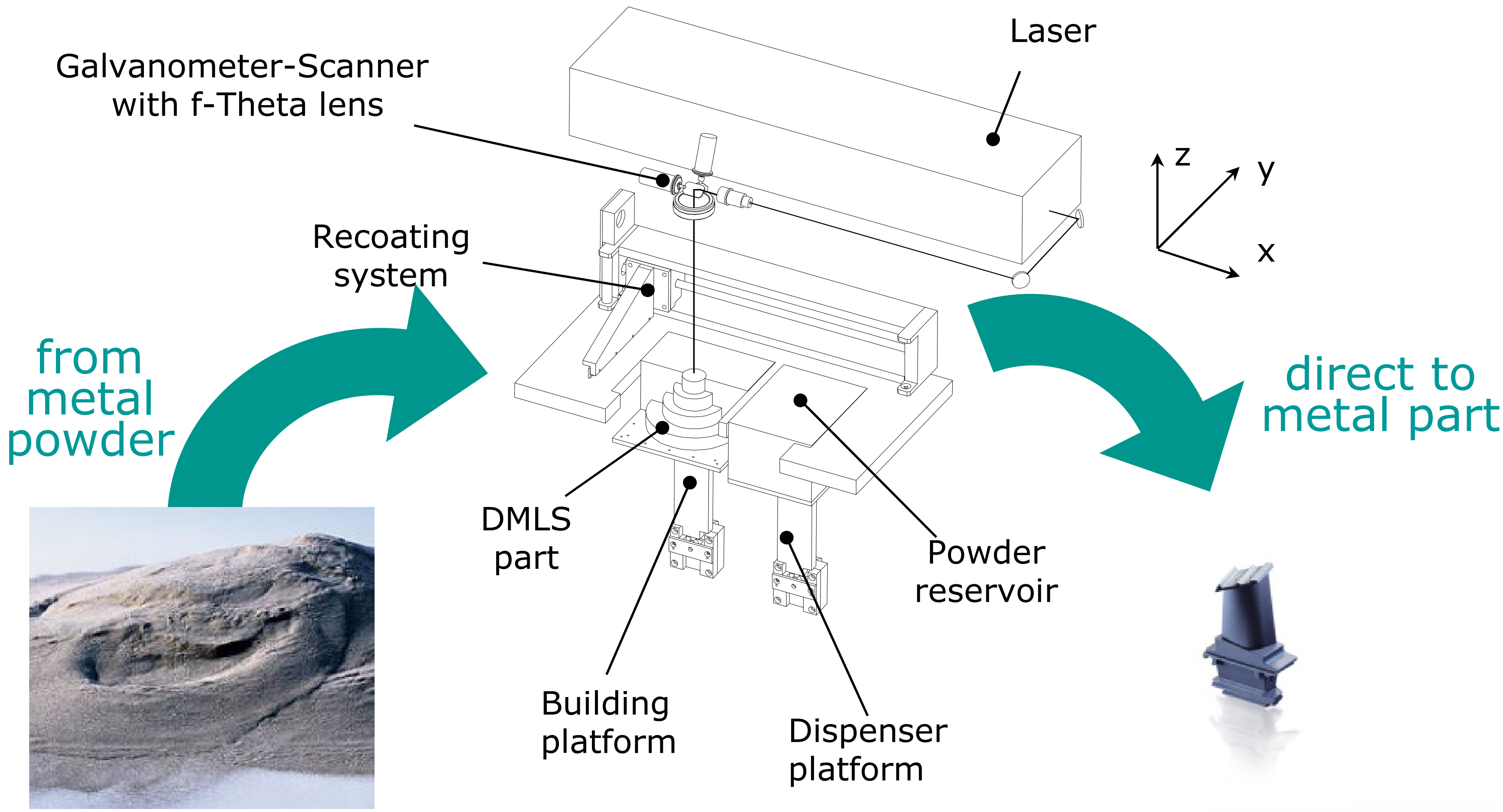
EOSINT M systems convert metal powder to metal parts in a single, direct process



Source: EOS

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EOSINT Materials

Source: EOS

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EOS offers a wide range of application-optimized metal powder materials for EOSINT M systems

Material name	Material type	Typical applications
DirectMetal 20	Bronze-based mixture	Injection moulding tooling; functional prototypes
EOS MaragingSteel MS1	18 Mar 300 / 1.2709	Injection moulding series tooling; engineering parts
EOS StainlessSteel GP1	Stainless steel 17-4 / 1.4542	Functional prototypes and series parts; engineering and medical
EOS StainlessSteel PH1	Hardenable stainless steel	Functional prototypes and series parts; engineering and medical
EOS CobaltChrome MP1	CoCrMo superalloy	Functional prototypes and series parts; engineering, medical, dental
EOS CobaltChrome SP1,2	CoCrMo superalloy	Dental restorations (series production)
EOS Titanium Ti64	Ti6Al4V light alloy	Functional prototypes and series parts; aerospace, motor sport etc.
EOS Titanium TiCP	Pure titanium	Functional prototypes and series parts; medical, dental

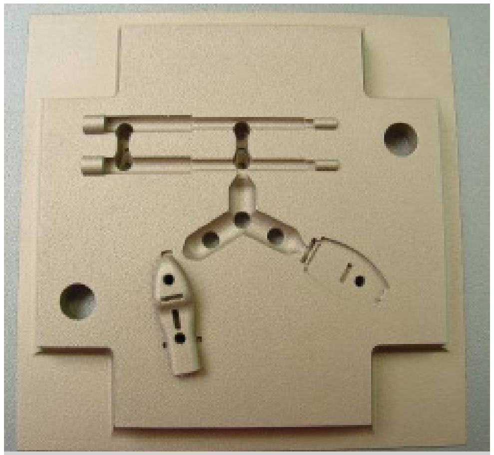
Source: EOS

DirectMetal 20 - bronze-based material for rapid tooling and rapid functional prototypes

Characteristics and applications

- Key characteristics
  - good mechanical properties
  - very fast build rate
  - very easy to finish

- Typical applications
  - injection mould tool inserts for moulding up to hundreds of thousands of plastic parts
  - other tooling applications
  - prototype parts, e.g. for functional tests, wind tunnel testing etc.
  - fixtures, test parts etc.



injection mould insert (Source:: EGi, EOS)

propeller prototype for wind tunnel testing

Source: EOS, EGi

DirectMetal 20 quickly and easily produces functional tooling and parts

Key properties

- Mechanical properties
  - UTS: approx. 400 MPa
  - yield strength: approx. 200 MPa
  - Young's Modulus: approx. 80 GPa
  - hardness: 115 HV
- Physical properties
  - min. remaining porosity : 8 %
    - surface porosity closed by micro-shot-peening
  - massive parts typically built using Skin & Core build strategy
  - max. operating temperature 400 °C

8 piece lockbox assembly in in DirectMetal 20.
Source: Morris Technologies

Injection mould in DirectMetal 20.
Source: FIT GmbH

Source: EOS, Morris Technologies, FIT GmbH

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EOS StainlessSteel 17-4 - stainless steel material for prototyping and series production

Characteristics and applications

- Key characteristics
  - raw material corresponds to 17-4 (1.4542, X5CrNiCuNb16-4)
  - corrosion-resistance
  - excellent ductility
- Typical applications
  - engineering applications including functional prototypes, small series products, individualised products or spare parts
  - parts requiring high corrosion resistance, sterilisability, etc.
  - parts requiring particularly high toughness and ductility

Sieve in EOS StainlessSteel 17-4 for foodstuff packaging machinery.

Benchmark test geometry in EOS StainlessSteel 17-4. Source: NASA / General Pattern.

Source: EOS

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EOS MaragingSteel MS1 - high performance steel for series tooling and other applications

Characteristics and applications

- Key characteristics
  - 18 Maraging 300 type steel (1.2709, X3NiCoMoTi18-9-5)
  - fully melted to full density for high strength
  - easily machinable as-built
  - age hardenable up to approx. 54 HRC
  - good thermal conductivity and polishability
- Typical applications
  - series injection moulding (high volume)
  - other tooling applications, e.g. die casting
  - high performance parts, e.g. in aerospace

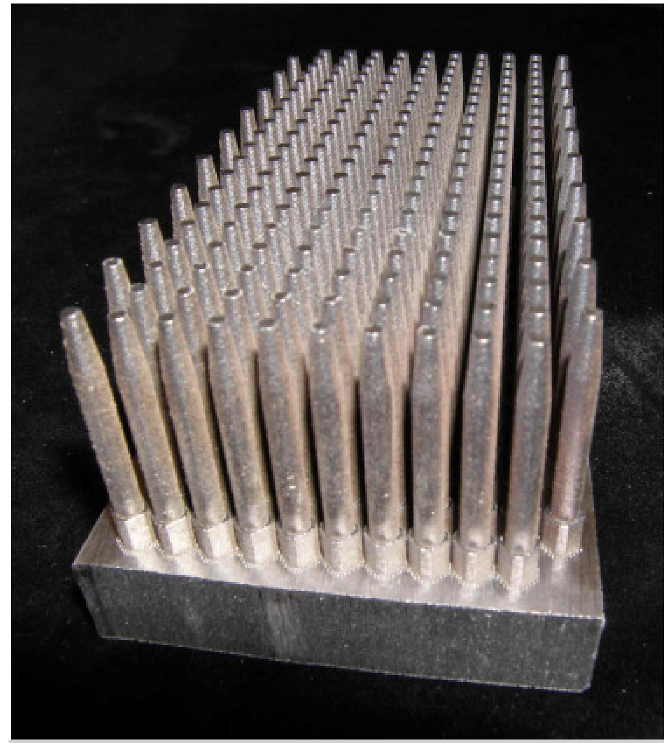
Injection mould insert with conformal cooling, built in EOS MaragingSteel MS1

Source: EOS, Oase

EOS MaragingSteel MS1 is a high performance steel for series tooling and other applications

Key properties

- Mechanical properties as built
  - UTS: 1100 MPa
  - yield strength: 1000 MPa
  - hardness: 33 - 37 HRC
- Mechanical properties after age hardening (6 hours at 490°C)
  - UTS: > 1950 MPa
  - yield strength: > 1900 MPa
  - hardness: 50 - 54 HRC
- Physical properties
  - relative density as built: approx. 100 %



200 internally cooled pin inserts for injection moulding, built in EOS MaragingSteel MS1. Source: LBC GmbH

Source: EOS, LBC

Various types of steels are conventionally used for injection moulds, depending on the requirements

Summary of tool steel types with examples

Material type	Examples / designations AISI / Material No. / German	Characteristics & applications
Nitriding steels	---- / 1.7735 / 14 CrMoV 6 9	Hard surface but low toughness. Used for screws and extruders
Case-hardened steels	P4 / 1.2341 / X 6 CrMo 4 P21 / 1.2764 / X 19 NiCrMo 4	Case-hardening: hard surface with tough core; warpage risk
Through-hardened steels	H11 / 1.2343 / X 38 CrMoV 5 1 D2 / 1.2379 / X 155 CrVMo 12 1	Typ. precipitation hardening. High hardness but low toughness
Maraging steels	18 Mar 300 / 1.2709 / X 3 NiCoMoTi 18 9 5	Age hardening: hard and tough, very low shrinkage
Pre-hardened steels	P20 / 1.2311 / 40 CrMnMo 7 P20+S / 1.2312 / 40 CrMnMoS 8 6	No post-hardening needed
Corrosion-resistant steels	420SS / 1.2083 / X 42 Cr 12 ---- / 1.2316 / X 36 CrMo 17	For moulding corrosive plastics, e.g. PVC

