THE INFLUENCE OF ACETON TO IMPROVE SURFACE FINISH OF 3D PRINTED PART FOR ABS AND PLA MATERIAL

Z Abdullah[1], N.N.N Rosli[2], S Maidin[3], MY Yaakob[4], MM Ghazaly[5], MA Ali[6]
[1,2,3,4,5,6] Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
Email: [1]zulkeflee@utem.edu.my

ABSTRACT: Additive Manufacturing (AM) is defined as according to ASTM is a process joining materials to create objects from 3D CAD model via layer upon layer. One of the common technology of AM is Fused Deposited Modelling (FDM), which uses the method of extrusion to form parts. FDM technology has been applied in many applications such as consumer product manufacturing. However, FDM suffers badly from low surface finish quality due to staircase effect and post treatment is required. In order to improve the surface roughness, the chemical treatment is one economic and fast method to enhance surface finish of ABS (Acrylonitrile Butadiene Stryene) fused modeled part by performing chemical treatment in Acetone solution. Therefore, this research aims to investigate the influence of chemical treatment on the FDM used parts in term of surface roughness.

Keywords: FDM Part; Surface Rouhgness; ABS and PLA Material

1. Introduction

Additive manufacturing (AM) is a group of technique used to fabricate quickly a scaled model of a physical part using a CAD system. The AM works that parts are made by adding material in layers, each layer in thin cross-section of the part derived from the original CAD data. One of the common technologies of AM is used Fused Deposition Modeling (FDM) machine (Gebhardt, 2016). Due this this application, the surface finish need to be considered to get the best quality and usability. Since FDM works by laying down material from the bottom-up, which process one layer at a time, the part is produced by heat the nozzle to form a solidified layer of material and maintain the lower temperature. Therefore, in order to attain a good finish, the research about the parameter of surface roughness of part produce had been done. In the literature review, the research was about the effect of surface roughness include the problem in surface finish for 3D printed specimen and post-treatment for printed part (Krolczyk et al., 2014). Nowadays, FDM parts having difficulty in improving the surface properties of FDM parts. There have several problem and troubleshooting that had found in 3D printing. Therefore, to investigate the problem face in surface finish to FDM end-used part. The objective of this project is as follows:

i. To perform a work study on the problem in surface finish for 3D printed specimens
ii. To investigate the influence of aceton in surface finish of 3D printed specimens.

2. Literature Review

Various problem face in surface finish of FDM part and method to improve the surface finish. The important of AM by defining the concept of AM and detail regarding of problem face has been discussed.

2.1 Definition of Additive Manufacturing (AM)

The fabrication process begins with creating 3D CAD models and transfer to STL file to be manufactured. Then, the STL file is used as input for slicing software into thickness layer and translated the data in standard data format. After that the part is being built with AM system and deposited layer by layer on AM system platform. The post processing is started when the part was finished printed by AM machine with used to clean and remove the support material from the part. Sometimes, the part is also need to be polishing, painting and chemical treatment for get the smoother surface finish. Lastly, the part used to be tested and verify that can be used or not.

2.2 Fused Deposited Modelling (FDM)

Fused Deposition Modelling (FDM) was established in April, 1992 by S. Scott Crump that can convert the 3D CAD model into STL file and directly print without support any tool or die. This machine using a material of thermoplastic and the part was cross section layer by layer through the extrusion nozzle. The advantage of using FDM is good in mechanical properties, easy operation, inexpensive machinery and durability build part (Galantucci et al., 2015).

2.3 Warping Problem

Warping is commonly caused by a natural characteristic of the plastic. As material of ABS and PLA filament it's happened when the plastic is cooled too quickly. The temperature slope while the print layer are deposited and cool down will cause the warping problem for the part produce. Normally, warping are not affected for the vertical structure and upper side as shown in Figure 1 (Wong & Hernandez, 2012).

2.4 Stringing Problem

Stringing is one of the most common problem face with adhesives in surface finish. Stringing is the peak of the dispensed material falls away from the part produces when the nozzle finished dispensing. From Figure 2, the factor of stringing happen due to ability of the material to bounce back into a well-defined shape after it has been dispensed, incorrect machine set up parameters, incorrect surface condition of nozzle (Singh & Kumar, 2014).

