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DEVELOPMENT OF THE IMPROVING PROCESS FOR THE 3D PRINTED STRUCTURE

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Abstract - *The article focuses on the Fused Deposition Modeling (FDM) 3D printer because the FDM 3D printer can print the utility resin material. It can print with low cost and therefore it is the most suitable for home 3D printer. The FDM 3D printer has the problem that it produces layer grooves on the surface of the 3D printed structure. Therefore the authors developed the 3D-Chemical Melting Finishing (3D-CMF) for removing layer grooves. In this method, a pen-style device is filled with a chemical able to dissolve the materials used for building 3D printed structures. By controlling the behavior of this pen-style device, the convex parts of layer grooves on the surface of the 3D printed structure are dissolved, which, in turn, fills the concave parts. In this study it proves the superiority of the 3D-CMF than conventional processing for the 3D printed structure. It proves utilizing the evaluation of the safety, selectively and stability. It confirms the improving of the 3D-CMF and it is confirmed utilizing the data of the surface roughness precision and the observation of the internal state and the evaluation of the mechanical characteristics.*

Keywords: - Fused Deposition Modeling (FDM), Chemically Melting Finishing (CMF) Acrylonitrile-butadiene-styrene (ABS), Stereo Lithography Apparatus (SLA)

1. INTRODUCTION

It has been observed the 3D Chemically Melting Finishing (3D-CMF) method for the 3D printed structure for precision surface. 3D printing has been used as rapid prototyping tool in the industrial field. 3D printer was recently-popularized because the principle patent on the Fused Deposition Modeling (FDM) that was developed by Mr. S. Crump in 1989 was expired at 2007 (4,6,9). As June of 2016, 3D printing technology is applied for following many fields. Artificial bone, artificial joint, and artificial organ in the bio medical technology field and solar cell in green technology field were fabricated by the 3D inkjet method. Complex metal products were fabricated by the Selective Laser Sintering (SLS). Commercial plastic products were fabricated by the FDM. Among these 3D printing methods, the FDM will be explosively sold by the following reasons. Acrylonitrile-butadiene-styrene (ABS), Poly-Lactic Acid (PLA), (11,14) and other polymers are used for the filament of the FDM. High skill to print is not required and the 3D structure is fabricated with PC and the Standard Triangulated Language (STL) data. In spite of the former merits, the market of the FDM was now gradually increased. When the layer was printed on the printed layer utilizing the FDM, layer grooves was formed. The layer grooves generated following two problems. First one was poor appearance due to the surface cracks. Second one was low rigidity due to the inner pores. So, the FDM was limited for fabricating the 3D sample. Because the main applications of the FDM were anime figurines and model structures, the customer of the FDM was not the public, but someone whose hobby was fabricating 3D anime figures, architect who used the building model, and engineers who used the prototype for discussion.

It is essential to create new and cheap method to finish the surface of the 3D printed structure to promote the 3D printer for home use. With the method, everyone can precisely print their original products those shape depends on their own design (for example, earphone, glasses, grip, helmet those match the shape of the individual) (2,5,10). When the FDM was applied for the fabrication of the products, low cost 3D structure was printed with rough surface due to the layer grooves that was generated by the former two reasons. However, the rough surface should be improved for fabricating the products for daily use. So, the method to remove the surface layer grooves, make the smooth surface, and improve the strength is required. In general, the hybrid process of surface finishing and coating was applied. When the surface finishing was applied for the 3D printed structure, there are following two problems. The first one was impossible to remove the inner layer grooves. The stiffness was low because of the inner layer grooves. The second one was difficulty to apply uniform treatment on the complex surface because the polishing was easy to remove the peak of the surface and difficult to fill the bottom of the surface. So, usually coating process was applied to fill the bottom after the polishing process.