Source: Mold-Making Handbook, ed. Menning, 1998

Various types of steels are conventionally used for injection moulds, depending on the requirements

DIN Spec	AISI/ SAE	Chemical Composition (Typical Analysis in %)										
Case hardening steels		**C**	**Si**	**Mn**	**S**	**Cr**	**Mo**	**Ni**	**V**	**Co**	**Ti**	**Al**
1.2764	~P2	0.18	0.2	0.4	-	1.2	0.2	4.0	-	-	-	-
Heat treated steels												
1.2311	P20	0.4	-	1.5	-	1.9	0.2	-	-	-	-	-
Corrosion resistant steels												
1.2063	420	0.42	-	-	-	13.0	-	-	-	-	-	-
Through hardening steels												
1.2344	H13	0.4	1.0	-	-	5.3	1.4	-	1.0	-	-	-
Nitriding steels												
1.8550	-	0.35	-	-	-	1.7	0.2	1.0	-	-	-	1.0
Maraging steels												
1.2709	18 Mar 300	0.03	-	-	-	-	5.0	18.0	-	10.0	1.0	-

Source: Mold-Making Handbook, ed. Menning, 1998

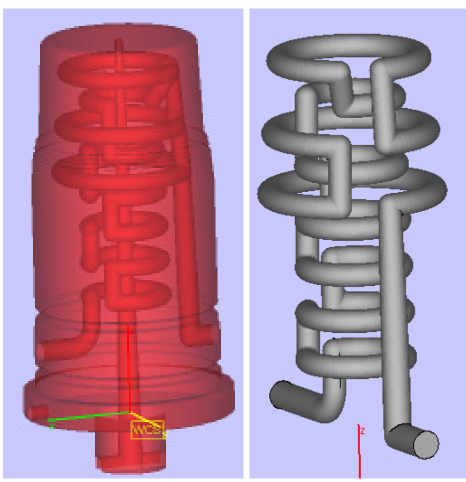
EOSINT Building Strategies

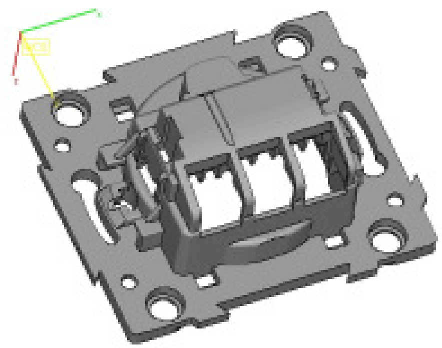
Source: EOS

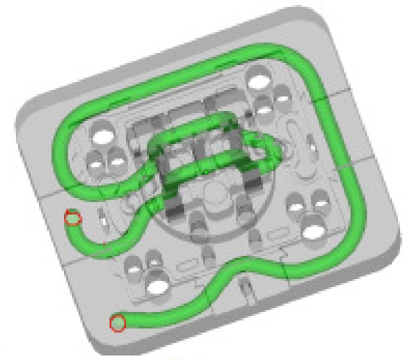
EOSINT M can build complicated conformal cooling channels along profile of parts

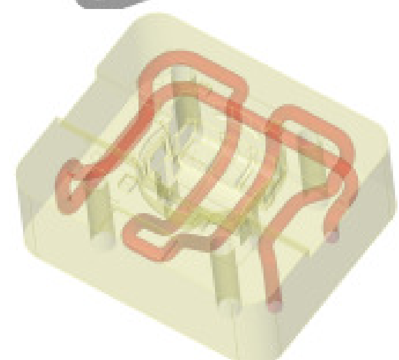
- Create optimum cooling channel in CAD data

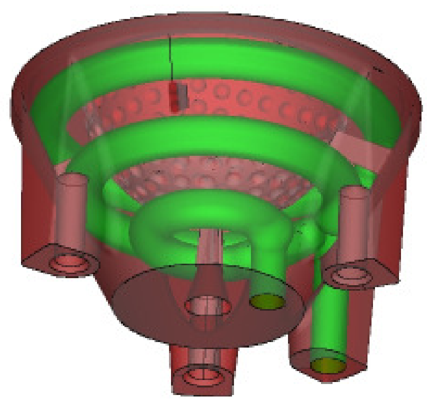
- Close to the model geometry





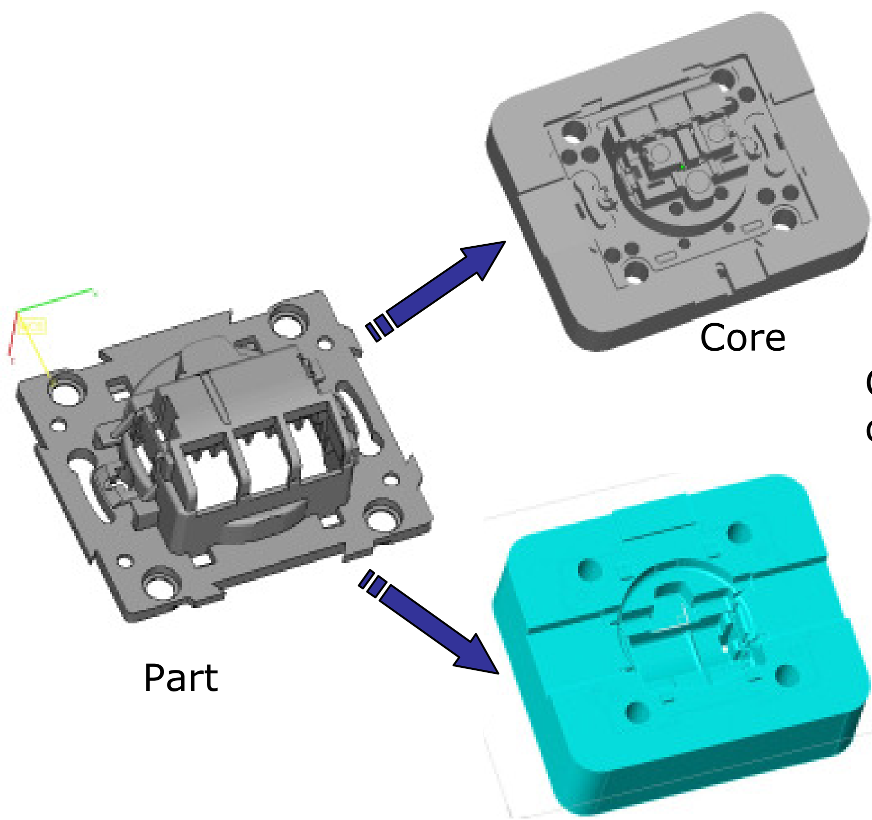


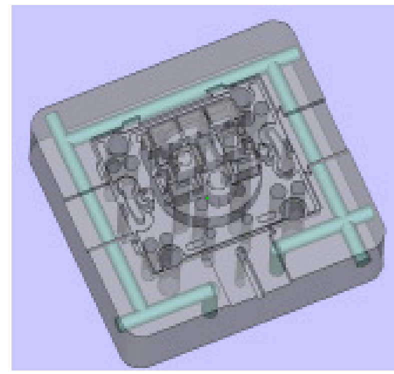


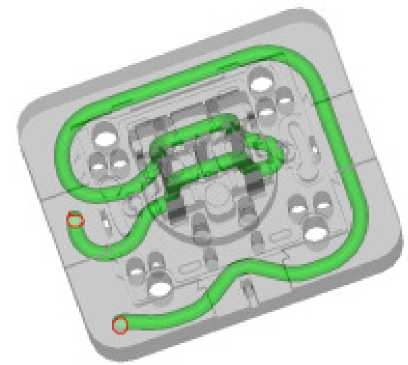


Source: EOS

DirectTool with EOSINT M enables optimization of tooling, e.g. by integrating conformal cooling

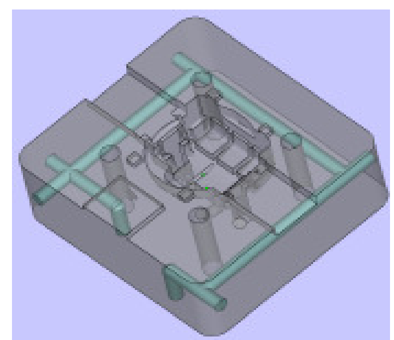


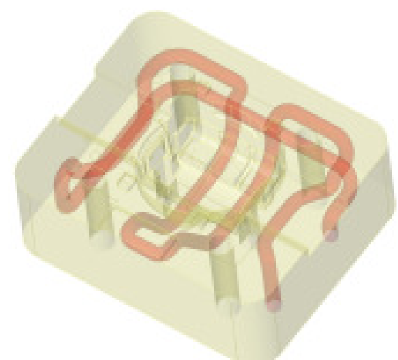




Conventional inserts with drilled cooling channels

DirectTool inserts with conformal cooling channels

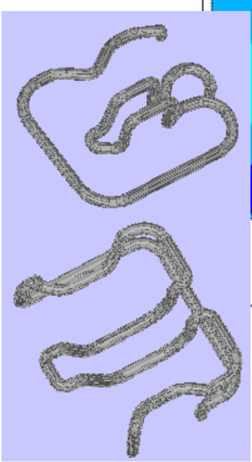


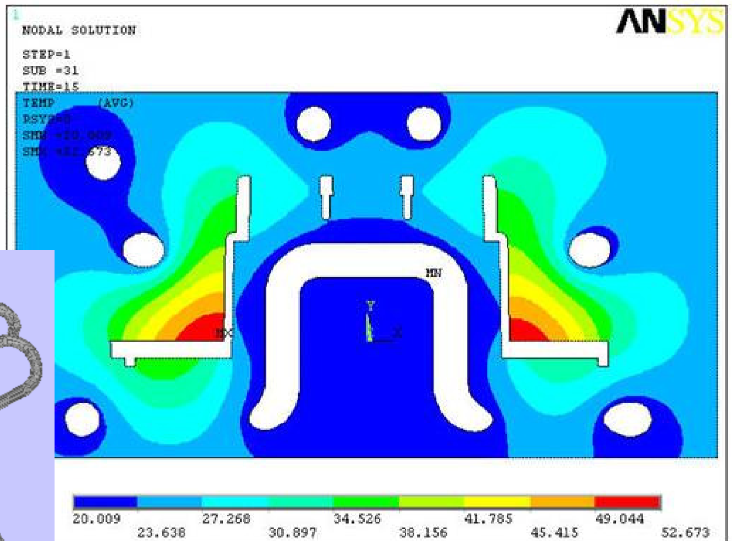


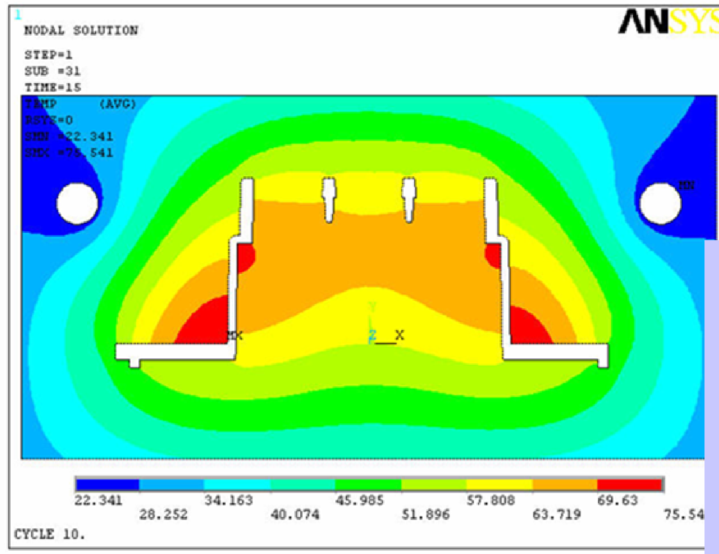
Source: PEP and Antiope project

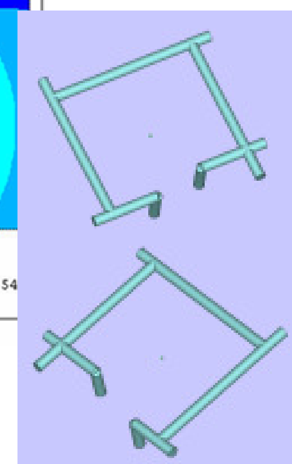
Conformal cooling can greatly reduce hot spots, temperature gradients and/or moulding cycle time

