DESIGNING FOR THE DMLS PROCESS
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Senior Quality Engineer

proto labs®
Designing for DIRECT METAL LASER SINTERING

① Overview
② Process Considerations
③ Design Considerations
④ Design Examples
⑤ Wrap-up
How DMLS Works
WHY USE DMLS?

- Reduction of components
- Reduction of weight
- Quicker assembly times
- Reduction of cost
- Complexity
APPLICATIONS FOR DMLS

- Complex geometries
- Manufacture the un-manufacturable
- Mass customization of parts
# PROTO LABS SPECIFICATIONS

<table>
<thead>
<tr>
<th>Max. Size</th>
<th>Normal Res.</th>
<th>High Res.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9.68 in. by 9.68 in. by 10.8 in.</td>
<td>3.5 in. by 3.5 in. by 2.9 in.</td>
</tr>
</tbody>
</table>

| Tolerances         | ± 0.003 in. plus 0.001 in./in. |

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Layer thickness</th>
<th>Min. feature size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.0012 in.</td>
<td>0.015 in.</td>
</tr>
<tr>
<td>High</td>
<td>0.0008 in.</td>
<td>0.006 in.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials</th>
<th>Aluminum</th>
<th>Stainless Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cobalt Chrome</td>
<td>Titanium</td>
</tr>
<tr>
<td></td>
<td>Inconel</td>
<td></td>
</tr>
</tbody>
</table>

**1 to 50+ parts**  
Less than 7 days  
Parts start at $95
OUR EQUIPMENT

5 - Concept Laser M2
8 - Mlab machines
## Direct Metal Laser Sintering

<table>
<thead>
<tr>
<th>Material</th>
<th>Aluminum</th>
<th>Cobalt Chrome</th>
<th>Inconel 718</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>37.7 ksi (260 MPa)</td>
<td>130 ksi (896 MPa)</td>
<td>180 ksi (1240 Mpa)</td>
</tr>
<tr>
<td><strong>Yield Strength</strong></td>
<td>31.9 ksi (220 Mpa)</td>
<td>75 ksi (517 MPa)</td>
<td>133.4 ksi (920 MPa)</td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>47.2 HRB</td>
<td>25 HRC</td>
<td>35.5 HRC</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material</th>
<th>Stainless Steel 17-4PH</th>
<th>Stainless Steel 316L</th>
<th>Titanium Ti 6-4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tensile Strength</strong></td>
<td>190 ksi (1310 MPa)</td>
<td>70 ksi (482 MPa)</td>
<td>129.8 ksi (894 MPa)</td>
</tr>
<tr>
<td><strong>Yield Strength</strong></td>
<td>170 ksi (1172 MPa)</td>
<td>25 ksi (172 MPa)</td>
<td>119.7 ksi (824 MPa)</td>
</tr>
<tr>
<td><strong>Hardness</strong></td>
<td>40-47 HRC</td>
<td>76.5 HRB to 25.5 HRC</td>
<td>39 HRC</td>
</tr>
</tbody>
</table>
DESIGNING FOR DMLS

Not a replacement for traditional machining, casting, sheet metal fabrication or metal injection molding (MIM)
CASE STUDY: HUGE DESIGN

Urban utility bike, EVO

Allows riders to easily attach and detach different components
CASE STUDY: HUGE DESIGN

DMLS was used to create the lugs, crankset shell and fork crown.
PROCESS CONSIDERATIONS
SMALL FEATURE RESOLUTION

Minimum feature size: 0.150 mm (0.006 in.)

Mesh structures
THIN WALLS
(<1 mm/0.040 in.)

