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

Contents

- Background
  - What is DMLS?

- EOSINT M technology
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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"

Source: EOS
EOSINT M Technology
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.)

Source: EOS
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
EOSINT M Technology

Real time processing of maraging steel powder

Source: EOS
EOSINT M systems convert metal powder to metal parts in a single, direct process.
EOSINT Materials
EOS offers a wide range of application-optimized metal powder materials for EOSINT M systems

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

Source: EOS

*EOS 2007 - EOSINT M Technology*
DirectMetal 20 - bronze-based material for rapid tooling and rapid functional prototypes

**Characteristics and applications**

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

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**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.

**Source:** EOS, EGi

**EOS 2007 - EOSINT M Technology**
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

Source: EOS, Morris Technologies, FIT GmbH
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

Source: EOS
EOS StainlessSteel 17-4 stainless steel material for foodstuff packaging machinery.

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

Source: EOS, Oase

Injection mould insert with conformal cooling, built in EOS MaragingSteel MS1
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 %
Various types of steels are conventionally used for injection moulds, depending on the requirements

## Summary of tool steel types with examples

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

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

<table>
<thead>
<tr>
<th>Chemical Composition (Typical Analysis in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIN Spec</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td><strong>Case hardening steels</strong></td>
</tr>
<tr>
<td>1.2764</td>
</tr>
<tr>
<td><strong>Heat treated steels</strong></td>
</tr>
<tr>
<td>1.2311</td>
</tr>
<tr>
<td><strong>Corrosion resistant steels</strong></td>
</tr>
<tr>
<td>1.2063</td>
</tr>
<tr>
<td><strong>Through hardening steels</strong></td>
</tr>
<tr>
<td>1.2344</td>
</tr>
<tr>
<td><strong>Nitriding steels</strong></td>
</tr>
<tr>
<td>1.8550</td>
</tr>
<tr>
<td><strong>Maraging steels</strong></td>
</tr>
<tr>
<td>1.2709</td>
</tr>
</tbody>
</table>

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

— Create optimum cooling channel in CAD data

— Close to the model geometry
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

Source: PEP and Antiope project
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**

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**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

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

Conventional design (machined):
- Cavity
- Piston

Optimized design with conformal cooling (DirectTool):
- 2-part insert replaced by single integrated piece

Source: PEP
EOS 2007 · EOSINT M Technology
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

Source: PEP

EOS 2007 - EOSINT M Technology
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 $T_w = 60^\circ C$  

$T_w = 45^\circ C$  

$T_w = 20^\circ C$

Number of parts

$tc = \text{cycle time}$  

$tr = \text{cooling time} (tr = tc - 10s)$

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

Results for ABS: cycle time difference

- Water temperature $T_w = 60^\circ C$
- $T_w = 45^\circ C$
- $T_w = 20^\circ C$

Source: PEP

EOS 2007 - EOSINT M Technology
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
EOSINT M can build on top of pre-machined preforms for highly efficiently hybrid tooling

Summary

— Requirements:
  • injection moulding tool inserts with optimized 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

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

Source: EOS, LaserBearbeitungsCenter GmbH

EOS 2007 - EOSINT M Technology
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
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
DirectTool - The Direct Process Chain

**Current tooling**

- Tool design
- Design of electrodes
- Milling paths of electrodes
- Milling of electrodes
- EDM

**DirectTool**

- Tool design
- Data preparation
- DirectTool Generation of tool
- Fitting of inserts
- Integration of sliders and ejectors
- Touch up
- Injection moulding

**Reduction of time & cost due to direct process chain**

**Time / Cost savings**

Source: EOS
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
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)
Building Strategy
Volume of the build

— Cost and time also depends on the volume built

— It is advisable to build relevant geometries only
Building Strategy
DMLS build optimisation

— Build only the complex areas

— Wall thickness for cavities 5 mm

Massive surrounding

Complex structure

Source: EOS
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
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
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
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.
Examples of typical DMLS post-processing chains:

- Injection moulding
  - Shot peening
  - Finishing
    - Texturing
    - Coating

- Die-casting
  - Heat treatment
  - Shot peening
    - Finishing
      - 2nd peening

- DirectPart
  - Shot peening
  - Support removal
    - Finishing
      - 2nd peening
      - (Coating)

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
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
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)**
WorldWide Presence

Source: EOS
EOS 2007 - EOSINT M Technology