Temperature of mould, cycle no. 10 @ t= 15 s









DirectTool, conformal cooling

Hot spot: 52.6 °C

Traditional machining

Hot spot: 75.5 °C

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Antiope

Source: PEP and Antiope project

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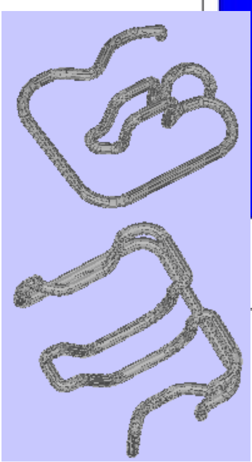
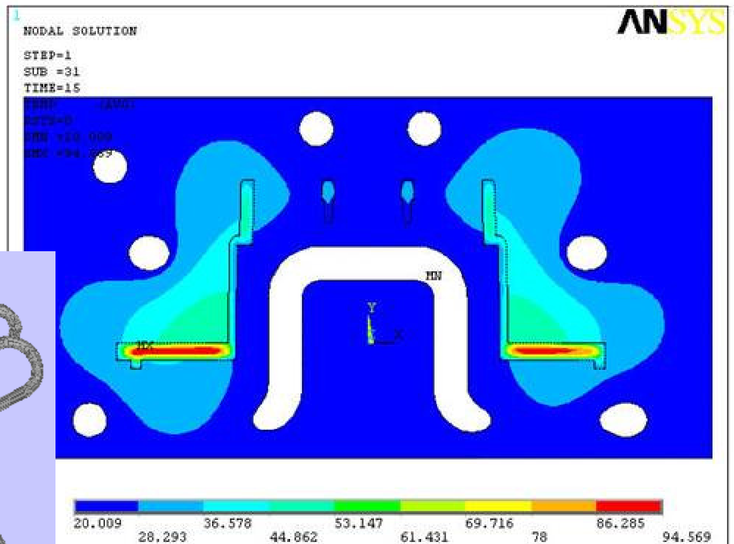
Conformal cooling can greatly reduce hot spots, temperature gradients and/or moulding cycle time

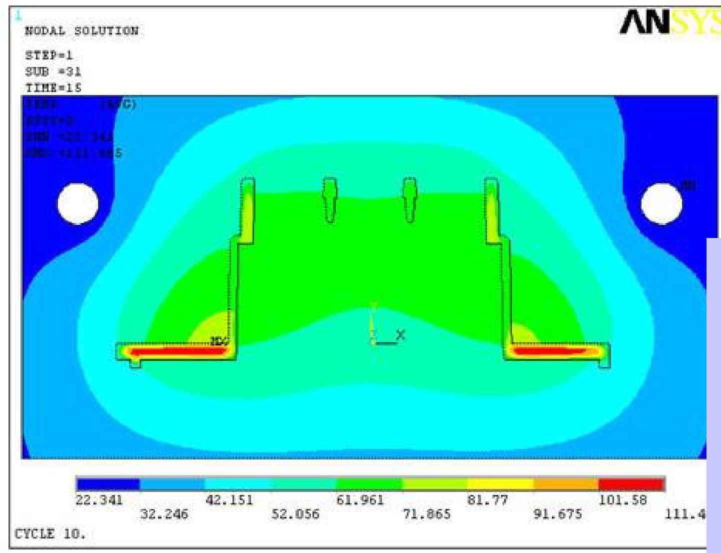
Temperature of plastic part, cycle no. 10 @ t= 15 s





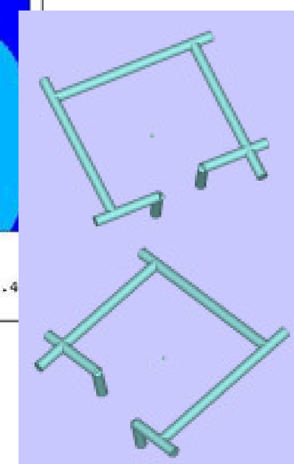
DirectTool, conformal cooling

Hot spot: 94.5 °C



Traditional machining

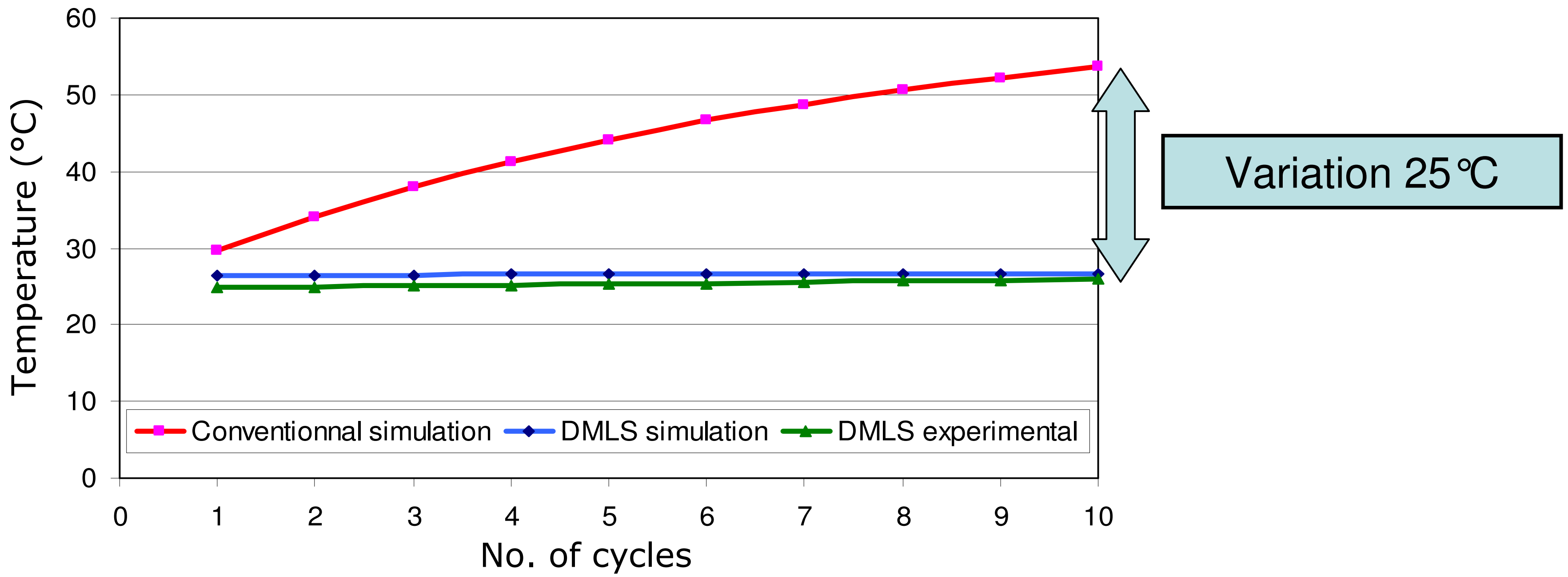
Hot spot: 111.5 °C



Source: PEP and Antiope project

Experimental measurements on the DirectTool mould verify the simulation results

Comparison using 5mm thermocouple on core

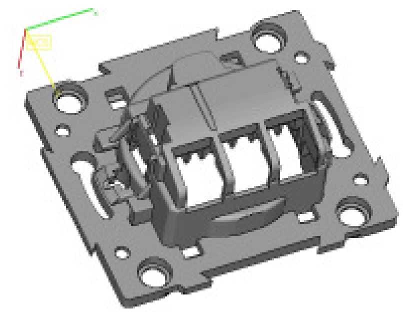


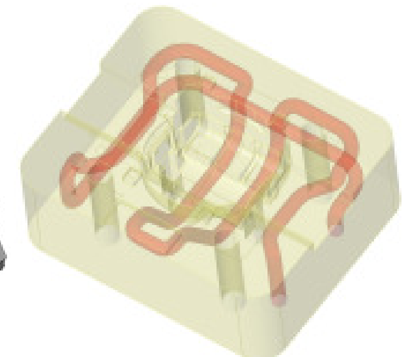
Source: PEP and Antiope project

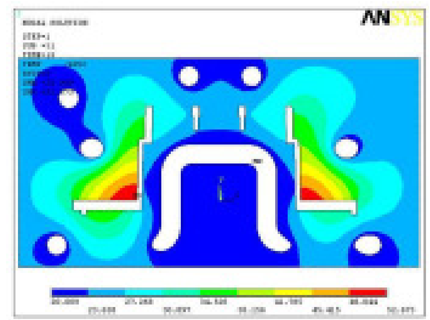
PEP and the Antiope project have investigated the optimization of tooling using DirectTool

Project summary

- Requirement:
  - injection moulding tooling for 50,000 parts in ABS or PP+50%GF
  - optimization of time and costs
- Solution:
  - DirectTool with EOSINT M
  - integrated conformal cooling channels
- Result
  - reduced lead time and costs for tool production
  - increased productivity







Top left: Plastic part (Legrand electrical box)
Top right: DirectTool cavity with conformal cooling
Bottom right: temperature distribution in mould