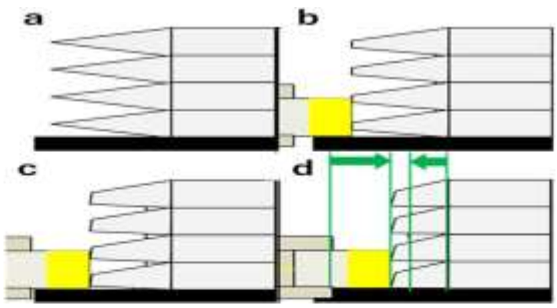

Figure 1: The principle diagram of the 3D-CMF.

A principle diagram of this 3D-CMF method is shown in Fig. 1. In this method, a pen-style device is filled with a chemical able to dissolve the materials used for building the 3D printed structures. By controlling the behaviour of this pen-style device, the convex parts of the layer grooves on the surface of the 3D printed structure are dissolved, which, in turn, fills the concave parts. The layer grooves are thus smoothed. Using this pen-style device, a localized removal of the layer grooves in 3D printed structures is possible, and the amount of solvent used can be kept to a safe level. Unlike polishing, as this method does not need to shave the materials, it does not create dust. In this study, a pen-style device was filled with acetone (an organic solvent that can dissolve the ABS resin commonly used as a filament for FDM 3D printers), thereby creating a 3D-CMF treatment mechanism. We report our findings on the basic characteristics of 3D-CMF, the improvement in 3D printed structures with 3D-CMF and its superior characteristics compared with other treatments.

2. RESULTS

The fundamental characteristics of the 3D-CMF

One of the factors hindering the widespread use of 3D printers is the outer appearance of the 3D printed structures which is rough because of the layer grooves. At present, the outer appearance of the 3D printed structures cannot be improved without sacrificing the low cost and ease of the 3D printer. The surface of the 3D printed structures was improved with 3D-CMF. Figure 2 shows samples of a 3D printed structure simulating a human left hand. The sample undergoing conventional polishing and painting for layer grooves on 3D printed structure showed luster in some areas, probably because painting was performed only on those areas that were polished. As felt was used on the tip of the pen during the 3D-CMF treatment mechanism, it was able to respond to the shape with free surface, thereby providing consistency to the treatment. Furthermore, the 3D-CMF does not create dust (potentially harmful to humans) while avoiding any negative impact on the surface condition. Thus, performing 3D-CMF on the 3D printed structures with free surface uniformly improved the surface roughness precision. In addition, it was superior compared to conventional polishing and painting methods.

Figure 2: The 3D-CMF processing for the various complex 3D printed structures.

The Strength of the 3D printed structure that were processed 3D-CMF

It has been confirmed that 3D-CMF achieves filling of the layer grooves on the surface layer of 3D printed structures, creating a layer of melted materials on the surface. As surface cracks are filled and a layer with less breaking factor forms on the surface, the 3D printed structures can withstand further deformation. Therefore, we prepared a 3D printer provided with a cantilever and performed a bending test. The amount of deflection at the break was measured, and the results are shown in Fig. 3(a). The result was 29.40 [MPa]. It could be seen that maximum tensile stress is improved by 3D-CMF from the results of the tensile test. This result was caused because the surface cracks were filled. Also, the 3D printed structures processed 3D-CMF could acquire the strength that is inferior to the injection moulding, which is much better than only 3D printed. This is because the printed layer is easy to be peeled. The layer grooves in 3D printed structures showed a significant impact on the strength of the 3D printed structures. 3D-CMF can remove such grooves, thereby improving the surface roughness precision while increasing the strength of the 3D printed structures. 3D-CMF treated 3D printed structures can handle even larger deformations.

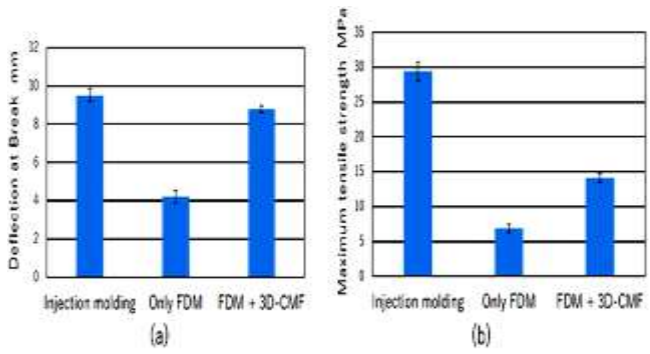

Figure 3: The evaluation of the improving in strength of the 3D printed structure by the 3D-CMF.

