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Finishing Processes of Fused Deposition Modeling (FDM) 3D Printer

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Abstract

3D printer is expected to spread currently. This paper describes the processing method of modifying the FDM printed products. We get the characteristics of each of the processing by evaluation using the time and surface roughness.

Introduction

Currently, 3D printing process is used in various fields. For example, Stereo Lithography (SLA) [1-3] using a light-curable resin has been used for such as accessories. Inkjet type of the 3D printer has been used for production of medical such as the artificial bone joints organs and solar cells [4-7]. Selective Laser Sintering (SLS) [8-9] has been used in the production of metal parts with complex shapes. Fused Deposition Modeling (FDM) [10-12] has been used to produce the test model of industrial products and architectural models. In this way, 3D printing technology will be applied for fabrication of complex and functional devices and/ or products in the industrial field and the medical field and academic field. In addition, the patent of FDM core technologies was already expired in 2007. Therefore, it becomes possible to produce a reasonable FDM 3D printer. Further FDM is able to modeling of resin material which is widely used.

However, it is difficult to recognize the 3D printer as an explosively widespread fabrication machine. The main reason is the layer grooves that were generated on the 3D printed objects. The grooves exacerbate and damaging the aesthetics of the 3D printed objects. The grooves are generated on 3D printed objects of any shape. The FDM principle is shown in Fig.1.This principle is the material dissolved in thermal is printed each layer. By repeating the curing, laminating, 3D object is fabricated. The layer grooves that were generated on 3D printed object are shown in Fig.2. It can be confirmed that the grooves were generated for each layer of the 3D printed object. The layer grooves are to the accuracy of the 3D printed objects in much lower quality than the user expectations.

The hybrid process of polishing [13-14] and painting was used for the method of removing the layer grooves. However, it was not suitable for finishing process of the 3D printer because the process had following problems. The first problem was losing the advantage of 3D printing that was possible to fabricate conveniently complicated shaped objects. The second problem was the nature of the polishing, problem of difficulty in processing for complex shaping objects. Finally the third problem was decreasing of convenience because the harmful dust was generated in the polishing process and the dust was removed with collecting device that was additionally installed.

There was the other finishing process that was reported instead of polishing and painting. The vaporized chemical solvent was used in this process [15]. Acetone dissolves the ABS [16] resin that is the major 3D printing material. When the 3D printed object was placed in vaporized acetone, the surface of the object was dissolved and the layer grooves on the surface were removed. However, there were several problems in this process. It was not suitable for local processing because this process utilized vaporized acetone. Vaporized acetone was dangerous because it is flammable gas.

In this study, we investigated the detail of the upper two processes. We evaluated the processing time and surface roughness. And we consider about the two processes based on the evaluation. For example the scenes in which each process is suitable.

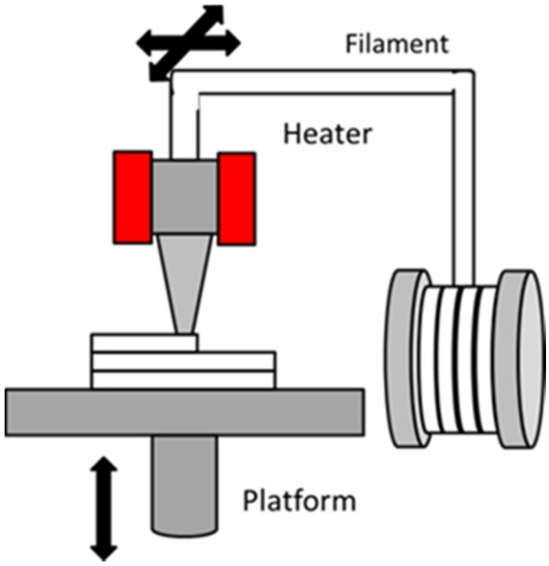
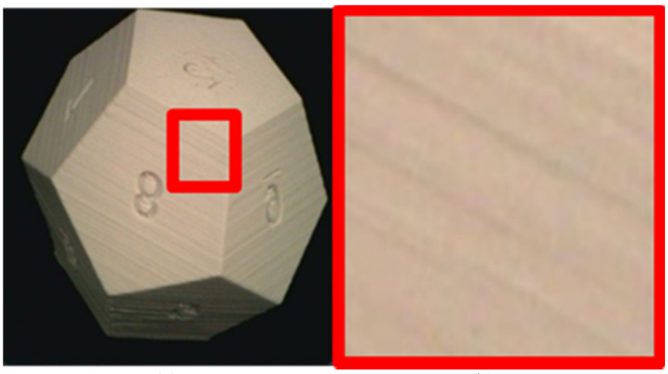


Fig.1 The Pattern Diagram of FDM 3D printer.