Source: PEP and Antiope project

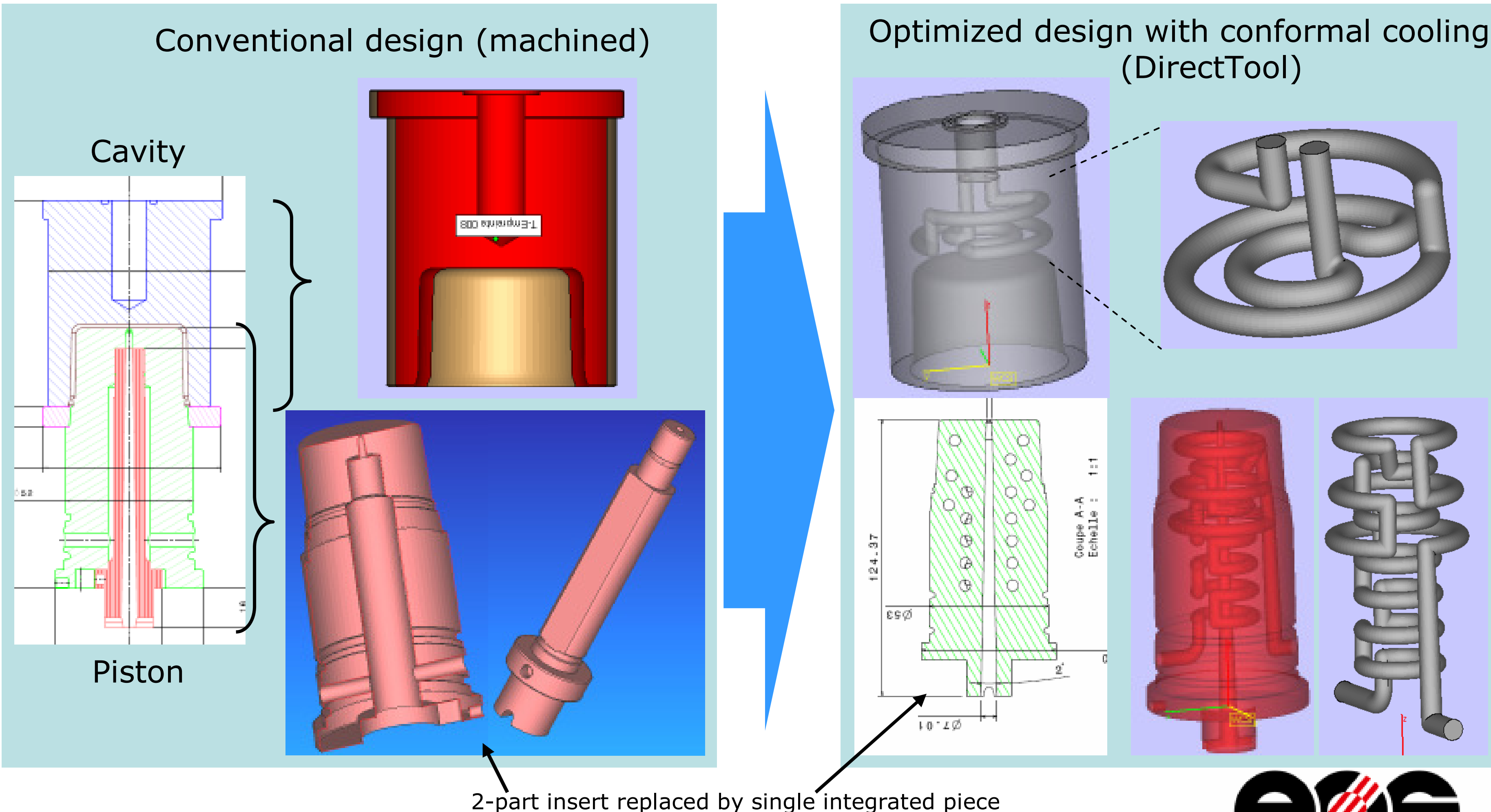
Conformal cooling can greatly reduce hot spots, temperature gradients and/or moulding cycle time

Conclusions

- DirectTool with EOSINT M offers time and cost savings compared to conventional methods:
  - working time for conventionally manufactured tooling: **300 h**
  - working time for DirectTool tooling with conformal cooling:
    EOSINT M 270 with MaragingSteel MS1: 35 h build + ca. 50 h finish = **85 h**
- Using conformal cooling enables better thermal management of injection mould tooling
  - hot spots and temperature gradients can be reduced → less risk of part warpage
  - operating temperature of tool can be reduced → moulded parts ejected faster
    → reduced cycle time → increased productivity → reduced cost per part

Source: PEP and Antiope project

Redesign for DirectTool reduced the number of tool elements whilst integrating conformal cooling



Source: PEP

PEP has made detailed investigations of conformal cooling on a cap moulding tool

Project summary

- Cavity and piston were built by DirectTool
  - build time with EOSINT M250 & DSH 20 was 120 h
  - (build time with new EOSINT M 270 & MaragingSteel MS1 would be 35 h)
- Cavity temperature was measured after each cycle on both DirectTool and conventional moulds
- Tests carried out with different:
  - water temperatures
  - cooling times
  - polymers

DirectTool piston and cavity built on EOSINT M system. Diameter 60mm, height 130mm.

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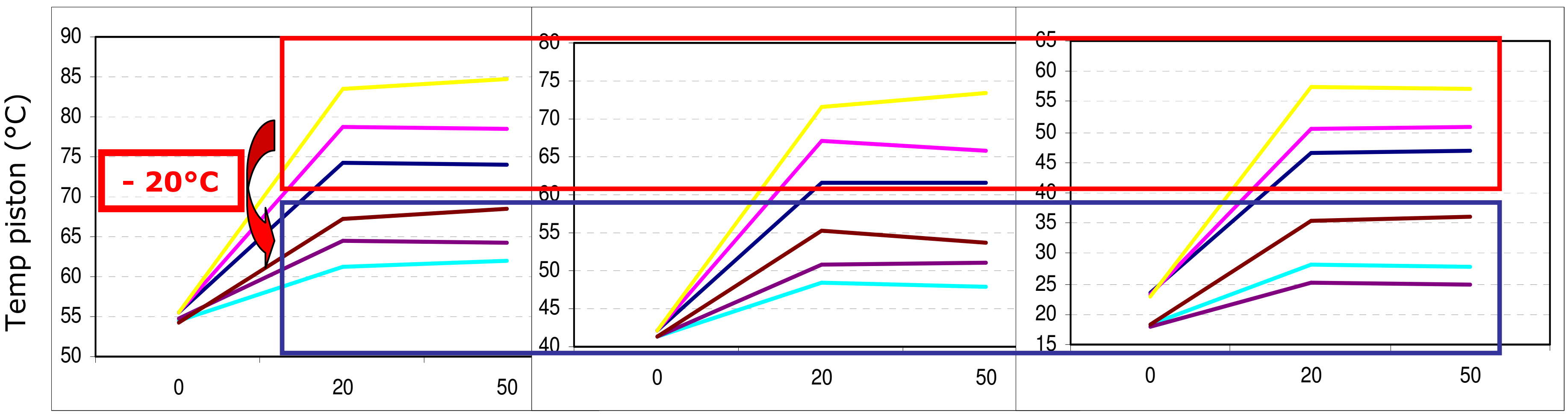
Source: PEP

Using DirectTool with conformal cooling reduced the temperature for a given cycle time by around 20°C

Results for ABS: mould temperature difference

Water temperature Tw = 60°C　　Tw = 45°C　　Tw = 20°C



Number of parts

Conventionnal - tc = 15s　Conventionnal - tc = 20s　Conventionnal - tc = 25s

DMLS - tc = 15s　DMLS - tc = 20s　DMLS - tc = 25s

tc = cycle time (tr = cooling time (tr = tc -10s))

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Source: PEP

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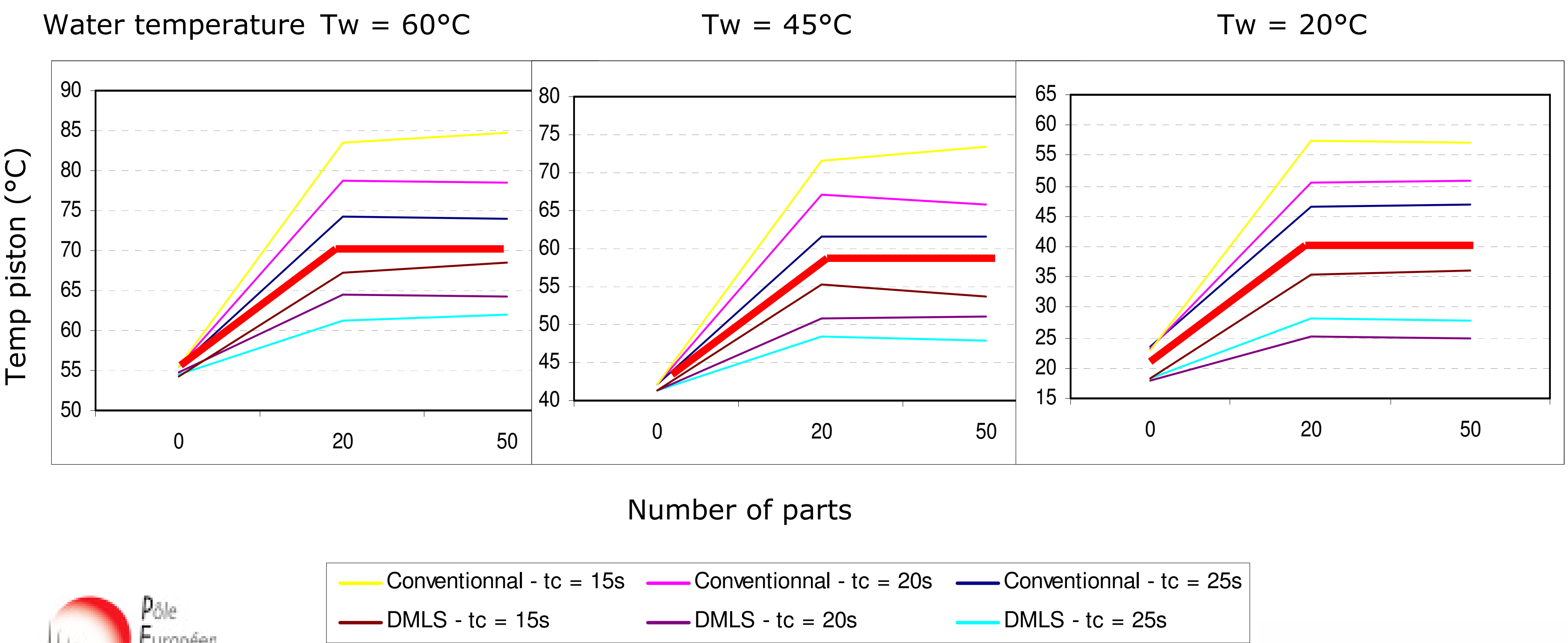
Using DirectTool with conformal cooling reduced the cycle time by around 20s

Results for ABS: cycle time difference

Conventional – tc = 30s
DMLS – tc = 10s
-20s



tc = cycle time (tr = cooling time (tr = tc -10s))

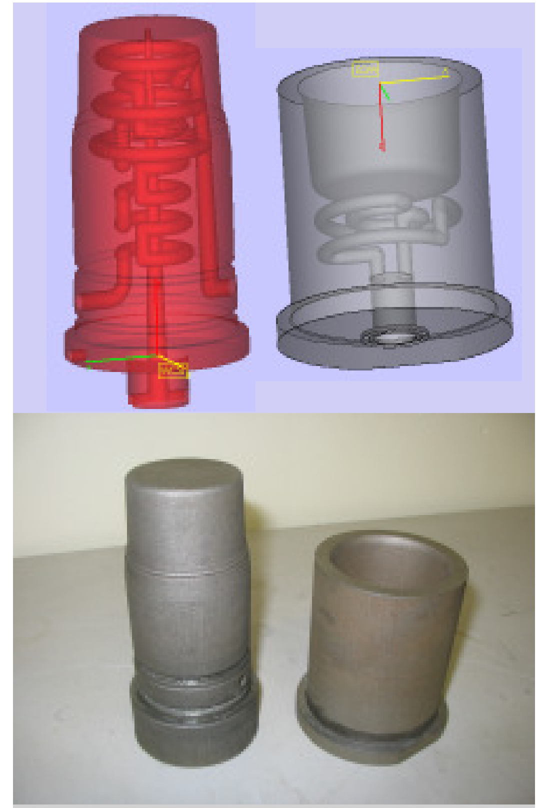
Pôle Européen Plasturgie Recherche - Développement

Source: PEP

PEP has made detailed investigations of conformal cooling on a cap moulding tool

Conclusions

- Number of tool elements could be reduced
- DirectTool with conformal cooling enabled
  - cycle time reduction of 20s
  - temperature reduction of 20°C
- Costs for tool production by DirectTool were originally higher than conventional, but with newest technology is now cheaper
  - build time with EOSINT M250 & DSH 20 was 120 h
  - build time with EOSINT M270 & MaragingSteel MS1 would be 35 h



