Additive Manufacturing Technology and Trends

MCA Session Topic: CAM for CAD and MCA Ideation

7/20/23

Instructor:
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Design for Additive Manufacturing (DFAM) ?

๏ Don’t print boxes or threads
๏ Use a printer to make it’s own parts
๏ Combine parts that need to function within your design
๏ If assembled with production part, make printed part tolerance higher
Design for Additive Manufacturing (DFAM)?

- Can the size be modified to make it function nearly as well as traditional manufacturing method?
- Is 3D printing the only way to manufacture the part?
- Script the model to customize & ensure fit/function: OpenSCAD
Design for Additive Manufacturing (DFAM)?

- All 300,000 were 100% inspected using non-destructive evaluation.
  - How many failed to print?
  - How many failed inspection?

- Nobody, has, can, or ever will print 2 parts that are exactly the same.
MCA Session 4, In-Class Activity #1

๏ If/when you can’t apply DFAM

๏ 3D print preparation software for DFAM

๏ Open benchy in Cura
  - Machines (how to setup, speed limits, & why you’ll use VRAC’s)
  - Extruder(s) material (nozzle and bed temp)
  - Settings (infill type and %, outlines, support type

๏ Export to 3D printer (local vs. remote)
Part Orientation

- Is there a best orientation?

- Software algorithms and experienced users can optimize and choose “optimal” orientation.

- How do we know if model is bad and/or when 2 disciplines are collaborating?

- Who knows (e.g., designer, 3D printing person, medical doctor)?
Print Preview Uses

- Tell you how long print will take to print and how much material will be used
- Where supports are located with respect to part (may help orient the part)
- Print type (and corresponding print speed) for the part on a single layer (due to computational expense)
- If connection to printer required: to make system proprietary or to get real-time print info
Print Previews Do Not Help Choose Settings

- If we had the Goldilocks Evaluation Matrix (GEM) it would show you the tradeoffs between print settings and part quality.

- Without GEM we have to print parts, try modifying settings, and print again.

- “Virtual Iterations” could be performed 1000s before printing 1 part.

<table>
<thead>
<tr>
<th>Per Layer Thickness</th>
<th>Increase Speed</th>
<th>Decrease Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase Extruder Temp</td>
<td>Yes or No?</td>
<td>Yes or No?</td>
</tr>
<tr>
<td>Decrease Extruder Temp</td>
<td>Yes or No?</td>
<td>Yes or No?</td>
</tr>
</tbody>
</table>
Teach Process So You Can Print Parts Better

- Alex is the “Chief Operating Officer” (-VRAC MakerBot Training Manual)
- “VRAC Maker”
- “Trained Personnel”
- Print failures are priceless
Limited Experience Still Print Cool Stuff

- Kate trained by Holly who was trained by Alex.

- Bottom up approach of learning the process effects at the road level helped learn how to make decisions about print settings.
MCA Session 4, In-Class Activity #2

- Print Benchy (each intern)
- Terminology / component labels: describe in your own words
- Common component terminology to be added after the in-class activity
- Focus on function - what does each component do to help 3D print parts?
Preview vs. Simulate

- Print Preview shows layers of ideally shaped 3D printed segments.
- Simulation uses the machines instructions and provides inter and intra-layer visualization of the whole process.
Virtual Additive Manufacturing Visualization Investigation and Simulation (VAMVIS)

- Alex Raymond Renner’s PhD Research application
- Desktop (Qt), C6, and HMD
- Why the name:
  - Using VR for AM
  - 0.4mm nozzle (half thickness of piece of paper) can be visualized in C6 at much larger scale an investigated by more than one person at a time
VAMVIS’s Thermal Process Simulation

- Any combination of 3D printer, software, and hardware
- Really?? How???
- Collect the information in the table for every print move from G-Code

<table>
<thead>
<tr>
<th>Property</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Set Temperature</td>
<td>( T_s )</td>
<td>230</td>
<td>°C</td>
</tr>
<tr>
<td>Envelope Temperature</td>
<td>( T_{\infty} )</td>
<td>25</td>
<td>°C</td>
</tr>
<tr>
<td>Layer Thickness</td>
<td>( L )</td>
<td>0.3</td>
<td>mm</td>
</tr>
<tr>
<td>Print Speed: Infill</td>
<td>( S_I )</td>
<td>90</td>
<td>mm/s</td>
</tr>
<tr>
<td>Print Speed: Insets</td>
<td>( S_S )</td>
<td>90</td>
<td>mm/s</td>
</tr>
<tr>
<td>Print Speed: Outlines</td>
<td>( S_o )</td>
<td>40</td>
<td>mm/s</td>
</tr>
<tr>
<td>Print Speed: First Layer</td>
<td>( S_f )</td>
<td>30</td>
<td>mm/s</td>
</tr>
</tbody>
</table>
VAMVIS’s Thermal Process Simulation

- Do some math for the roads’ size (calculate volume/surface area)
- Account for print head speed changes and update frequency of the simulation app
- Include the roads’ material properties in a fancy heat transfer analysis model (Lumped Capacitance assumptions)

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<th>Property</th>
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<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convective Heat Transfer Coefficient</td>
<td>$h$</td>
<td>0.000058</td>
<td>$W/mm^2K$</td>
</tr>
<tr>
<td>Characteristic Length</td>
<td>$L_c$</td>
<td>$\frac{V}{A_s}$</td>
<td>$mm$</td>
</tr>
<tr>
<td>Biot Number</td>
<td>$B_t$</td>
<td>$\frac{h(L_c)}{k}$</td>
<td>$N/A$</td>
</tr>
<tr>
<td>Alpha</td>
<td>$\alpha$</td>
<td>$\frac{k}{\rho C}$</td>
<td>$mm^2/s$</td>
</tr>
<tr>
<td>Time</td>
<td>$t$</td>
<td>$\frac{1}{60}$</td>
<td>$s$</td>
</tr>
<tr>
<td>Fourier</td>
<td>$Fo$</td>
<td>$\frac{a t}{(L_c)^2}$</td>
<td>$N/A$</td>
</tr>
<tr>
<td>Extruding Temperature</td>
<td>$T_i$</td>
<td>$T_\infty + (T_s - T_\infty)e^{(-B_t*Fo)}$</td>
<td>°C</td>
</tr>
<tr>
<td>Extruded Temperature</td>
<td>$T_{i-1}$</td>
<td>$T_\infty + (T_i - T_\infty)e^{(-B_t*Fo)}$</td>
<td>°C</td>
</tr>
</tbody>
</table>
MCA Session 4: Download a thing to print Wednesday