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Sandia National Laboratories

PARAMETER OPTIMIZATION FOR FUSED DEPOSITION MODELING PEEK

QUANG HA, BAXTER TINDALL & DEBORAH HAGEN

INTRODUCTION

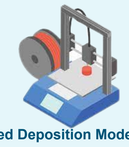
PEEK
Polyetheretherketone

https://www.weerg.com/guides/peek-3d-printing-all-you-need-to-know

- High strength and stiffness
- Outstanding chemical resistance
- Excellent performance in high temperature environment
- High melting point (343°C)
- Good wear and abrasion resistance
- Easy to machine
- Exceptional strength to weight ratio vs metal

FDM Additive Manufacturing

- Able to produce complex model and unique internal features
- Eliminate expensive tooling
- Support rapid iterative prototyping
- Good dimensional tolerances.

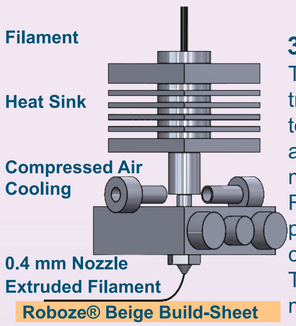


Fused Deposition Modeling

Challenges for Printing PEEK via FDM

Although PEEK has very desirable properties, its high viscosity and shrinkage leads to difficulty in achieving tight dimensional tolerances, quality surface finishes, and low warpage when processed via FDM.

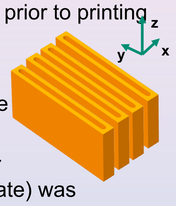
MATERIAL & METHODS



3D Printer

The **Roboze® Argo 350** utilizes a traditional air-cooled hot end, mounted to a core x/y axis with the z-axis attached to the build-plate. PEEK material is printed onto a proprietary Roboze® build-sheet held down to plate with vacuum. The heated chamber is capable of reaching 160°C. The experiment was done using a 0.4 mm hardened nozzle.

The filament used is **Ensinger TECAFIL PEEK LDS** 1.75mm. The filament is dried at 120°C for minimum of 10 hours prior to printing samples.



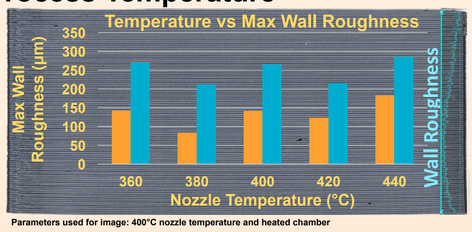
The sample model used in the optimization experiment is a rectangle with a center cut-out. The sample was printed in a 4x1 array.

Printer parameter for nozzle temperature, chamber temperature, speed, and extrusion multiplier (flowrate) was altered in **simplify3D** software.

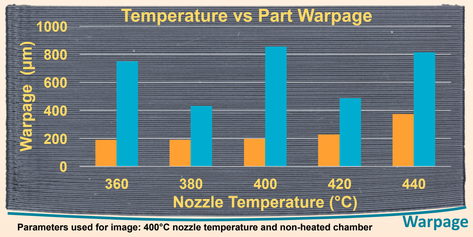
Images and dimensional data were collected using a Keyence VHX-7000

DATA

Process Temperature



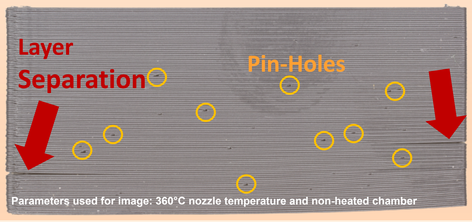
Parameters used for image: 400°C nozzle temperature and heated chamber



Parameters used for image: 400°C nozzle temperature and non-heated chamber

Legend
- Heated Chamber(160°C)
- Non-Heated Chamber(35°C)

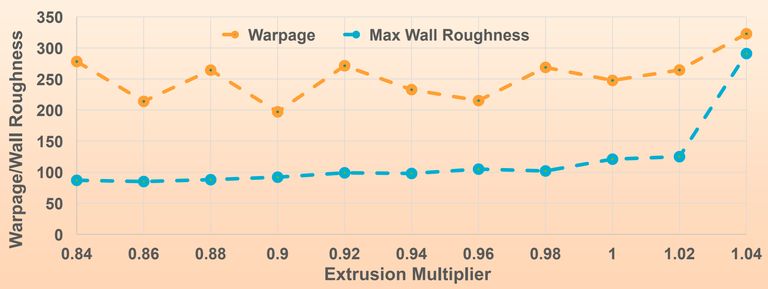
Samples printed without a heated chamber displayed greater warping and wall roughness vs those printed in a heated chamber.

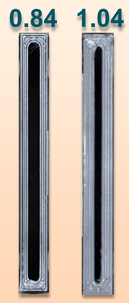


Parameters used for image: 360°C nozzle temperature and non-heated chamber

Pin-holes and layer separation defect increased on samples printed at lower nozzle temperature and without a heated chamber.

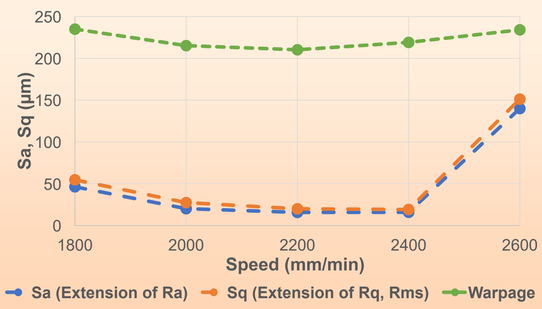
Flow Rate/Extrusion Multiplier (EM)





Print Speed

Speed (mm/min)	Print Time (hh:mm)	Arithmetical mean height Sa (µm)	Root Mean Square height Sq (µm)
1800	2:20	46.27	54.63
2000	2:08	20.12	27.39
2200	1:58	15.66	19.92
2400	1:49	15.8	19.1
2600	1:42	139.98	151.22



RESULTS

Process temperature

Chamber Temperature

Heated Chamber is critical to decrease part warpage and defects.

- Over 2x reduction on warpage on sample printed in heated chamber
- Eliminated layer separation and decreased pin-hole defects

Nozzle Temperature

Temperature range from 380°C to 420°C resulted in the least defects.

- (>420°C) Increased part warpage and wall roughness.
- (<380°C) Increased pin-holing defect on layer surface.

Extrusion Multiplier (*flow-rate*) parameter:

- **High flow rate (>1)** resulted in added part warpage and increased wall roughness.
- **Low flow rate (<0.94)** no significant impact on part warpage but did produce gaps between extrusion path.

Print Speed

- Part warpage was negligible on speed dependent samples
- 2000 mm/min to 2400 mm/min yield best surface roughness
- Roughness significantly increased (>2400)

DISCUSSION & FUTURE WORK

Defect such as pin holes, layer separation, wall roughness, and part warpage are common when processing PEEK via FDM, however, these defect can minimize or eliminate by optimizing the processing temperature, flow rate, and speed. While the optimized value may vary for different printers, the derived values from the experiment can be a strong start point in producing a quality PEEK print utilizing FDM.

- 160°C Heated Chamber
- 380°C- 420°C Nozzle
- 2000 - 2400 mm/min (30-40 mm/s)
- Increase flow-rate if voiding in extrusion path
- Decrease if flow-rate if wall are over-extruded (rough)

Future Work

- Impact of optimized print parameter on mechanical properties
- Part Dimension Comparison to STL Model with Keyence 6200

REFERENCES

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