Senior Project – Mechanical Engineering – 2018

Optimizing a Connecting Rod Through 3D Printing

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Background

Direct Metal Laser Sintering (DMLS): The process illustrated in Figure 1 starts with a bed of powdered metal spread out, then a laser is used to sinter the powder of that layer together where desired [1]. A new layer of powder is then spread, and the process is repeated until the part is completed [1]. Parts printed with DMLS are strong, highly ductile, and resistant to corrosion, making them good candidates for use in fields such as automotive, aerospace, and medical [2]. Drawbacks of the DMLS process include a longer print time, design restrictions, and in some cases the need of supports [1].

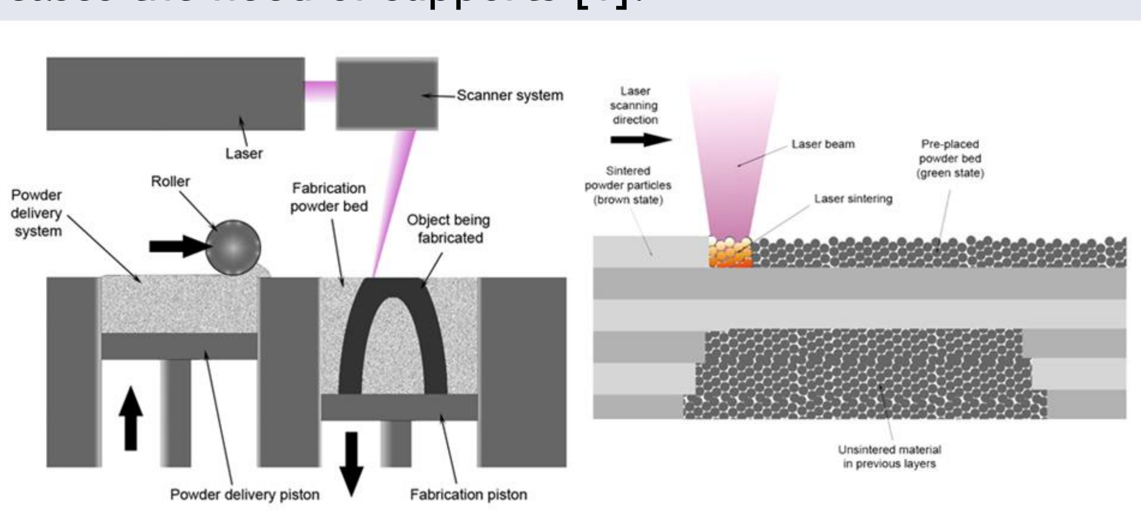

Figure 1: Image showing how parts are created with the DMLS process [3].

Binder Jetting: The binder jetting process is similar to the DMLS process in that it uses layers of powdered metal. But, instead of immediately sintering or melting the powdered metal together it uses a liquid resin to bind the powder, then the part is put in a kiln where the particles are melted together [1]. The part is then brushed to remove any excess powder and then polished [4]. Parts produced with this process are resistant to corrosion, have a fast print time, and are relatively cheap, making them good for consumer use [4].

Topographic Optimization: Topographic optimization is a method that takes a given load, then optimizes the material layout of the part with the goal of reducing weight while maintaining strength. This is completed through a finite element analysis and mathematical programming techniques [5]. The output is the optimal shape of the part under the given load conditions, but due to the complexity of the geometry it very often is not possible to manufacture the part with traditional methods.

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Objectives

The use of 3D printing metals has become an increasingly popular manufacturing method in the automotive and aerospace industry, causing a push for faster and cheaper processes. 3D printing has the unique ability to fabricate parts that have been topographically optimized, a method that takes given loads and uses finite element analysis to optimize material layout while maintaining strength. A standard and optimized automotive connecting rod have been printed with the direct metal laser sintering and binder jetting processes using stainless steel 316L. Another bulk connecting rod has been machined at the Union College Machine Shop. The parts will be put under a load identical to the one used for the finite element analysis (FEA) and data will be collected through a digital image correlator measurement system. Data will be compared to FEA results. The effect of the printing process and optimization will be explored with the goal of finding whether the optimized parts have equivalent strengths.

Methods

Assumptions:

- Static load
- Fatigue neglected

Modeling and Analysis:

A 1/3 scale model of the connecting rod (~2.75" long) was created in Solid Works. Using load data acquired from testing the connecting rod at 5700 rpm a finite element analysis was run, shown in Figure 2. Then, solidThinking Inspire was used to run the optimization with the same load inputs, shown in Figure 3.

