INVESTIGATING THE MACHINABILITY OF 3D PRINTED RECYCLED CARBON FIBER

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ABSTRACT

Additive manufacturing and composite recycling are two popular topics of discussion within today's aviation industry. Although both additive manufacturing and composite recycling are not entirely new concepts, their popularity has only recently begun to gain momentum. Additive manufacturing such as 3D printing has been steadily gaining popularity [1] within the aviation industry due to its ability to quickly fabricate components, maintain low material waste, and low cost [2]. These benefits of 3D printing make it a popular technique for fabricating prototypes, molds, and production components. However, most of the 3D printed components require some form of post process machining before the 3D printed components or molds are ready for use. As the popularity of additive manufacturing continues to grow, increasing focus on creating a sustainable future has also led to the growing popularity of composite recycling. Many alternative methods of utilizing recycled composite materials are currently being evaluated [3]. In this pilot study, a team of Purdue University faculty and students has teamed up to investigate the machinability of 3D printed recycled carbon fiber. The specimens used for the study will be fabricated from a prototype 3D printed recycled carbon fiber part. Different combinations of machining processes will be tested on the specimens using computer numerical control (CNC) machining to determine the optimal machining process for molds fabricated using 3D printed recycled carbon fiber.

1. INTRODUCTION

Additive manufacturing such as 3D printing has been steadily gaining popularity [1] within the aviation industry due to its ability to quickly fabricate components, maintain low material waste, and low cost [2]. These benefits of 3D printing make it a popular technique for fabricating prototypes, molds, and production components. Especially when 3D printing can accommodate a wide variety of material such as metals and composite materials. As the popularity of additive manufacturing continues to grow, increasing focus on creating a sustainable future has also led to the growing popularity of composite recycling. Many alternative methods of utilizing recycled composite materials are currently being evaluated [3]. One of these alternative methods include the 3D printing of recycled composite materials. Recycled composite materials can be 3D printed and repurposed into manufacturing molds or other useful components. No matter what final form the 3D printed recycled composite components are destined for, the 3D printed recycled composite components require some post process machining before the 3D printed recycled composite components or molds are ready for use. The post process machining of 3D printed

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components or molds can be accomplished using many different techniques such as turning, drilling, or milling provided that the proper operating conditions are adopted [4]. Therefore, the correct machining conditions such as spindle speed and feed rate for 3D printed recycled composite components must be determined due to these parameters' ability to greatly affect the surface quality of the final product.

In this pilot study, a team of Purdue University faculty and students has teamed up to investigate the machinability of 3D printed recycled carbon fiber. The specimens used for the study will be fabricated from a prototype 3D printed recycled carbon fiber part. Different combinations of machining processes will be tested on the specimens using a Haas VF1 computer numerical control (CNC) machine to determine the optimal machining process for molds fabricated using 3D printed recycled carbon fiber.

2. EXPERIMENTATION

2.1 Sample Preparation

A prototype 3D printed recycled carbon fiber part shown in Figure 1 was provided for the study by a third party supplier who has requested for the makeup of the prototype 3D printed recycled carbon fiber part to remain proprietary. Randomly selected sections of the 3D printed recycled carbon fiber part was sectioned into uniform samples shown in Figure 2 using a waterjet. The samples were 50.8 mm in length.

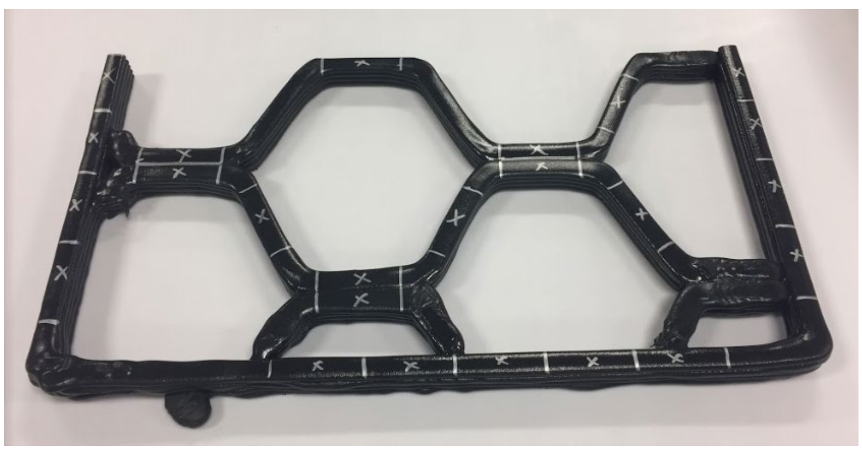

Figure 1. Prototype 3D printed recycled carbon fiber part.