DirectTool piston and cavity with conformal cooling channels

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Recherche & Développement

Source: PEP

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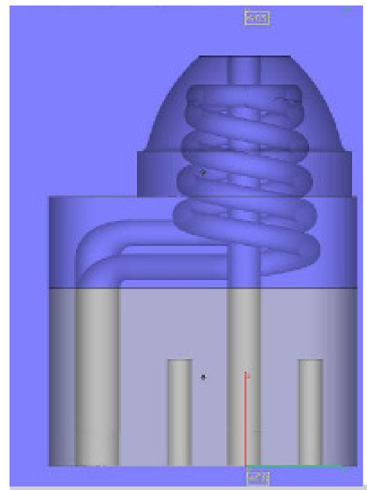
EOSINT M can build on top of pre-machined preforms for highly efficiently hybrid tooling

Summary

— Requirements:
- injection moulding tool inserts with optimzed cooling to greatly improve performance in series production
- rapid and cost-effective production
- high performance tool steel

— Solution:
- hybrid tooling: CNC machining + EOSINT M 270 with EOS MaragingSteel MS1 (1.2709)

— Result:
- EOSINT M 270 with positioning pins enables building on preforms and easy alignment for post/machining
- an efficient solution for advanced tooling

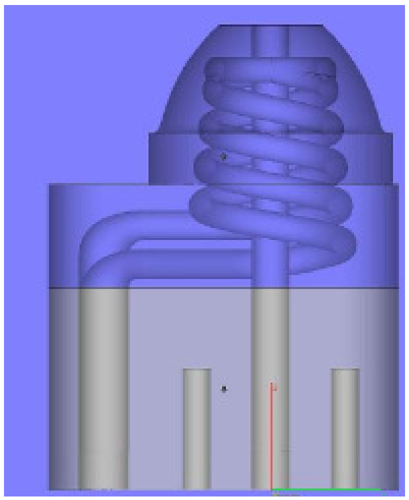



Left: Tool insert designed for hybrid production.
Right: Hybrid insert produced in EOSINT M270 by building on top of a machined preform

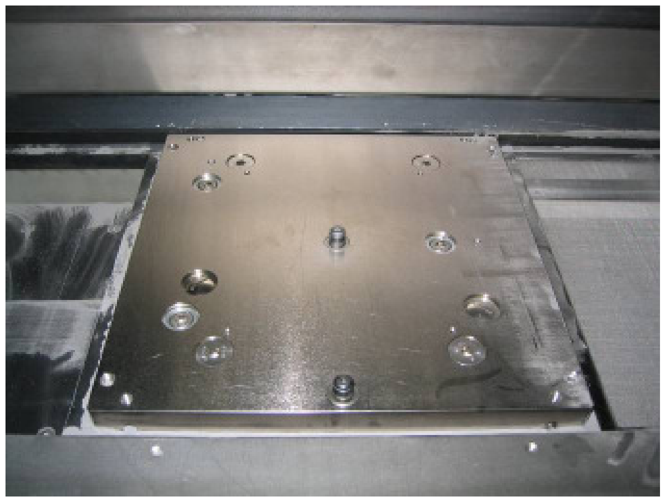
Source: EOS, LaserBearbeitungsCenter GmbH

LBC uses positioning pins integrated into EOSINT M270 to easily and accurately build hybrid tooling

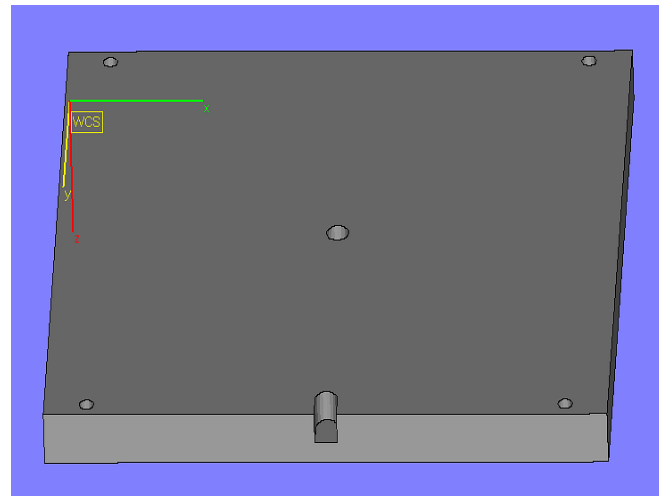
Building a hybrid core in EOSINT M270



1. Core designed as machined preform (grey, including positioning holes) and laser-sintered addition (blue, including complex cooling channels)



2. Platform carrier in M270 prepared with locating holes and positioning pins

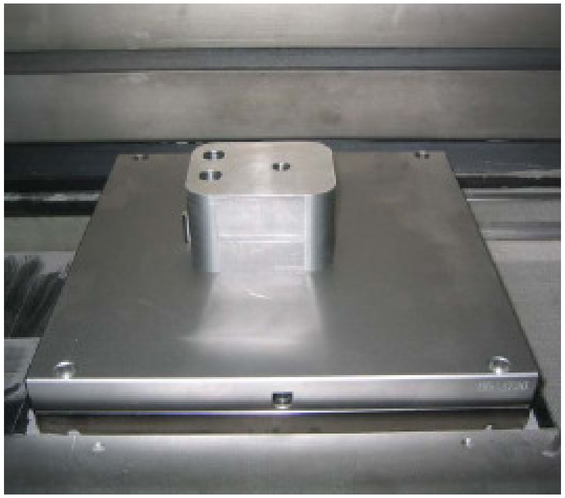


3. Bottom of build platform prepared with locating holes to match platform carrier (precise tolerances)

Source: EOS, LaserBearbeitungsCenter GmbH

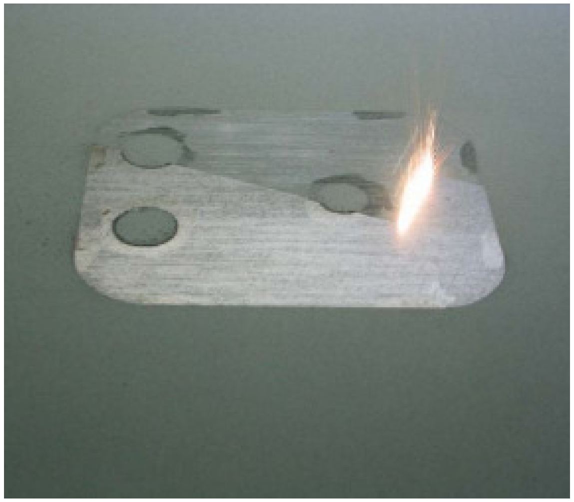
Reference position pins and PSW alignment feature enable accurate exposure on preforms

Building a hybrid core in EOSINT M270



4. Machined preform mounted onto prepared build platform (screwed from behind, including positioning pins) and loaded into EOSINT M270

5. Top surface of preform positioned at building plane (Z=0) in powder bed



6. Building starts with first layer exposed onto top of preform, creating a metallurgical bonding

LBC

Source: EOS, LaserBearbeitungsCenter GmbH

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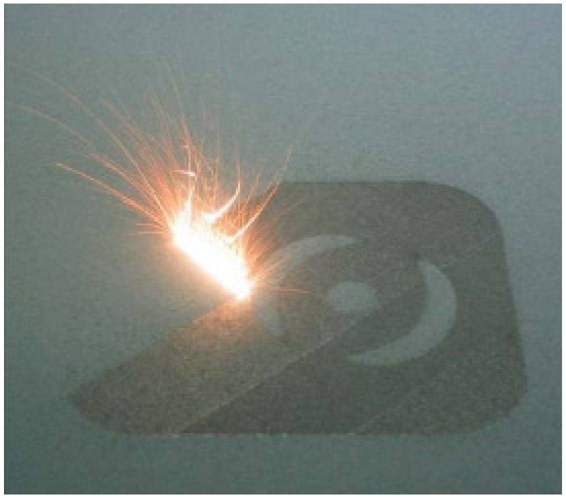
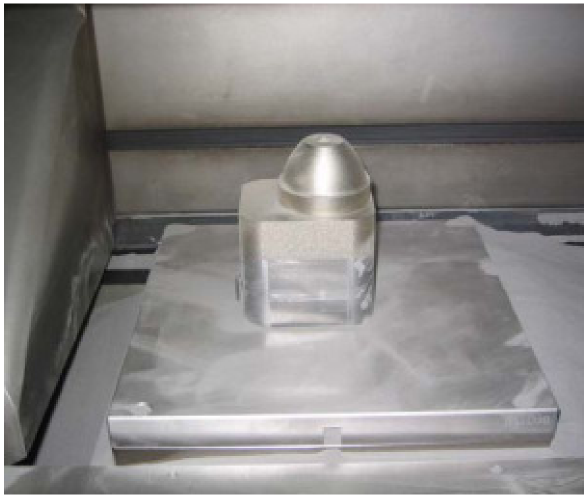
Reference position pins enable coordinate system to be transferred to post-machining systems

Building a hybrid core in EOSINT M270



7. Remaining layers including cooling channels are built fully automatically by EOSINT M270



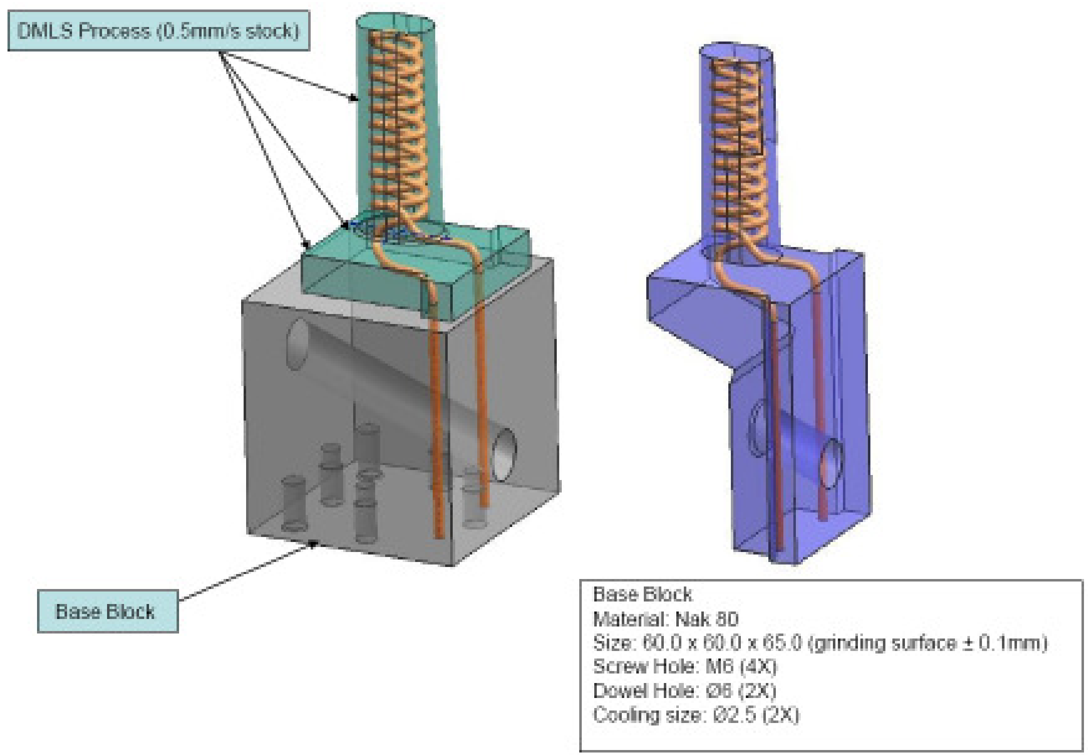
8. At job end the complete hybrid insert is ready for removal from the EOSINT M270