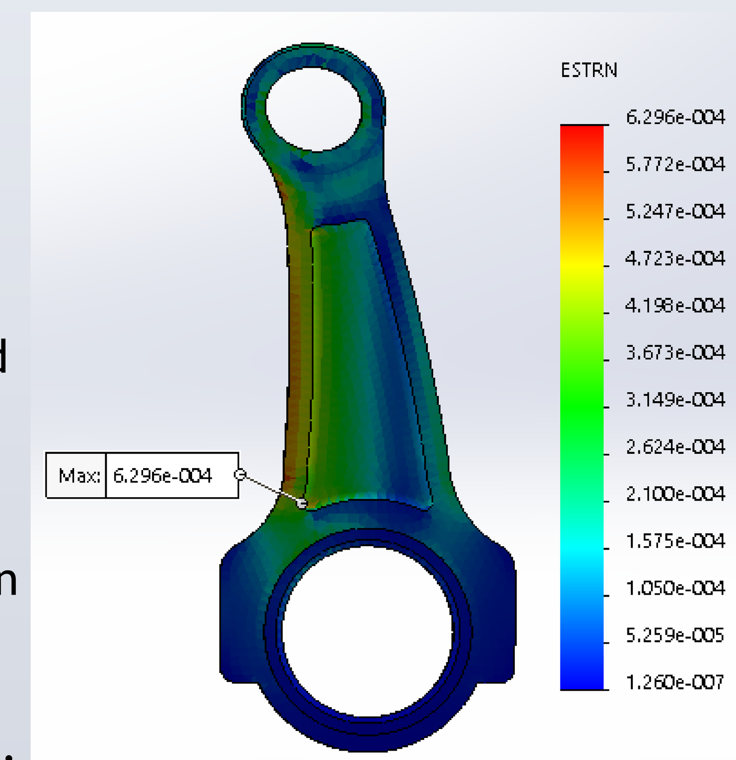

Figure 2: Strain results of FEA of 1/3 scale connection rod at the 60 degree position.

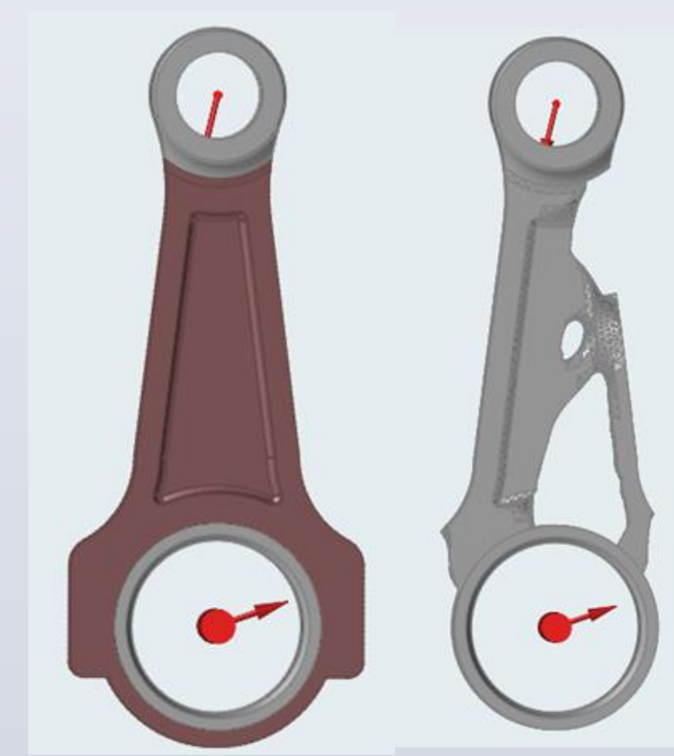

Figure 3: Connecting rod before optimization on the left and after optimization on the right.

Compression Testing:

The parts will be placed under a compressive load identical to what was input for the FEA and optimization. The crank end of the rod will be fixed by setting the rod in Wood's metal. Strain will be measured through a digital image correlation (DIC) measurement system.

Results to Date

Once the binder jetting and DMLS printed parts were received they were examined under an optical microscope. Figures 4 and 5 show images of the connecting rods with 50x magnification views. The binder jetting surface, shown in Figure 4, is uniformly rough which was expected. During the printing process the metal particles are bound together with a resin and are later melted together in a kiln, meaning no track lines are expected to be seen. The part is then finished by sandblasting, which typically leaves a rough surface. The DMLS surface, shown in Figure 5, is more smooth and displays lines where the laser was moving across the part. This is expected because the metal particles are immediately sintered together by the laser. The part is expected to have a coarse and granular finish without any post processing, however this part has been polished with a mechanical polisher, explaining the smoother finish.

