Post-Processing Effects on 3D Dynamic Models Created from Additive Manufacturing

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ABSTRACT

Recent advancements in 3D printing have made it a more viable option for rapid and inexpensive modeling of three dimensional (3D) dynamic systems. This shift in modeling techniques comes with inherent issues. The rough finish of raw 3D printed parts can cause dynamic models to stick and bind due to excess friction. This friction can also result in heat related fatigue of the printed parts. Traditional methods of finishing printed parts are labor intensive and involve coating the parts in acrylic or other chemical coatings. We propose using the technique of post-processing 3D printed parts to remove the rough edges with minimal change in the dimensions of the parts. To test our theory, we 3D printed a 1/3 scale replica of an internal combustion engine to prove viability. With our experimentation, we have quantified a 38% reduction in surface roughness and a 20% to 50% reduction in moving resistance after post-processing cycles with PostProcess Technologies™ NITOR™ machine.

Keywords: additive manufacturing, post-processing, dynamic models, 3d printing, surface finishing

1 INTRODUCTION

Advancements in 3D printing have made it a viable option for rapid and cost effective modeling of dynamic systems. Most of these printing methods offer a high printing resolution, but often leave printed parts with a rough and jagged surface due to layer by layer construction of parts through fused deposition modeling. Although 3D printing as a technology has been rigorously explored and is still a large area of current research, post processing of these parts to smooth and finish these parts has been rarely covered. PostProcess Technologies introduces the world's first automated and intelligent post processing methods aimed for support removal and surface finishing of 3D printed parts created from a variety of printing techniques. We seek to quantify the effects of these automated post processing methods, comparing parts that went through these surface finishing procedures to raw 3D printed parts. We will utilize their Suspended Rotational Force technology to surface finish 3D printed parts, created from an entry level printer using polylactic acid printing material.

2 RELATED WORK

Fused Deposition Modeling [3],[5],[8] uses thermoplastic filament fed through a heated nozzle laying down thin layers one on top of the other to create a 3-dimensional object. This printing technique has become the standard for advanced prototyping and modeling of various projects and applications [9],[7]. Advancements in most recent years have been made in order to make these processes more effective for use in to-market applications such as surgical equipment and consumer products. Current limitations of FDM 3D printing such as surface roughness, strength of parts, and speed of production can be improved based on the specific selection of printing properties [6]. Some limitations are currently unavoidable, such as poor surface roughness caused by the process of stacking thin layers on top of each other which creates a rough finish in which the individual ridges parallel to the printing bed. This rough surface subjects the parts to poor tensile properties and premature failures [4].

Traditional methods of finishing printed parts involve manual use of abrasives [1] or an acetone vapor smoothing process [2] to surface finish parts. Using the patented automated PostProcess techniques, 3D printed parts were processed, removing rough edges with minimal change in the dimensions of the parts.

3 METHODS

The proprietary post processing technology offered by PostProcess: Submerged Vortex Cavitation, Suspended Rotational Force, Thermal Atomized Fusillade and Volumetric Velocity Dispersion allows for 3D printed parts to undergo automated and intelligent support removal and surface finishing procedures.

PostProcess™ NITOR machine (Figure 1) allows for surface finishing, controlling heat, frequency, amplitude and lubricity control parameters. The NITOR utilizes the Suspended Rotational Force technology, which suspends parts within a circulating motion inside of a mixture of composite abrasives and fluids. The constant mechanical force on the surface of the parts removes rough edges, as well as smoothing the surface of the part.