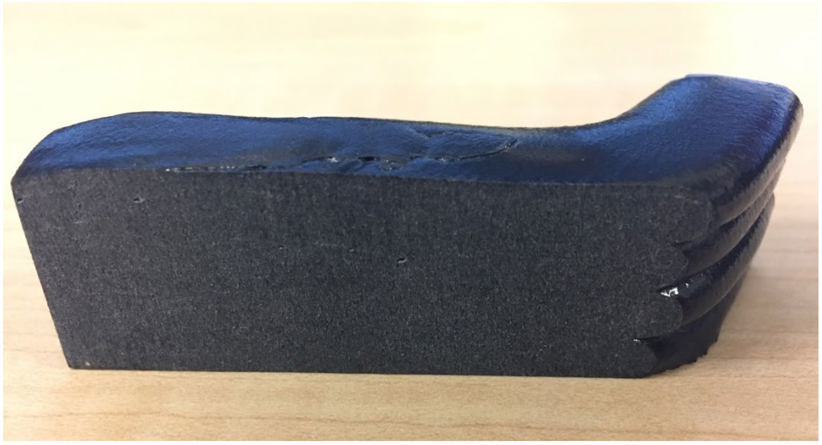

Figure 2. Waterjet sectioned samples.

2.2 Machining

The 50.8 mm samples were mounted in the vice of a Haas Automation VF1 CNC for the machining operations as shown in Figure 3. An initial trial machining operation was performed using a spindle speed of 10,000 revolutions per minute (rpm) due to numerous current research focusing on high speed machining (HSM) for cost effectiveness and increased production rate [5]. However, the 10,000 rpm spindle speed created an undesirable and rough surface quality due to the specimen's part surface overheating. According to a study by Ho-Cheng and Dharan, high spindle speeds result in an increase in surface temperature [6]. High surface temperature is an undesirable condition for thermoplastics used for the 3D printing process. Therefore, in order to avoid issues of high surface temperatures, the spindle speeds for the study were selected from the lower rpm range. The rpm trialed in the study were 50, 100, 150, 500, 100, 1500, and 2500 rpm. At each rpm, four different feed rates were used. The feed rates were 127, 254, 381, and 508 mm/min.

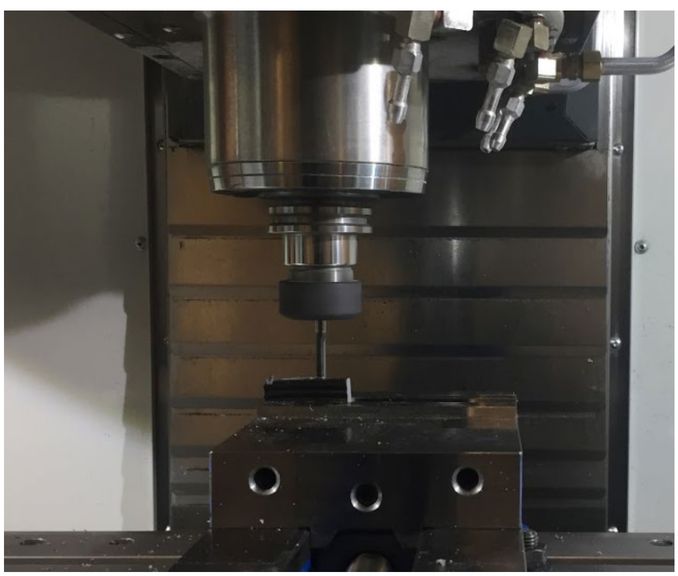

Figure 3. Machining setup for samples.

3. RESULTS

The surface quality of the machined specimens for this pilot study was assessed based on visual observations on the smoothness of the machined surface. Figure 4 shows the initial machining trials using a high spindle speed of 10,000 rpm which resulted in an undesirable and rough surface finish with the samples showing clear signs of melting due to surface overheating. These initial results reinforced the study's decision of selecting spindle speeds from the lower rpm range.