The examination of the mechanical characteristics of the 3D printed structures after 3D-CMF treatment confirmed that this treatment produced 3D printed structures which more resistant to deformation.

The fundamental characteristics of the 3D-CMF

It aims to grasp the fundamental characteristics of the 3D-CMF. The experiment apparatus that we developed is shown in Fig. 4. Samples were printed ABS resin as a material. The STL data of the sample shaped 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 was set to 30 [mm/s]. Acetone dissolves the ABS resin.

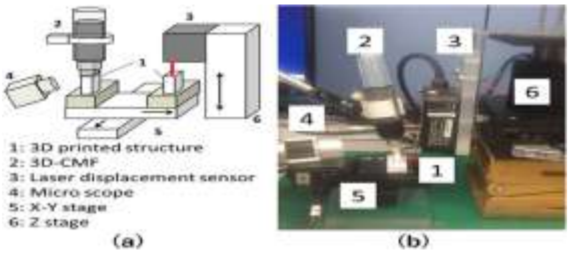

Figure 4: The device that verifies the change surface state of the 3D printed structure by the 3D-CMF.

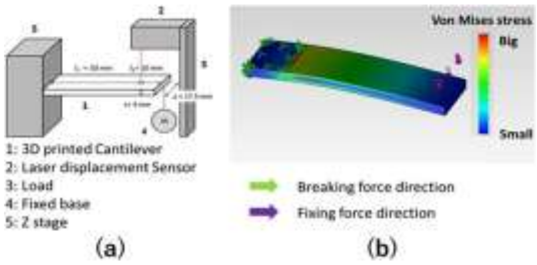

Figure 5: The device of the bending test mechanism of cantilever

The Reforming of the surface material according to the 3D-CMF

The shooting of the changes of the internal state that is produced by 3D-CMF is utilizing FE-SEM (HITACHI, Ibaraki, S-4500S). It is necessary to expose the cross section of the sample when shooting with FE-SEM. It is necessary to expose the sample cross section not to cause plastic deformation. Therefore, the test piece is broken under the glass transition point of ABS resin (−80~90 [°C]). This temperature environment is created by liquid nitrogen. The identification of the ABS resin layer that is produced by 3D-CMF is utilizing XRF (RIGAKU, Tokyo, ZSX Primus II). Also this time, the error becomes smaller if the measurement range becomes larger. Therefore, the measurement range was set at a maximum of φ30 [mm].

The Strength of the 3D printed structure that were processed 3D-CMF

It aimed to grasp the fundamental characteristics of the 3D-CMF. The experiment apparatus that we developed is shown in Fig. 5(a). Cantilevers were printed ABS resin as a material. The cantilever is fixed as shown in Fig. 5(a). Fix the laser displacement sensor and the measurement position set as Fig. 6(a). Attach the sling to hang the load at the free end of the cantilever. Attach the load which can break the cantilever reliably at the end of the sling. Prevent shaking pressed by hand. Start the measurement utilizing the laser displacement sensor. And it moves the load down slowly. The cantilever is broken when it could not bear the load. Record the amount of deflection at break. It measures the amount of deflection at break of the 3D printed cantilevers in the above methods. Analyze data of the cantilever that is produced with injection molding. The 3D-CAD (Dassault Systems, France, Solid works 2011) is used for the analysis. First, identify the stress concentration portion. Next calculate the load amount (M) that reaches the maximum bending stress at the stress concentration portion. And then it calculates amount of the deflection when add the load (M). The stress concentration zone is the fixed end of the cantilever. It is shown in Fig. 5(b). Young's modulus of the ABS resin (E) is 2.65 [GPa]. The maximum bending stress of the ABS resin (F) is 68.5 [MPa]. Section modulus (Z) and moment of inertia is calculated from the shape of the cantilever.

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