9. The insert can be aligned for post-machining (e.g. wire EDM) using the same positioning holes in the platform base

Source: EOS, LaserBearbeitungsCenter GmbH

Reference position pins enable accurate building of hybrid core

Building a hybrid core in EOSINT M270



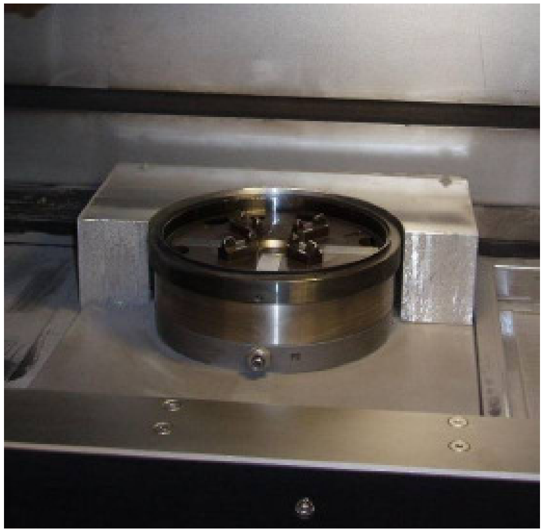
Source: EOS, LaserBearbeitungsCenter GmbH

e-Manufacturing Solutions

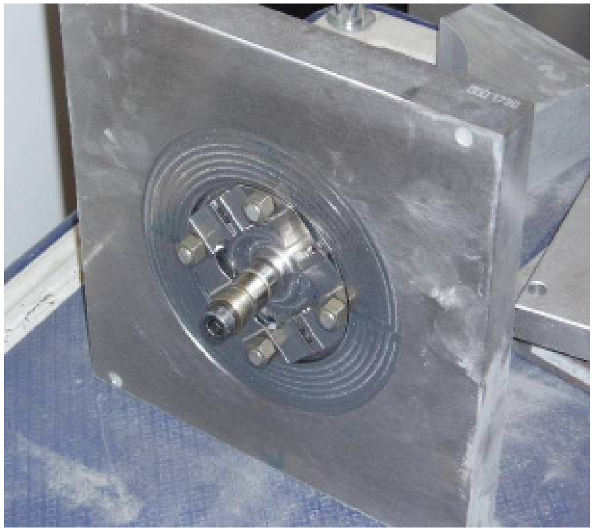
EOSINT M offers an optional Erowa clamping system to interface to other machines with Erowa interface

Use of the Erowa clamping system in EOSINT M270 (1)

1. Erowa Powerchuck 150 unit fits onto platform carrier in M270 process chamber



2. Erowa Powerchuck 150 unit in M270 with spacer blocks (only rear block shown)

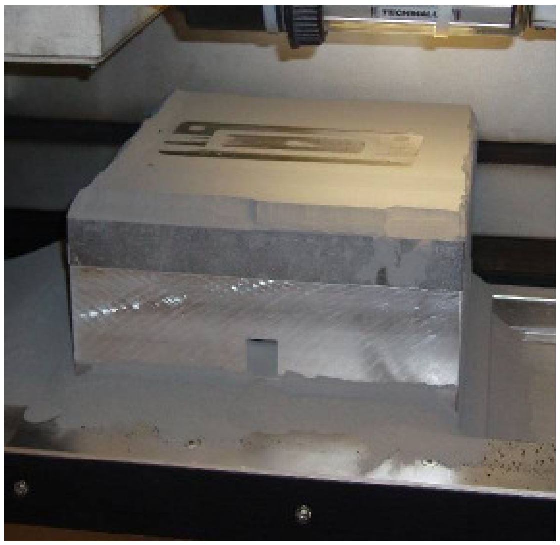


3. Palette (prepared build platform) with mating element for Powerchuck

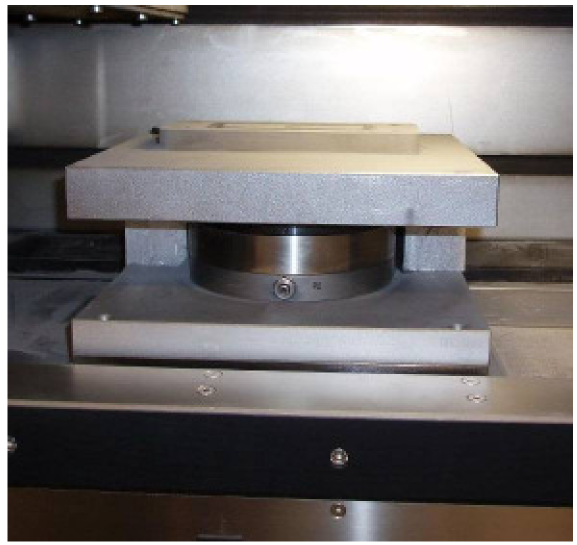
Source: EOS

EOSINT M offers an optional Erowa clamping system to interface to other machines with Erowa interface

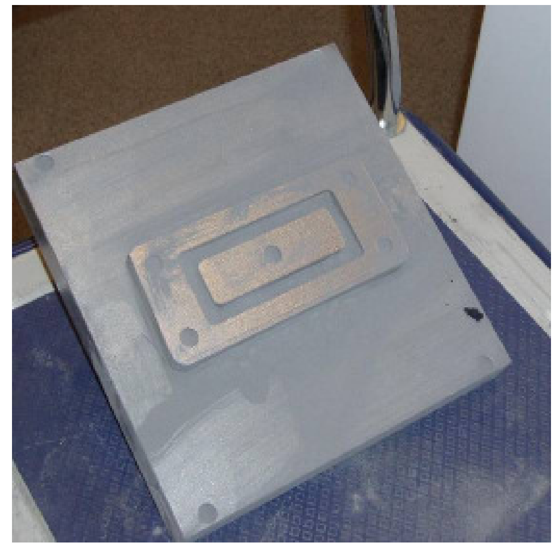
Use of the Erowa clamping system in EOSINT M270 (2)



4. Completed job after raising the build platform



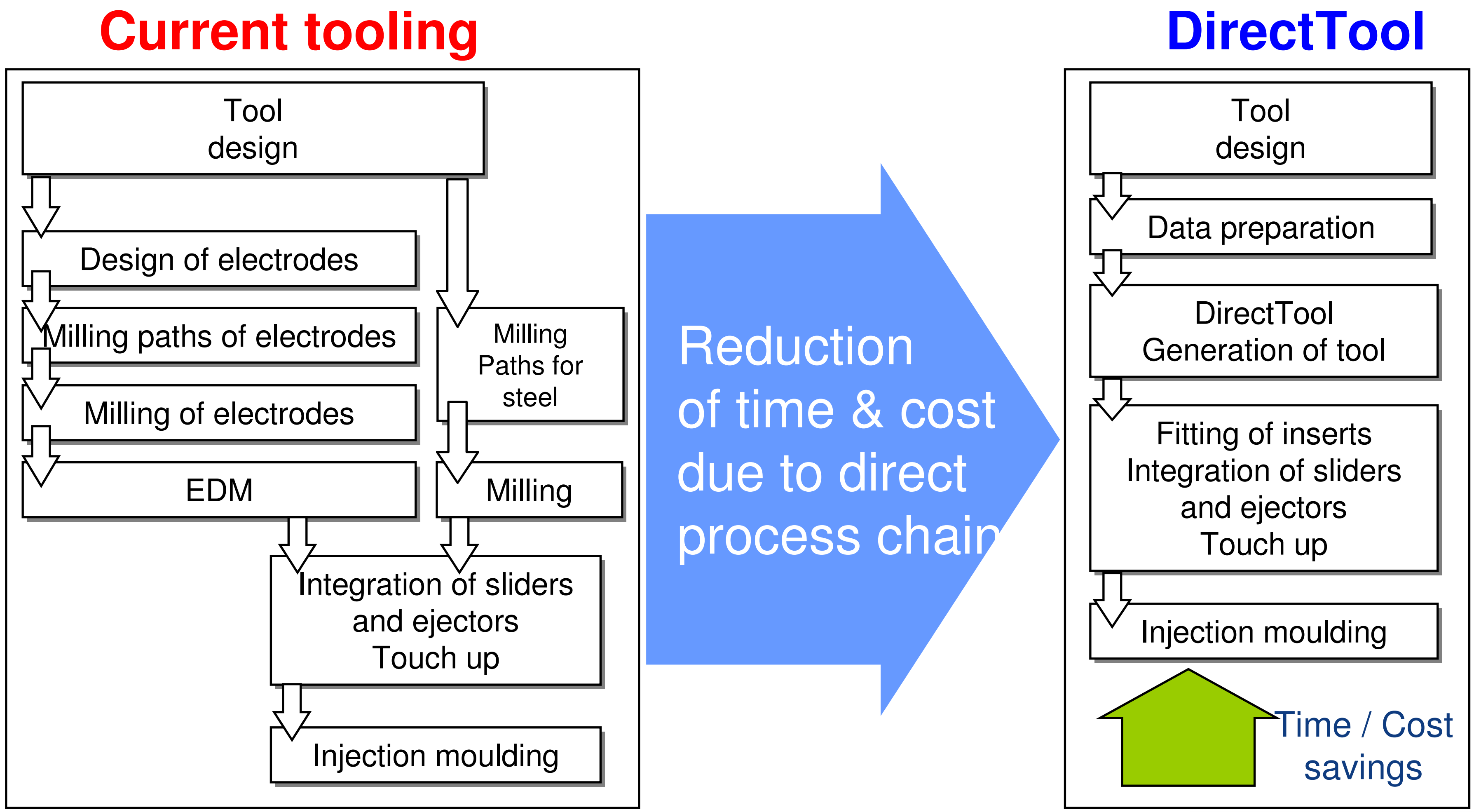
5. Completed job after removing powder and front spacer block



6. Laser-sintered part on palette, ready to be transferred to e.g. CNC mill or EDM machine

Source: EOS

DirectTool - The Direct Process Chain



Source: EOS

e-Manufacturing Solutions

DMLS Design Rules-Overview

— A part that can be easily milled, should be milled

DMLS should be used in cases which needs

— EDM (spark erosion)

— Five axis milling

— Multiple clamping position

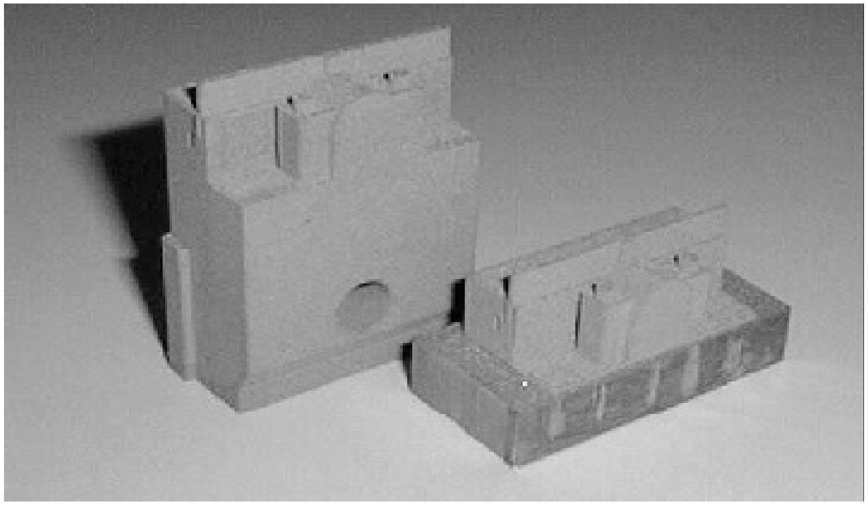
— Hybrid tooling is an option

Source: EOS

e-Manufacturing Solutions

Building Strategy
Z-Height optimised

— In DMLS it is not the complexity of the geometry that determines production time & cost, but rather the z- height (no of layers)