(a) (b)

Fig.2 The sample of FDM products which has layer grooves ((a): Over all view of the FDM 3D printed products which has layer grooves, (b): Enlarged view of (a))

The Polishing process for the 3D printed products

This chapter confirms the change of the layer grooves processed utilizing the polishing process. The diagram of the experimental set-up that we developed is shown in Fig.3. Samples are printed utilizing ABS resin as a material. The STL data of the sample whose shape is 5*15*25 are modeled utilizing 3D-CAD (Dassault Systems, France, Solidworks 2011). Samples are printed utilizing the FDM 3D printer (abee, Tokyo, SCOOVO X9). The head speed of the 3D printer is set to 30 [mm / s]. The polishing process utilizes the pen type mechanism with #800 paper rasp. The surface displacement is measured utilizing laser displacement sensor (KEYENCE, Osaka, LK-H008). The processing, the measuring and the shooting are carried out in the same system. Therefore the deviation of the measurement is minimized.

The surface displacement results before and after the polishing process is shown in Fig.4. It aims to grasp the fundamental characteristics of the polishing process from the micro point of view. The solid line is the surface displacement before the polishing process in Fig.4. It can be observed the width of the layer grooves is dependent on the layer pitch from the distance between the valley and the valley in Fig.4. The dashed line is the surface displacement of the after the polishing process in Fig.4. It is found that the height of the layer grooves was furnished by the polishing process. There are layer grooves that are scraped small and layer grooves that are scraped large when viewed individually by layer groove. In the polishing process there are irregularities in the removal of the layer grooves. The surface of the product is flat in the data and the polishing process utilizing the flat surface data. But there are the dents and scratch from the point that is not visible by human eye. Therefore the processing irregularities are generated. The decreasing of the products strength that is caused by layer grooves cannot be recovered by the polishing process. In addition the polishing process generates dust that is bad for human body. Therefore it is necessary to recover the dust. But the collecting mechanism for the dust deprives the FDM 3D printer of its convenience.

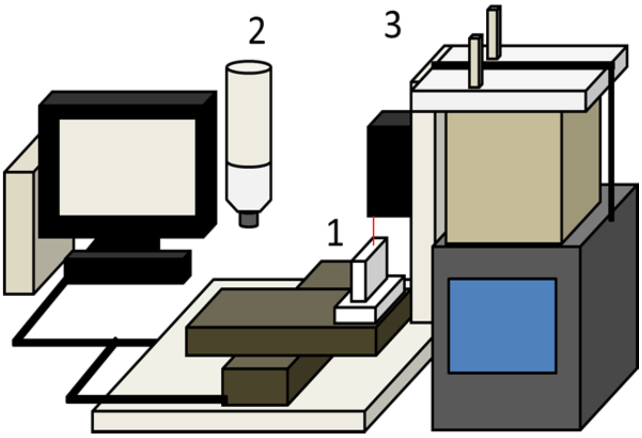


Fig.3 The experimental set-up for the polishing process and the measurement of the surface displacement
(1: The sample printed utilizing FDM 3D printer, 2: The polishing process that is utilizing pen type mechanism, 3: Laser displacement sensor)

The FDM 3D printed samples that simulated the left hand with a free form surface are shown in Fig.5. The layer grooves deteriorate the appearance of the FDM 3D printed products. (a) is the sample immediately after FDM 3D printing. (b) is the sample printed utilizing FDM 3D printer and processed utilizing the polishing process). There are some layer grooves sparsely. They can be the selectively processed utilizing the pen-type mechanism. One of the characteristics of the polishing process is to process easily to the convex portion of the structure and to process difficultly to the recessed portion. Laser grooves exist sparsely in Fig.5 are generated by this characteristics.

The polishing process is able to selectively process 3D printed products by devising mechanisms. However, depending on the shape of the FDM 3D printed product is there is a problem that the completely removal is not possible of the layer grooves. There is also a problem in the generation of dust. Furthermore, it needs long time for processing the complex product.

