WASHINGTON STATE UNIVERSITY

Group Project Report

TEAM 4

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Additive Manufacturing 507 - WSU

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For this project, we were tasked to additively manufacture a component unique to fused deposition modeling (FDM) material extrusion processes. The goal was to design a system that satisfied predefined dimensional tolerances and geometry requirements and contained moving parts, all to be constructed in one continuous build.

Preliminary design

Our preliminary design was a ring that had airfoils evenly distributed around it and was placed on a threaded shaft to travel up and down, with the ultimate goal of it spinning off and flying upwards. The initial SolidWorks drawing file can be seen in Figure 1. Required design specifications included: rotating parts, pillars with varying cross-sections, walls of varying thicknesses, grooves, internal channels, and size constraints. Internal channels were included as continuous circular and oval sections inside the rotating ring. Pillars with varying cross-sections were obtained through the curved base connected to the threaded pillar. The rotating part was the winged ring built onto the threaded pillar, grooves were incorporated into the rotating ring for the threads, and walls of varying thicknesses were designed in the base as its thickness varied along a curved surface.

First Print

Although the first print appeared accurate, fabrication showed multiple issues with replicating our design, as seen in Figure 2. Measured post-processing dimensions generally reflected designed dimensions by deviating mostly less than 6%, as seen in Table 1. However, the largest dimension change was in the diameter of the inner circular channel, which expanded 37.5% past the designed specification. The tolerance of the rotating ring was set to be too small, as the ring rotated but the fit was snug and would not rotate as freely as desired. We cut open the ringed piece of the system to examine the shape of the internal channels and realized that the support material was still present as there was no way for the support-dissolving bath to penetrate to the channel. The circle geometry also maintained its original dimensions easier than the oval geometry after processing, which was identified through their cross-sections. The wings were also very fragile due to the small size and fillet radius at their connections. Threads were too small as well, which did not allow the ring to easily engage the threads. To address these issues, larger threads, fillets, and internal channels were created. The main components of the updated SolidWorks drawing are presented in

Figure 3. A single, larger, circular internal channel in the rotating ring was designed, and an internal channel of changing cross-section was placed within the threaded shaft. Drains were incorporated for the wings' internal channel to allow the bath to reach and dissolve all support material. The threads were scaled three times larger to create a more pronounced path for the ring to rotate on. More space was also allowed between the inside of the rotating ring and the wall of the threaded shaft to allow the ring to spin more freely.

Final Print

The final print, seen in Figure 4, demonstrated that printer reliability can be an issue. Some of the regions that printed well in the initial build did not build well in the final print. This was seen in the wings, which fluctuated thickness between the builds with no design changes and the part was partially translucent. After examining our measured dimensions in Table 1, we found the wing thickness dimension only expanded by 6% compared to the initial 16%, which supported that our final wing thickness was thinned. Alternatively, our thread changes as well as increasing the gap between the rotating ring and the shaft proved to be very helpful with the part's movement as the ring tracked easier along the shaft. Internal channels seemed to be improved with the addition of drainage channels as well. Overall, our final part was improved in some aspects compared to our initial print but worsened in other details.

What was learned

We learned that with additive manufacturing, what seems to be a limitless fabrication process actually has many limitations that need to be considered to create a part that fully reflects the initial design. Support material made some features possible, yet hindered the application of internal channels with no drains in the initial design. Despite some of the issues, additive manufacturing was still able to produce a part that could not be built using conventional manufacturing techniques in a single, continuous step. We also learned that designers must start to think of the limitations of additive manufacturing and break out of the conventional manufacturing mindset before fabricating a component, as the design process can be surprisingly complex compared to conventional techniques.

Tables and Figures

	First Print			Second Print		
Dimension (in.)	Drawing	Actual	Difference	Drawing	Actual	Difference
Base Height	2.00	2.011	0.6%	2.00	2.010	0.5%
Base Width	1.80	1.802	0.00%	1.80	1.797	-0.2%
Shaft Diameter	0.75	0.747	-0.4%	0.75	0.746	-0.5%
Ring Height	0.25	0.255	2.0%	0.25	0.254	0.6%
Ring Inner Diameter	0.77	0.760	-1.3%	0.78	0.771	-1.2%
Ring Outer Diameter	1.15	1.140	-0.9%	1.15	1.145	-0.4%
Wing Thickness	0.05	0.058	16.0%	0.05	0.053	6.0%
Ring Channel Diameter	0.08	0.050	-37.5%	0.09	N/A	N/A
Base Channel	N/A	N/A	N/A	0.15	0.144	-4.0%

Table 1 - Dimensions before (Drawing) and after (Actual) processing and the differences between the two.