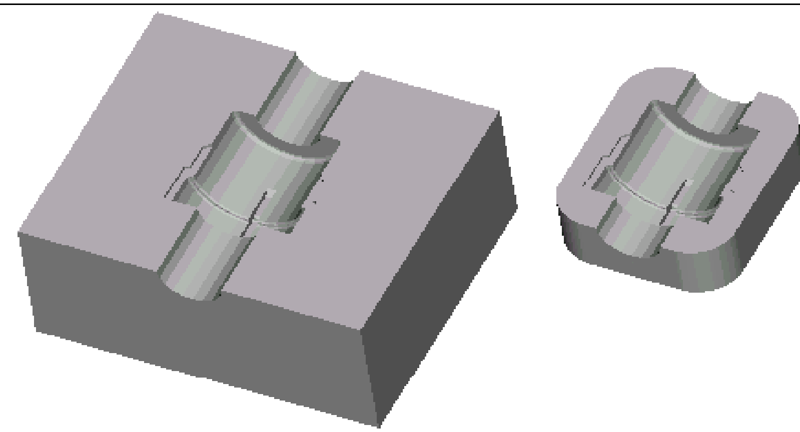


Source: EOS

Building Strategy
Volume of the build

— Cost and time also depends on the volume built

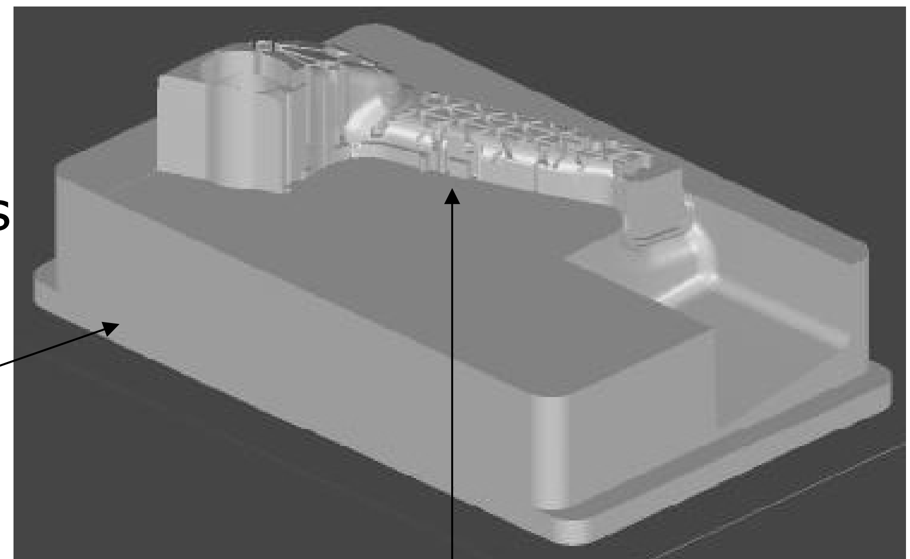
— It is advisable to build relevant geometries only



Source: EOS

Building Strategy
DMLS build optimisation

- Build only the complex areas
- Wall thickness for cavities 5 mm



Massive surrounding

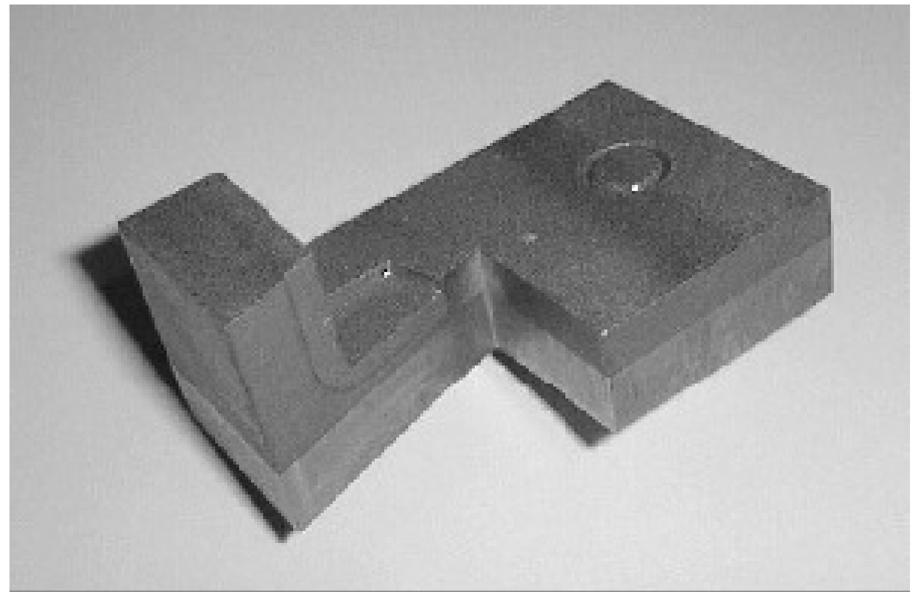
Complex structure

Source: EOS

e-Manufacturing Solutions

Building Strategy
Building platform

- Use 22 or 36mm build platform as Direct Base to eliminate
- high building time
- reduce cost
- strong fixation on the mother tools



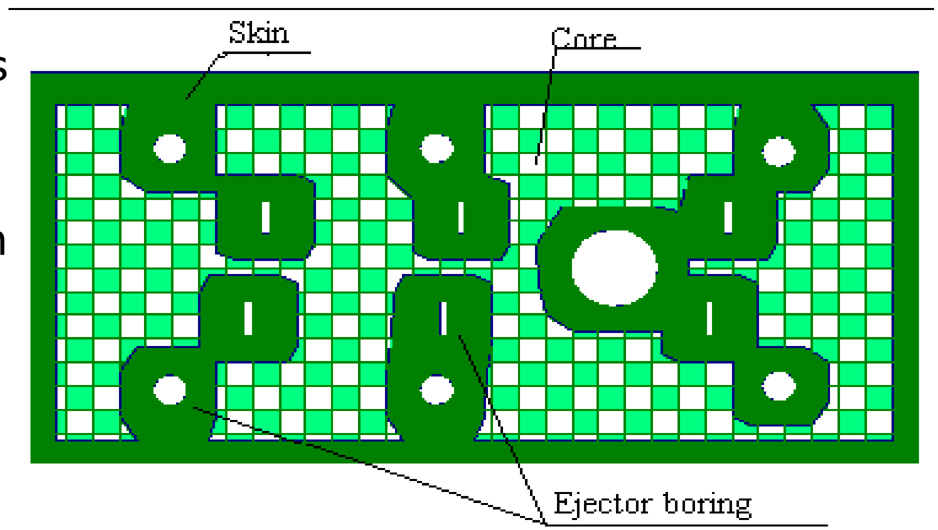
Source: EOS

Building Strategy
Drill Holes /Skin & Core

All drill holes of the ejector pins, holes for fastening screws or similar feature should be provided in CAD

Desired drill holes to be 0.6mm undersized

Reason: skin & core Building technique; Otherwise tapped thread breaking out



Source: EOS

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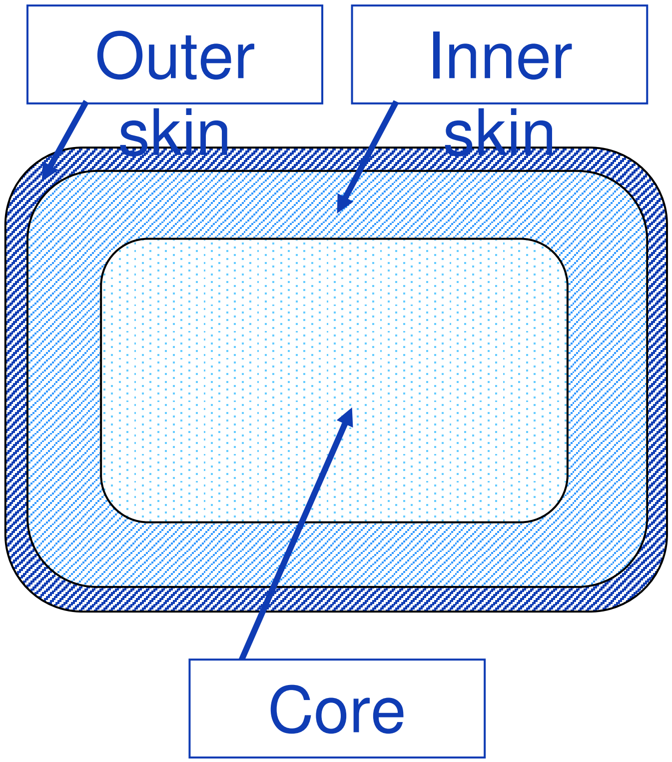
Building Strategy
Skin & Core

- Example of optimized strategy:
- Skin regions require best surface quality and highest density
  - every 20µm layer is exposed for high resolution
  - "hard" 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



Source: EOS

Building Strategy
Machining Allowance

— Machining allowance of 0.1-0.5 to be provided on every relevant area for fitting the inserts into the mother tool- edges usually milled

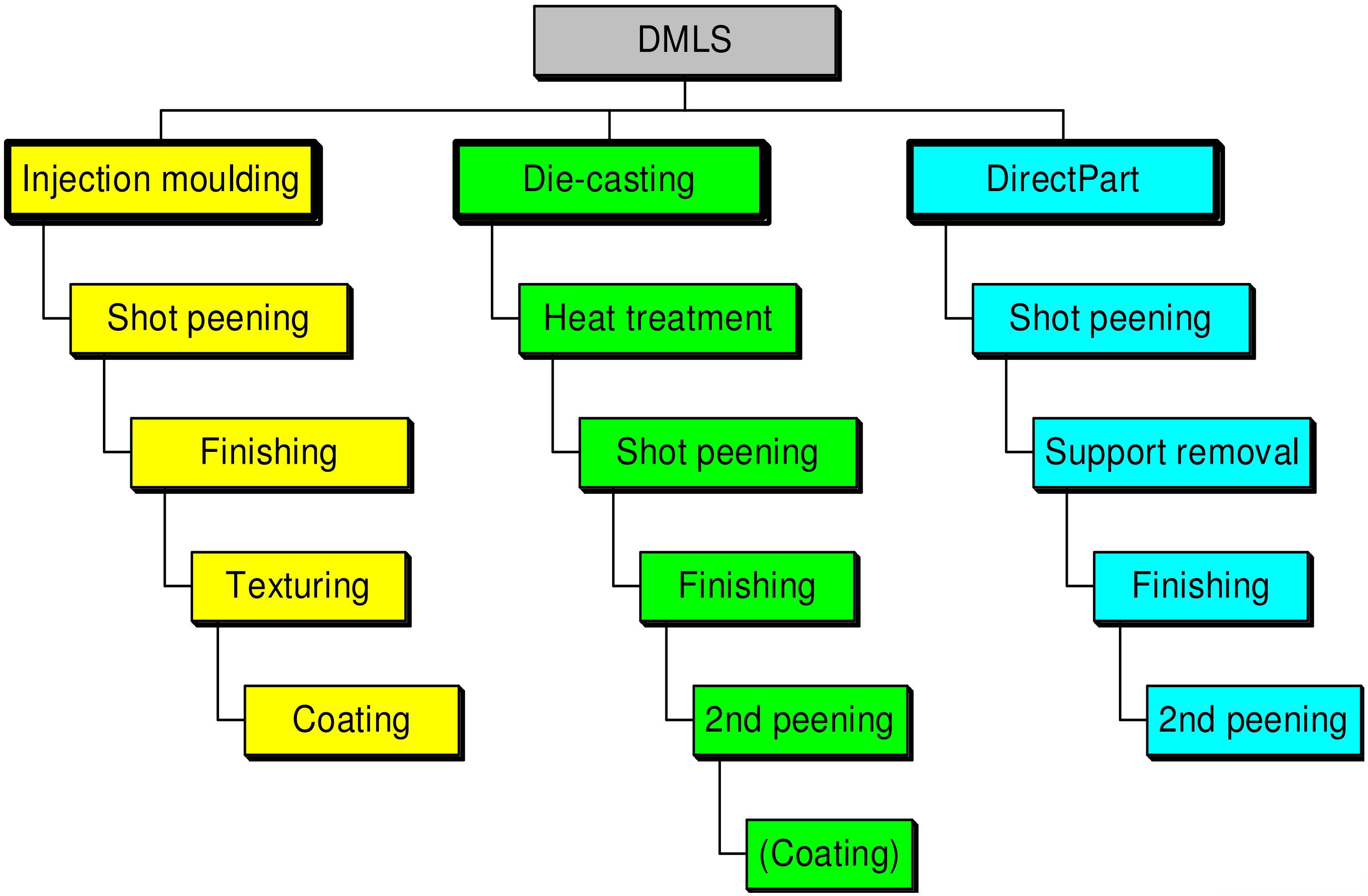
— Parting surface needs to be shot-peened and manual polish

— Shot-peening –system takes offset allowance of 0.05mm

— Polishing – 0.03 mm is provided.