Figure 1: *The NITOR Suspended Rotational Force machine from PostProcess. This was used to suspend the parts in an abrasive and fluid solution to conduct surface finishing.*

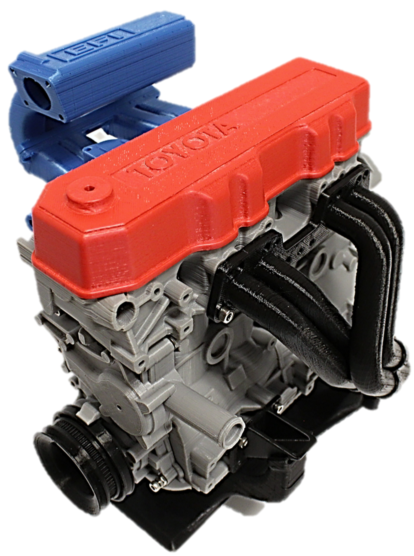

Figure 2: *1/3 scale Toyota 22RE dynamic engine model that is not put through the NITOR machine. This engine was equipped with operational pistons, crankshaft, camshaft, and valves. This allows for a realistic representation of the engine's functionality when operational.*

Utilizing fused deposition modeling technology, dynamic models including a Toyota 22RE engine model and a 2:1 ratio gearbox were printed with a FolgerTech FT-5 in PLA for a comparison study of post processing effects. Both dynamic models are passed through cycles of the NITOR Suspended Rotational Force machine using default control parameters specified by PostProcess.

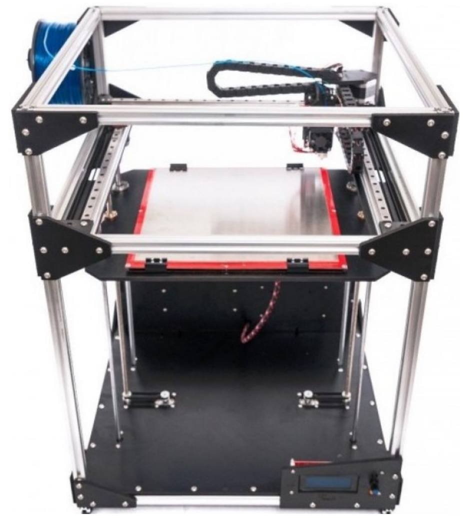

Figure 3: *The Folger Tech FT-5 3D printer. This FDM printer allows for printing of a large surface area of 300mm x 300mm x 400mm allowing for large scale models to be printed in one solid piece. This printer allows for a .05mm resolution producing high quality 3D printed parts. This printer is capable of printing multiple materials including PLA, ABS, Nylon, and other polymers.*

The NITOR machine has a tumbling reservoir that the 3D prints are inserted into. The prints are then spun with a combination of different substrates and liquids in order to equally apply mechanical force to the surfaces of the 3D printed parts. This force wears away at the print ridges of 3D printed parts equally across the surface. A smooth finish can be observed on the models that can then be painted in order to output models that look as though they were injection molded plastic parts.

4 EXPERIMENTS

We subject our test parts to usage similar to what would be experienced in the real world. This included rigidity testing, thermal properties, and rolling resistance.

4.1 Surface Roughness

To quantify the change in surface roughness from PostProcess' Suspended Rotational Force technology via the NITOR machine, two identical parts were printed from the Folger Tech FT-5 using identical printing parameters for each part. One of these parts went through post processing cycles according to company specifications for PLA parts. These are shown in Figure 4.

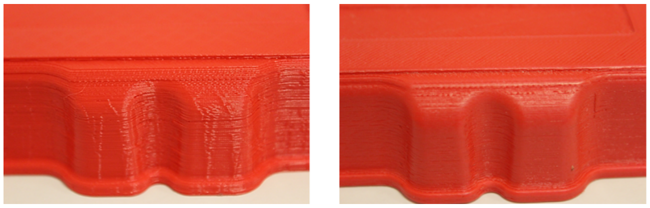

Figure 4: *Comparison images between unfinished (left image) and post processed (right image) test parts. The post processed part shows a reduction in jagged edges from the FDM printing method, as well as an overall visual reduction in surface roughness.*

A Tencor profilometer was used in order to measure surface roughness of the unfinished and post processed testing parts. This allowed for multiple height vs. length graphs as seen in Figure 5. A 38% reduction in surface roughness, from 0.2815m to 0.1092m was experienced after post processing via the NITOR.