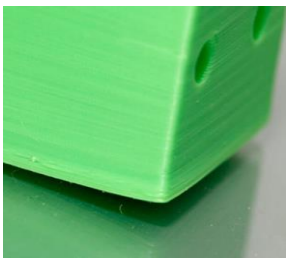


Figure 1 Warping Problem

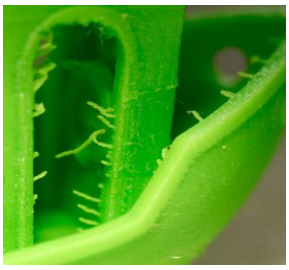


Figure 2 Stringing Problem

2.5 Surface Roughness

One of significant disadvantage of FDM is the weakness on surface roughness. The surface roughness occurs due to its staircase effect. Staircase effect can be defined as the angle between the vertical axis and surface tangent. This effect attribute when the part is print layer by layer principle of FDM that create part in 3D aggregation of 2D cross section. Therefore, it may be effect on quality of surface finish degrades as well as precision of the parts. It also happened by slicing the layer thickness while producing parts (Kuo & Su, 2013).

3. Methodology

The process planning of the project illustrate the relationship between different stages and make project run smoothly and act as guideline to conduct for the entire project as shown in Figure 3. In this project, the 16 specimen had been used for test experimental by ABS and PLA material as shown in Figure 4 below. Each material used 8 specimens in order to conduct the project.

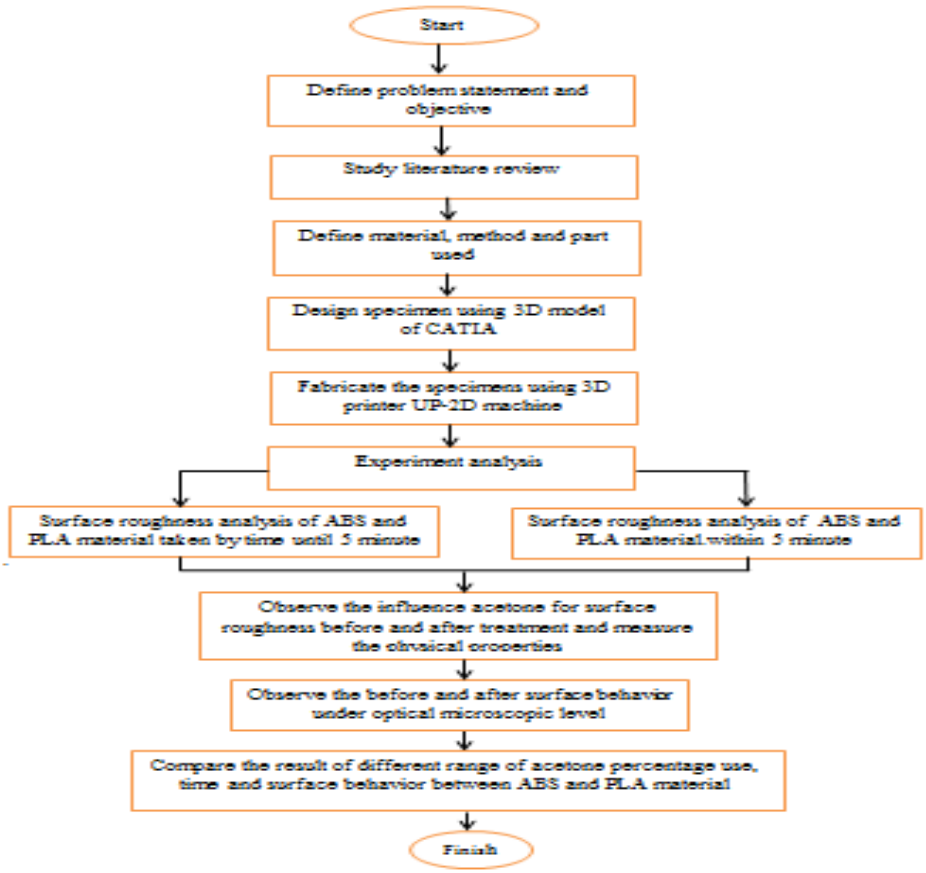


Figure 3 Process Flow Project

3.1 Fabrication Test Specimen Using FDM Machine

In a fabrication of test specimen the UP Plus 2D printing was used to produce the part as shown in Figure 5. The UP Plus 3D printing is one of the products Fused Deposition Modelling (FDM) technology to build the 3D model and convert to STL file. This printing is printed layer by layer through extruding nozzle and can support for both materials. In addition, the printer also able to produce high quality parts with complex geometries that is ready to use.