Source: EOS

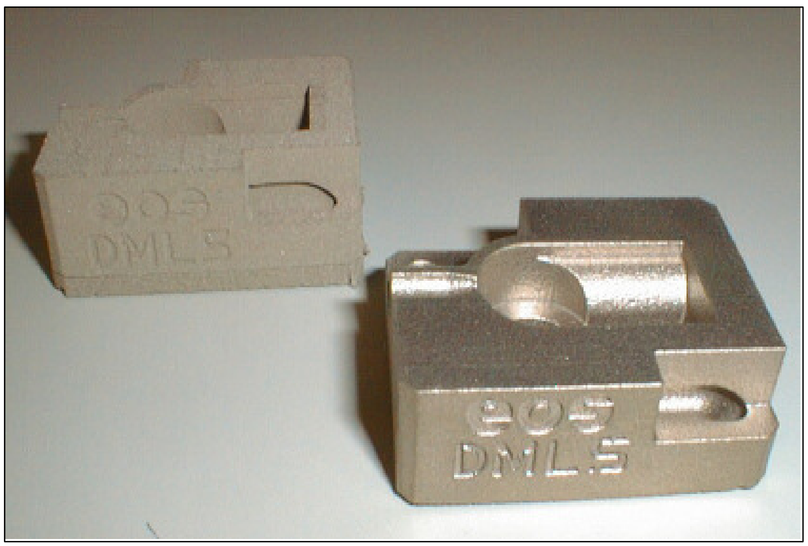
Examples of typical DMLS post-

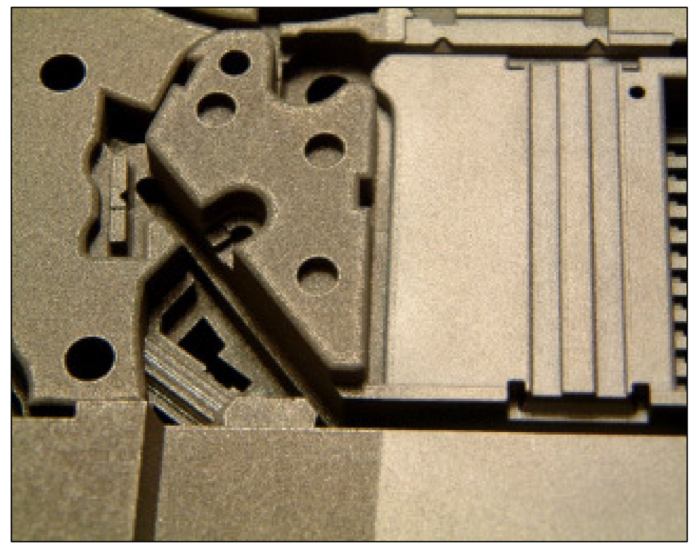


Source: EOS

Micro Shot-Peening - Results

- Improved surface quality
  - normally sufficient for DirectPart
  - often sufficient for demoulding in injection moulding
- Compacted surface as basis for grinding and polishing





Source: EOS

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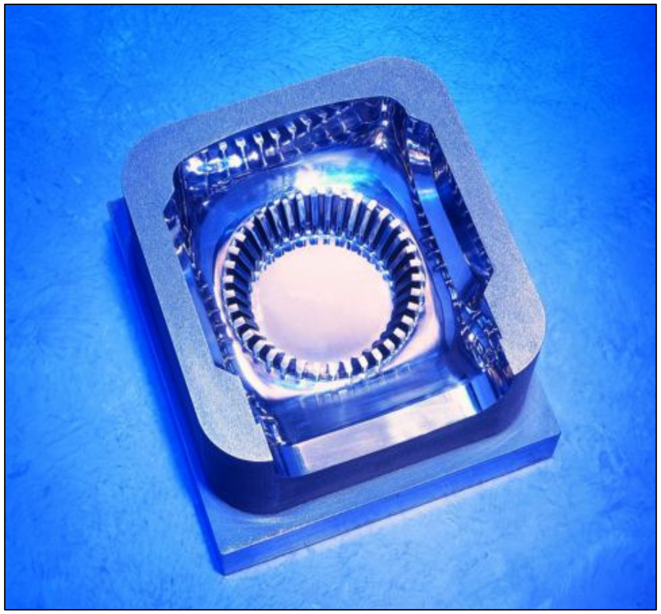
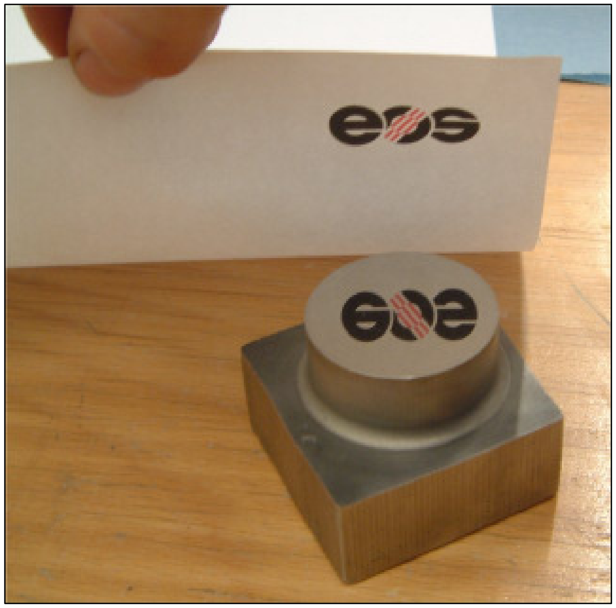
Polishing - Results

Good to best surface quality

- for injection moulding tools with high surface requirements and critical geometries in injection moulding and die casting tools





Source: EOS

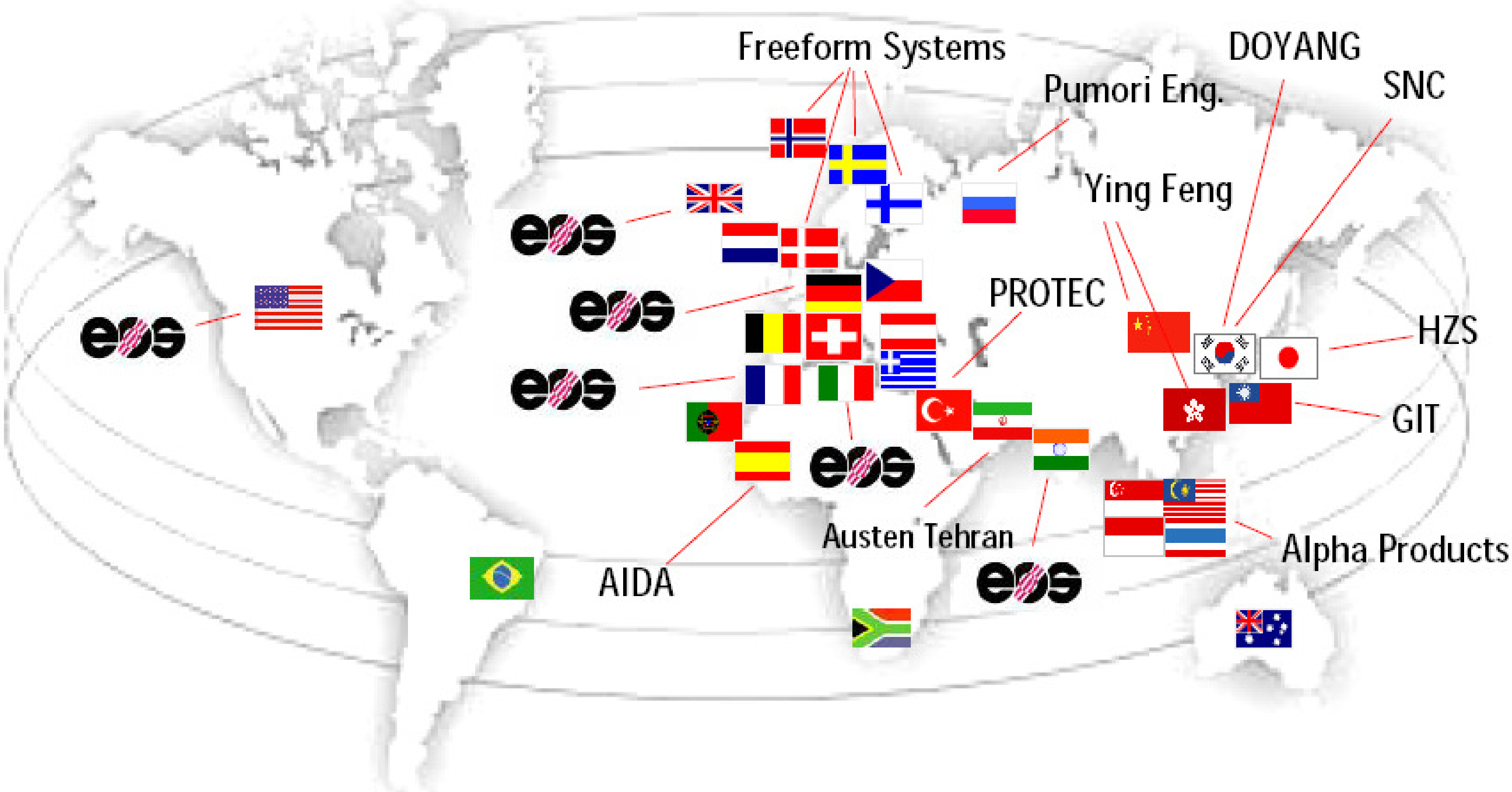
EOSINT M history - More than 10 years of continuous innovation

- 1994 Cooperation with Electrolux, 1st EOSINT M installation
- 1995 EOSINT M 250; DirectMetal 100
- 1997 DirectMetal 50
- 1999 EOSINT M 250 Xtended; DirectSteel 50
- 2001 EOSINT M 250 Xtended 2001; DirectSteel 20
- 2002 DirectMetal 20
- 2004 EOSINT M 270; EOSTYLE; DirectSteel H20
- 2006 CobaltChrome and StainlessSteel
- 2007 Titanium and MaragingSteel

Approx. 250 systems installed in over 26 countries (11/2007)

Source: EOS

WorldWide Presence



Source: EOS

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Source: EOS