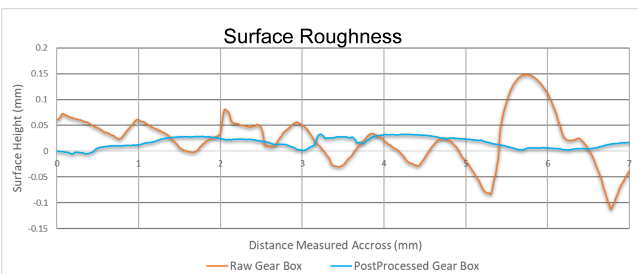

Figure 5: *The Tencor profilometer surface roughness measurement showing the variation between the original, raw part and the post processed part. Measurements were done on the same location of each part.*

4.2 Thermal Properties

When the dynamic models are subject to rotation, heat buildup becomes a concern as a fully 3D printed model has plastic to plastic contact, causing excess heat buildup from friction. These changes in heat generation before and after post processing were captured using a FLIR Pro thermal imaging camera. After spinning both the unfinished and post processed gearbox dynamic model at 300 rpm for 120 seconds, the post processed gearbox showed a smaller average temperature and a reduction in heat concentrations at high friction points shown in figure 6.

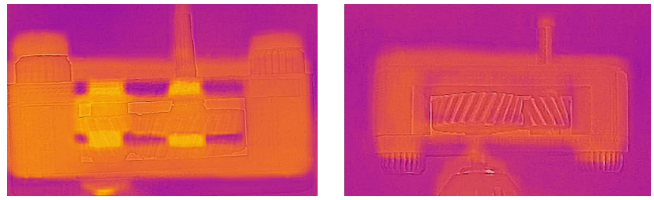

Figure 6: *Comparison between heat buildup of raw 3D printed gearbox (left image) versus post processed gearbox (right image). As shown, the raw gearbox experiences more heat generation as well as a higher concentration of heat at contact points.*

4.3 Rolling Resistance

After post processing is conducted on the dynamic models, a smaller coefficient of friction is experienced due to smoother contact points as shown in the previous experiments. This reduction in friction will also cause a change in input torque needed to rotate these dynamic models. Peak static input torque and average moving torque were measured using a mechanical torque gauge.

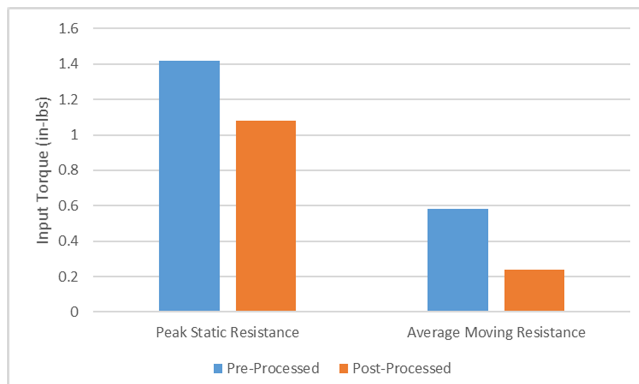

Figure 7: *Comparison of peak static and moving resistance between the pre and post processed engine model.*

An average of 20 input and moving torque measurements were recorded at various points of rotation within the engine dynamic model. As a result of post processing, a 23.9% reduction in peak static resistance and a 58.6% drop in average moving resistance was measured (Figure 4C).

5 CONCLUSION

Post-processing techniques have proven their usefulness for improving the operation and longevity of dynamic models. Through the testing of the dynamic models produced with FDM PLA, a 38% reduction in surface roughness, reduction of heat generation during movement, as well as a 20% to 50% reduction in input torque has been shown after cycles with the PostProcess NITOR machine. These improvements to dynamic models can be extended to real world applications as well. The NITOR machine, as well as other machines from PostProcess work for metal 3D printed parts as well as plastics. As technology is advancing along with the use of finite element analyses, 3D printed parts are being used within engines and other dynamic models to improve performance and efficiency over conventional parts. Post processing these parts will further improve performance as friction is reduced on contact points. Further analyses on the effects of post processing on different printing materials and printing technologies will be conducted. In addition a stress/strain analysis will be done to quantify the internal and structural changes 3D printed parts experience after post processing occurs.

6 ACKNOWLEDGEMENTS

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