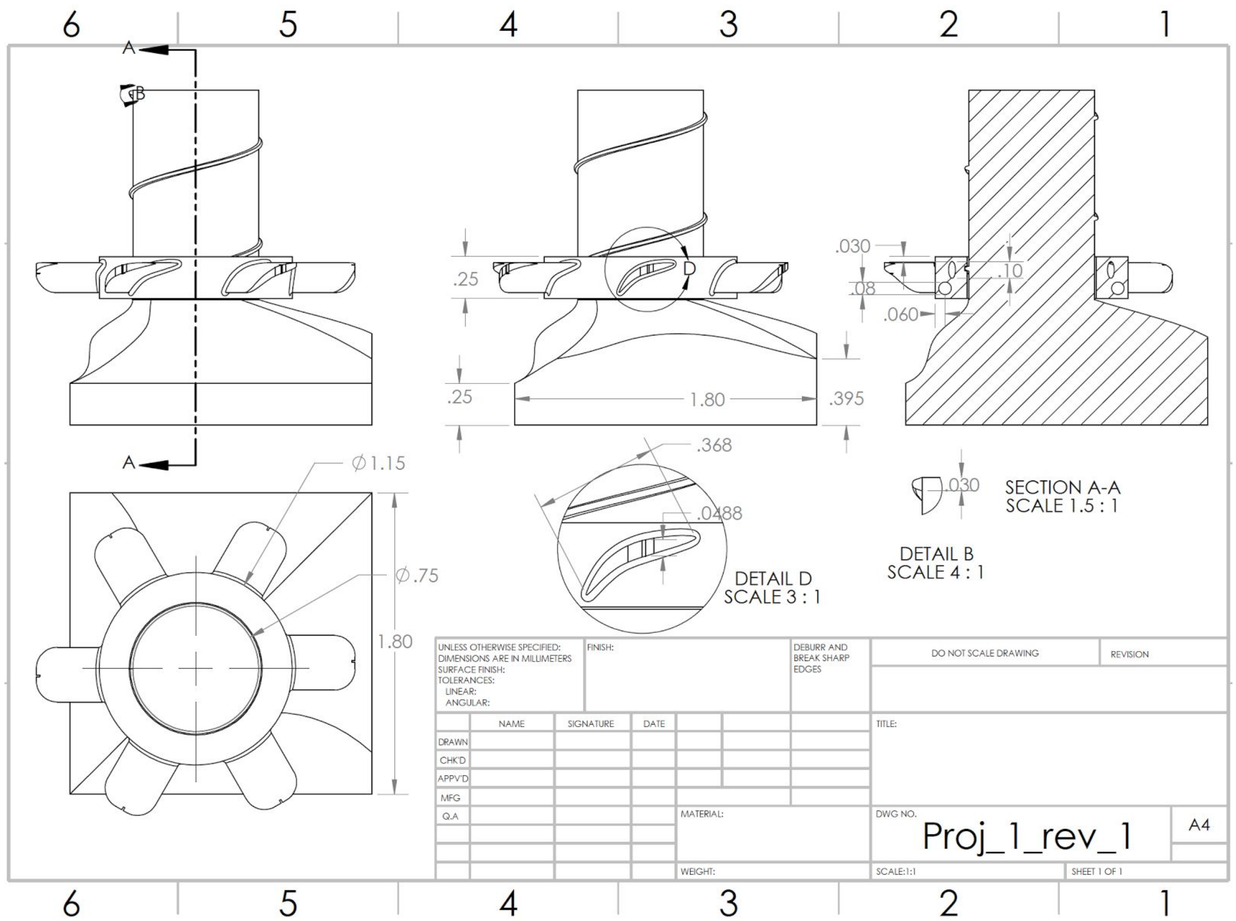

Figure 1 - SolidWorks drawing of initial part design.