Rule of thumb:
40 : 1
height : wall thickness
SURFACE ROUGHNESS

Material dependent
Build parameters, normal or high resolution
Part orientation
200 to 400 μin Ra
Select surfaces can be machined or polished
## SURFACE ROUGHNESS

<table>
<thead>
<tr>
<th>Machine</th>
<th>Material</th>
<th>Vertical Sidewall (Ra)</th>
<th>Angled Upfacing Surface (45°) (Ra)</th>
<th>Upfacing Surface (Ra)</th>
<th>Angled Downfacing Surface (45°) (Ra)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Concept Laser M2 (250 mm)</strong></td>
<td>Stainless Steel (316L)</td>
<td>195</td>
<td>225</td>
<td>395</td>
<td>565</td>
</tr>
<tr>
<td></td>
<td>Titanium (Ti64 ELI)</td>
<td>215</td>
<td>250</td>
<td>305</td>
<td>335</td>
</tr>
<tr>
<td></td>
<td>Aluminum (AlSi10Mg)</td>
<td>250</td>
<td>295</td>
<td>415</td>
<td>435</td>
</tr>
<tr>
<td></td>
<td>Inconel 718</td>
<td>350</td>
<td>405</td>
<td>610</td>
<td>960</td>
</tr>
<tr>
<td><strong>Concept Laser Mlab (90 mm)</strong></td>
<td>Stainless Steel (316L)</td>
<td>135</td>
<td>170</td>
<td>355</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>Stainless Steel (17-4 PH)</td>
<td>155</td>
<td>185</td>
<td>440</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>Cobalt Chrome</td>
<td>255</td>
<td>135</td>
<td>325</td>
<td>340</td>
</tr>
</tbody>
</table>
SUPPORTS

Connect part to the platform

Hold features in place

Prevent warping

Photo courtesy Concept Laser
SUPPORT removal process

Machining
EDM
Grinding
Sawing

Design tip: Design parts that will require minimal supports. This will also improve part quality.
DESIGN CONSIDERATIONS
INTERNAL FEATURES

Channels, overhangs, self-supporting angles, bridge dimensions

Support and powder removal access

**Design tip:** Lattice structures can be used internally to reduce weight and provide support
# SELF-SUPPORTING ANGLES

<table>
<thead>
<tr>
<th>CAD</th>
<th>50 degrees</th>
<th>45 degrees</th>
<th>40 degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 degrees</td>
<td>30 degrees</td>
<td>25 degrees</td>
<td>20 degrees</td>
</tr>
</tbody>
</table>
OVERHANGS

If the next layer is larger than the previous layer, it will create an overhang.

DMLS has a small allowance for unsupported overhangs
(0.5 mm/0.020 in.)
CHANNELS AND HOLES

Channels and holes are self-supporting features.

Great for conformal cooling applications.
CHANNELS AND HOLES

As the diameter increases, the overhanging increases

15mm (.6")
12mm (.47")
8mm (.31")
6mm (.24")
5mm (.2")
Minimum allowable unsupported bridge distance is small (~2 mm/0.080 in.)
INTERNAL STRESS | WARPAGE

Changes in cross-sectional areas can lead to warpage.

Large flat surfaces can bend build plates and shear bolts.

Design tip: Design in additional material to gradually transition into larger cross-sections.
DESIGN EXAMPLE
DESIGN EXAMPLE: REV 1

Three-component assembly

Requires a lot of supports
DESIGN EXAMPLE: REV 2

Reduction of components, assembly time, and weight ...

BUT...supports interfere with function
DESIGN EXAMPLE: REV 3

Best surface finish, small warpage potential

Self-supporting features eliminate need for most supports
HOLLOW PARTS

Hollow Model

Section View

Drain Hole

Vent
WRAP UP
Select Build Direction - Fineline_demo_heatexchanger.STL

- **Fineline Selected**
  Select this option if you would like us to choose the best build direction that will optimize the quality of your part while minimizing your price.

- **Custom**
  Select this option if you want to explicitly control the build direction of your part.
DMLS is also a low-cost, quick-turn method for prototyping components using actual end-use materials.

DMLS can be a production method for complex geometries.
## CASE STUDY

### TRANSITION TO CONVENTIONAL MFG

<table>
<thead>
<tr>
<th>Part Quantity</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>200</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

**Total Cost (Tooling + Parts)**

![Graph showing the total cost for different manufacturing processes (DMLS, CNC, MIM) as a function of part quantity. The graph highlights the breakeven point where the costs are equal.]
CONCLUSION

DMLS opens up new design options, but it will not replace conventional manufacturing methods.

Understanding constraints will maximize benefits of DMLS for part design.
WIN A DRONE
Stop by booth #N-72 to enter to win!

DJI Phantom 3
Standard Quadcopters
QUESTIONS?
STOP BY BOOTH
#N-72