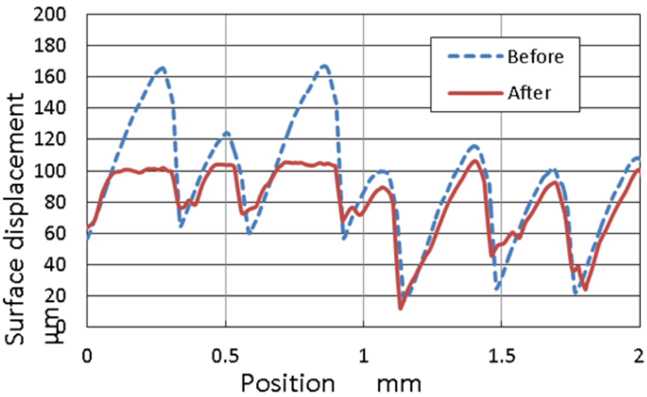
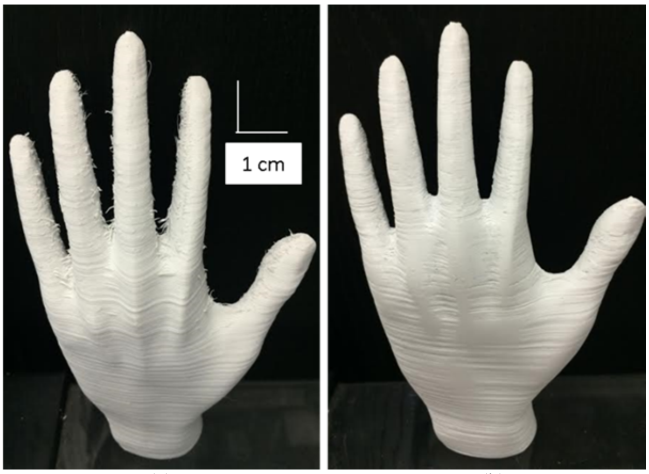


Fig.4 Changes in the surface displacement of the sample printed utilizing FDM 3D printer and processed utilizing the polishing process



(a) (b)

Fig.5 FDM 3D printed samples simulating the left hand with a free-form surface
((a): The sample immediately after FDM 3D printing, (b): The sample printed utilizing FDM 3D printer and processed utilizing the polishing process)

The acetone vapor process for the 3D printed products

This chapter confirms the change of the layer grooves processed utilizing the acetone vapor process. The diagram of the experimental set-up that we developed is shown in Fig.6.The acetone vapor process uses the same shaped samples with the polishing process. The same surface displacement measurement mechanism is utilized with the polishing process. The acetone vapor process is the method of coating the entire surface of the products with vaporized acetone. Controlling the temperature utilizes the Peltier element to vaporize the acetone. The boiling point of acetone is 56℃. Therefore acetone in the beaker is heated to 110 ℃ with a Peltier element and acetone is vapored in the beaker. The acetone vapor process was carried out for 5 minutes.

It aims to grasp the fundamental characteristics of the acetone vapor process in micro point of view.

The surface displacement results before and after processed the acetone vapor process is shown in Fig.7. The solid line is the surface displacement before the acetone vapor process in Fig.7. The dashed line is the surface displacement of the after the acetone vapor process in Fig.7. The dissolved material utilizing the acetone vapor process is filled into the recess of the layer grooves by surface tension. The acetone vapor process smooth layer grooves uniformly regardless of the shaped products. The vapored acetone is able to enter the portion where it is impossible to the polishing processing are recessed. This uniform process improves the strength of the FDM 3D printed product. Because of the acetone vapor process decreases the fracture cause.

The FDM 3D printed samples simulating dog with the complex structure are shown in Fig.8. (a) is the sample immediately after FDM 3D printing. (b) is the sample printed utilizing FDM 3D printer and processed utilizing the acetone vapor process.

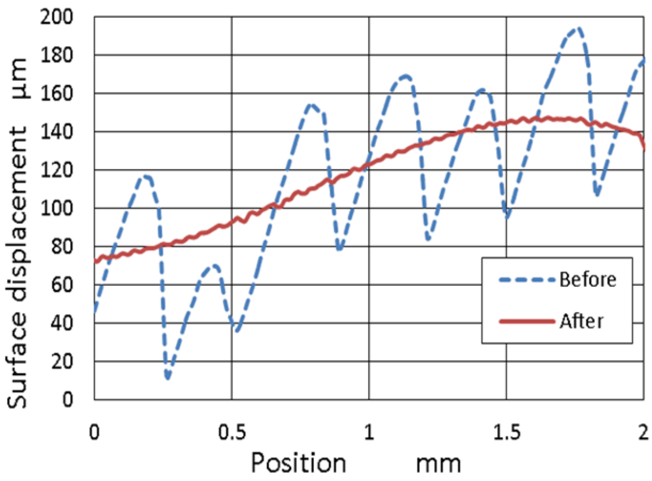


Fig.7 Change of the surface displacement of the sample printed utilizing FDM 3D printer and processed utilizing the acetone vapor process