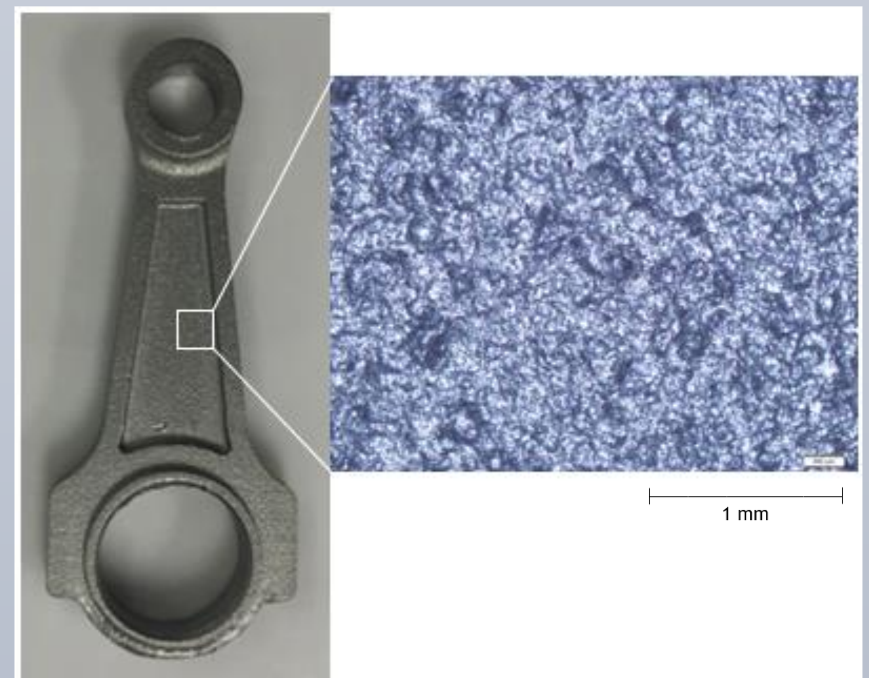

Figure 4: Image of part printed with binder jetting process and 50x magnification view.

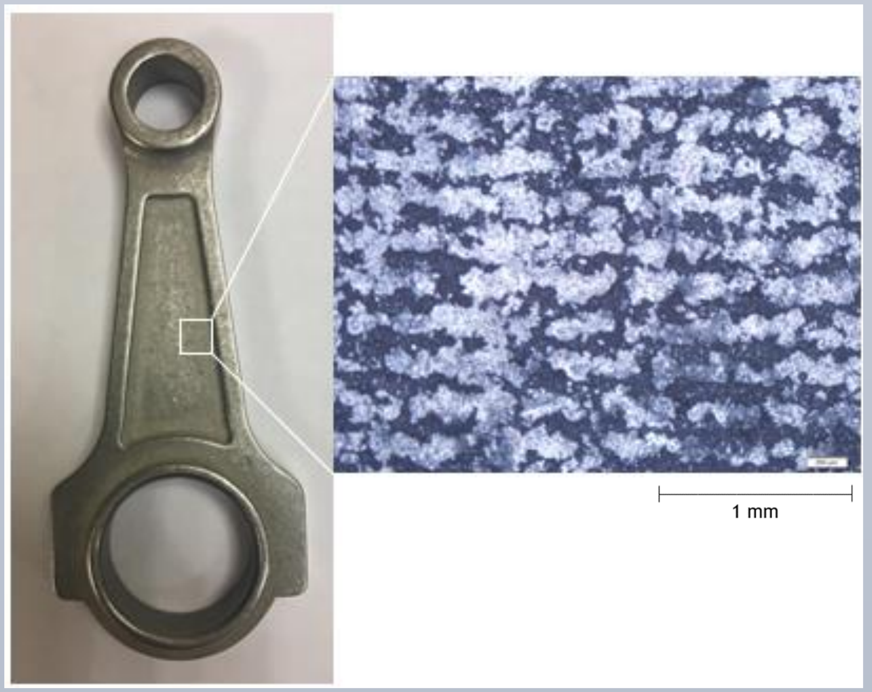

Figure 5: Image of part printed with DMLS process and 50x magnification view.

Properties

Table 1 describes the DMLS, binder jetting, and bulk mechanical properties of stainless steel 316L.

Table 1: Mechanical properties of stainless steel 316L for different printing processes. [2,4,6]

Process	Mechanical Property	Unit	Value
Direct Metal Laser Sintering	Density	g/cm^3	7.900
	Tensile Strength (XY)	MPa	640
	Yield Strength (XY)	MPa	530
Binder Jetting	Density	g/cm^3	7.900
	Tensile Strength (XY)	MPa	582
	Yield Strength (XY)	MPa	224
Bulk	Density	g/cm^3	8.027
	Tensile Strength	MPa	515
	Yield Strength	MPa	205

Digital Image Correlation

Digital image correlation (DIC) is an optical technique that is used to measure strain in a part. DIC works by comparing digital images and tracking blocks of pixels in order to map strain on the part. The results are accurate to 5 με and can then be directly compared to a finite element analysis. [7] The increased accuracy and amount of information gathered makes DIC a much better option than a conventional strain gage.

Future Work

In the coming weeks the parts will be tested and strain data will be collected with the DIC measurement system. The experimental results will be compared to the finite element analysis in order to understand the effects of the optimization and printing processes. To improve the project I would pick a part that is loaded statically and is small enough that 3D printing is a more reasonable option.

References

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