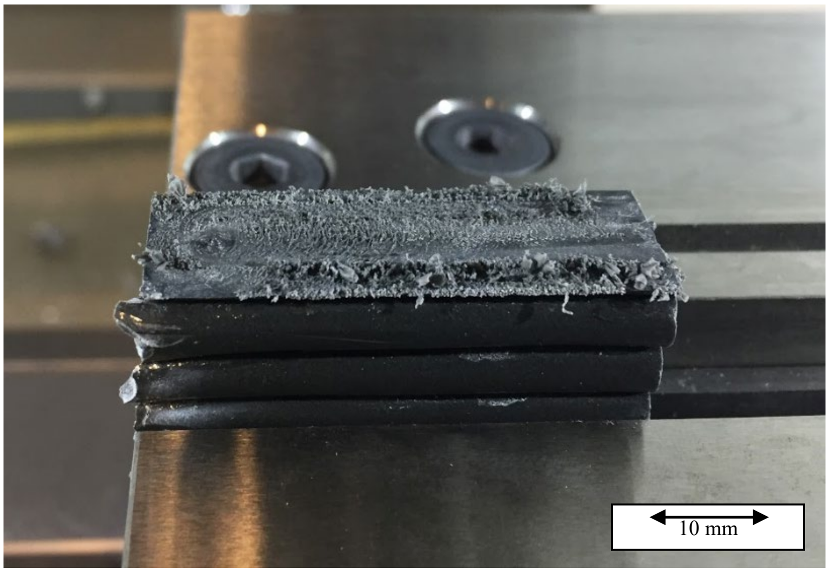

Figure 4. Machined surface quality with 10,000 rpm spindle speed.

At 50 rpm spindle speed, the specimens in Figure 5 no longer showed signs of overheating. However, the milling bit was unable to create chips and expel the chips fast enough leaving the machined surface with obvious imperfections and roughness.

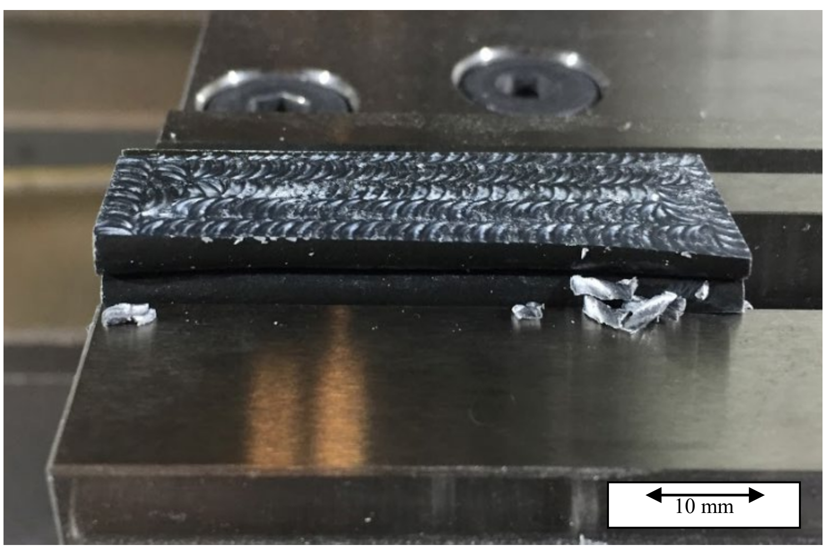

Figure 5. Machined surface quality with 50 rpm spindle speed.

With the spindle speed increasing from 50 rpm to 500 rpm, the chips gradually reduced in size and surface quality began to improve as seen in Figure 6. Surface imperfection and roughness also showed improvements as the rpms increased.

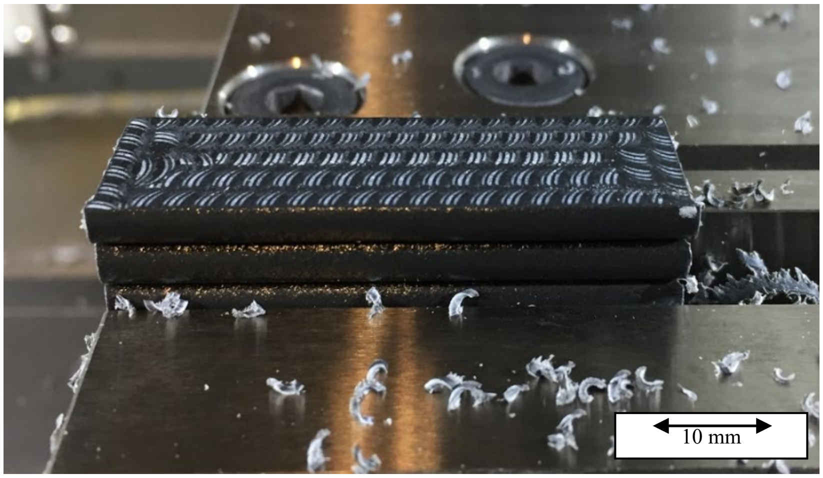

Figure 6. Machined surface quality with 100 rpm spindle speed.