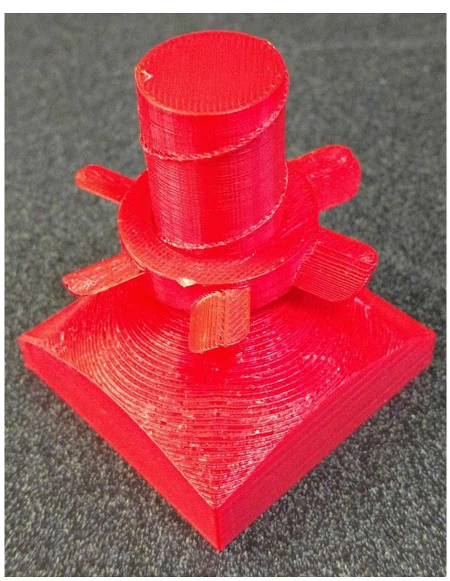

Figure 2 - Print of initial design after support material removal.

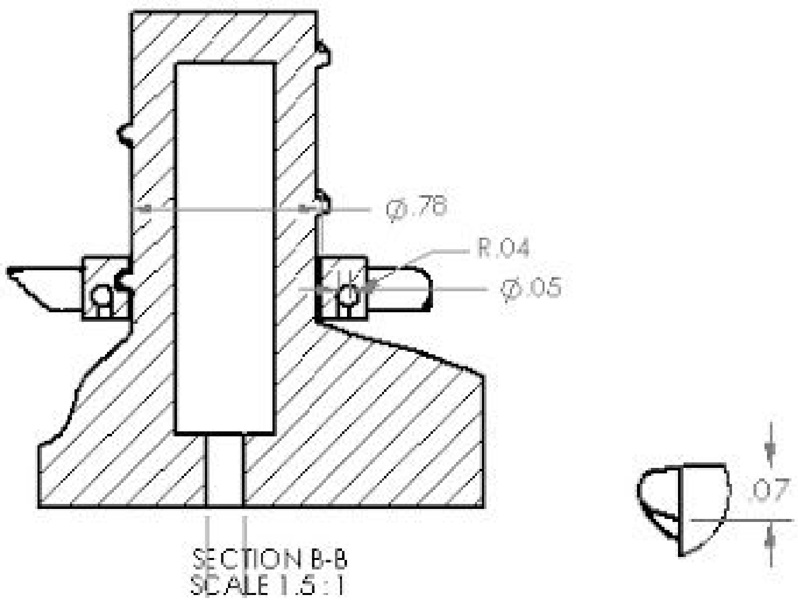

Figure 3 - Design modifications showing a single internal channel, channel drain, and enlarged threads.

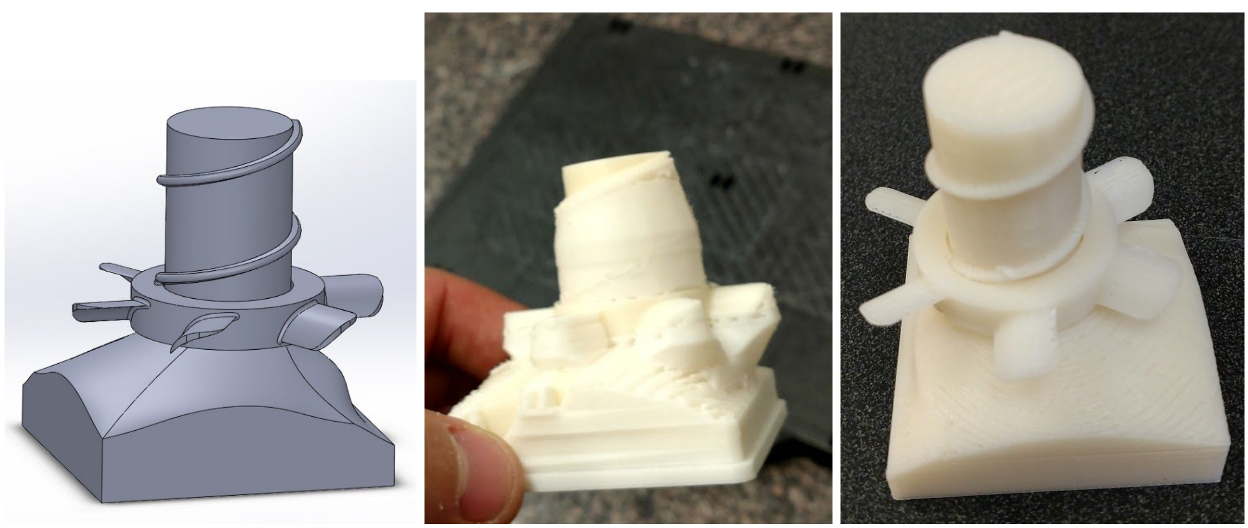

Figure 4 - Revised design CAD file (left) and final print with support material (middle) and after support removal (right).