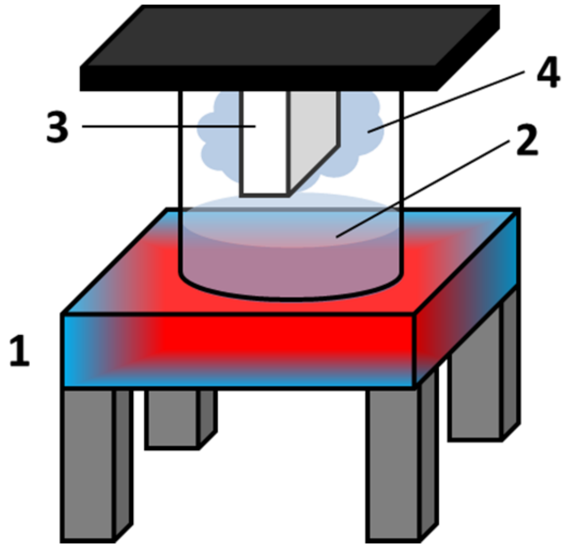


Fig.6 The experimental set-up for the acetone vapor process (1: Peltier device that control the temperature of acetone, 2: Acetone in the liquid state, 3: The sample printed utilizing FDM 3D printer, 4: Acetone in a gaseous state)

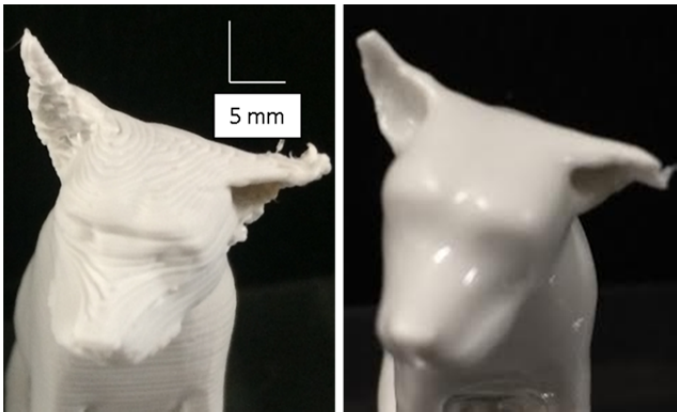


Fig.8 FDM 3D printed samples simulating dog with the complex structure ((a): The sample immediately after FDM 3D printing, (b): The sample printed utilizing FDM 3D printer and processed utilizing the acetone vapor process)

The acetone vapor process smooths layer grooves and makes it hidden. However, the line to represent the eye of the dog has disappeared by the acetone vapor process. Because vaporized acetone processes all portion of the products in the acetone vapor process. Therefore the acetone vapor process is not able to selectively process.

The acetone vapor process is able to uniformly smooth the layer grooves. The vaporized acetone covers and processes all of site of the products in the acetone vapor process. Therefore time required is at a critically low. However, the acetone vapor process is impossible to selectively process. The acetone vapor process is not suitable for the process to the product that has representation of fine line. In addition there is also a problem that leaking dangerous vaporized acetone.

The Comparison of the polishing and the acetone vapor

This chapter compares the polishing process and the acetone vapor process. It was compared with the polishing process and the acetone vapor process in the four items (time, safety, surface precision, selective) in table.1. When intend the uniformly process to the products the acetone vapor process is suitable. The acetone vapor process requires less time than the polishing process and surface precision is more accuracy. However the acetone vapor process is more dangerous than the polishing process. Because the acetone gas is easily ignite. In addition the acetone vapor process is not able to selectively process. Therefore when there is a portion that should not be processed the polishing process is suitable. The acetone vapor process is suitable when the improving of the strength for the FDM 3D printed products. Because the acetone vapor process is able to smooth and filled layer grooves. The new type process for the FDM 3D printed products is resolving the respective bad combines the good points of the respective the polishing process and the acetone vapor process are desired.

Table.1 The comparison of the polishing and the acetone vapor

	Polishing	Acetone vapor
Time	×	○
Safety	△	×
Precision	×	○
Selective	○	×
Other	Dust	Flammable gas

Conclusion

The behavior of the polishing process and acetone vapor process when applied on FDM 3D printed products was investigated. Each characteristic of the polishing process and the acetone vapor process were grasped by experiments. The new type process for FDM 3D printed products that is required by the users was revealed from the properties that were measured. In the new type process for the FDM 3D printed products, the ability to apply selectively and smoothing uniformly at the same time in a short time with safety is required.

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Author Biography

Kensuke Takagishi obtained his bachelor in Engineering at the University of Waseda in Japan. (2016). The topic include printed electronics, 3D-printer, micro-nano finishing and printed bio-materials. He is freshman of master course student. He was awarded three times.