The surface quality of the machined specimens continued to show further improvements as the rpm were increased from 500 rpm to 2000 rpm. At 1500 rpm, minimal surface imperfection and roughness remains as shown in Figure 7.

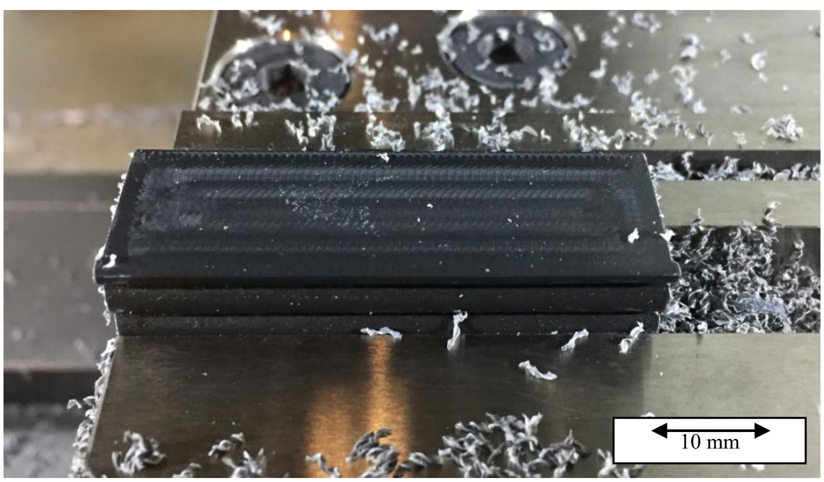

Figure 7. Machined surface quality with 1500 rpm spindle speed.

Finally in Figure 8, at 2500 rpm spindle speed and 508 mm/min feed rate, the machined surface still showed no signs of overheating and the surface imperfections and roughness had been eliminated effectively. The resulting surface smoothness would be adequate for composite tooling and production components.

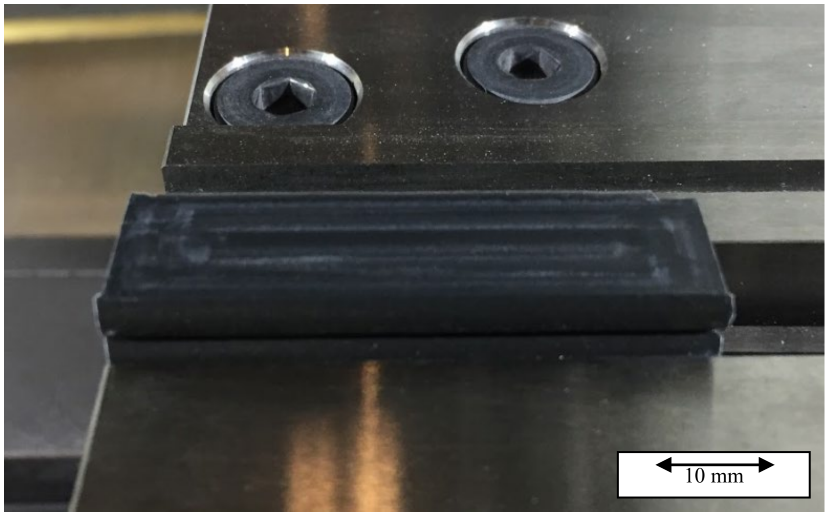

Figure 8. Final machined surface quality with 2500 rpm spindle speed.

4. CONCLUSIONS

Final surface quality is an important aspect for both composite molds and composite production component. The surface quality for composite molds plays a vital role to determine the quality of the parts manufactured from the mold. While the surface quality of a composite production component determines the over appearance and quality of the product before reaching the end user. In this pilot study, the researchers were able to determine a spindle speed and feed rate that is suitable for 3D printed recycled carbon fiber. Through the use of 50.8 mm specimens, the researcher was able to determine that 2500 rpm and 508 mm/min was a combination that produced a visually smooth machined surface quality suitable for composite molds and production components. However, the results only apply when the machining surface remains flat and an end mill being the tool of choice. Further testing is required in order to determine if the results apply for more complex machining processes and various different types of tools.

5. REFERENCES

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