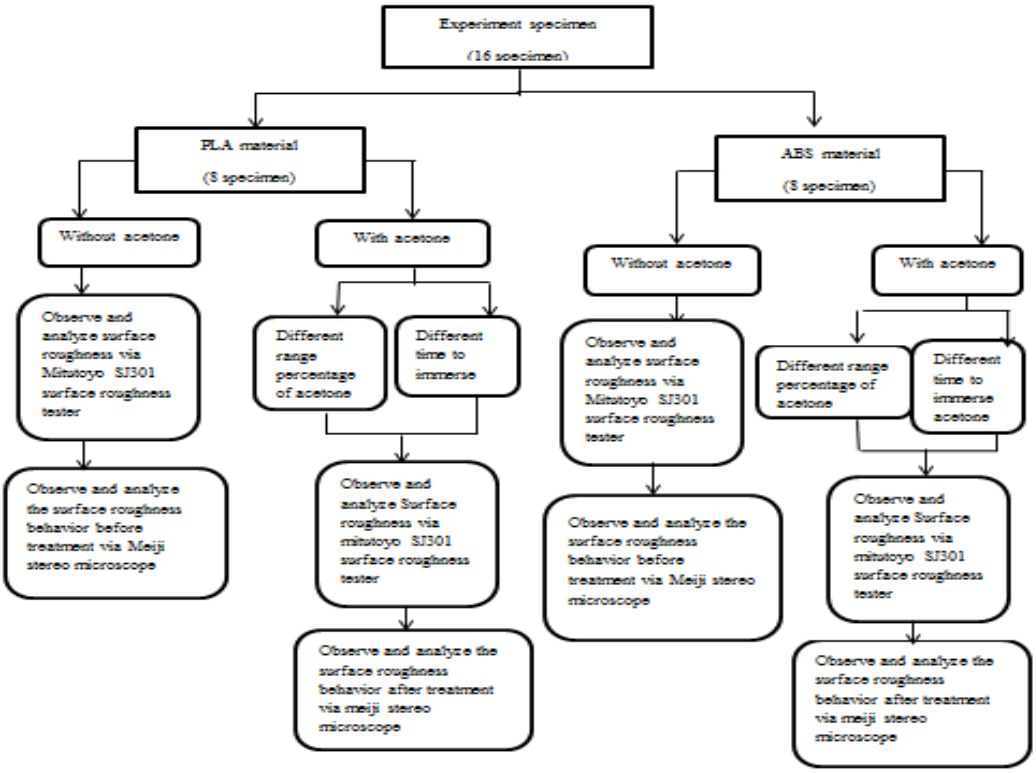


Figure 4 Fabrication Process

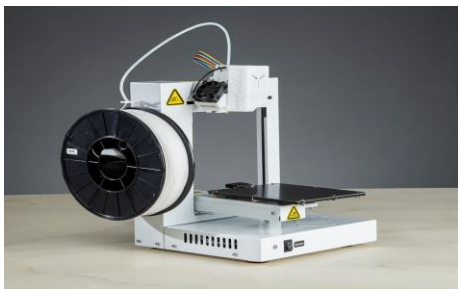


Figure 5 UP Plus 3D Printer

3.2 Stereo Microscope

Stereo microscope is used to capture the image for the further analyze of test specimen. Stereo microscope is as shown in Figure 6.

Figure 6 Stereo Microscope

3.3 Surface Roughness Analysis

The treated specimens of experiment part were analyzed before the chemical treatment. The 2 specimens include ABS material and PLA material are used to perform their chemical treatment using acetone. To analyze the surface roughness of treated and untreated, the Mitutoyo Surftest SJ 301 as shown in Figure 7 was used to measure the surface roughness.

Figure 7 Surface roughness tester

3.4 Chemical Treatment

The chemical treatment is important method in doing the post-processing process in order to get the good surface finish of the parts after being printed. Aceton is chosen in this project due to it's properties of very low toxicity, high diffusion, and low cost chemical solution as shown in Figure 8. The method to used the chemical treatment is by using a chemical bath where different percent of Aceton was added with water to make the soluble reactive between the chemical and water and it highly mixable and increase the compressive strength. So the specimens were immersed in the chemical bath that the liquid can cover the entire surface of the parts (Raja, 2016). The chemical bath used from previous study is 90% Aceton added with 10% water within 5 minutes to make the surface become smooth. The effect of chemical treatment on the compressive strength in order to get the better surface (Krolczyk et al., 2014). So, in order to conduct the experiment, the used different percentage of Aceton and water by time 5 minutes and within 5 minutes had been analyzed.

Figure 8 Acetone

4. Results and Discussion

4.1 Fabrication Process

The parts are built using the UP Plus 2D Printer as the Additive Manufacturing Machine. There have two types of material have been used that are PLA and ABS specimen. The part that had been printed for conduct this experiment is 16 parts which are 8 parts of ABS material and another 8 parts of PLA material as shown in Figure 9.

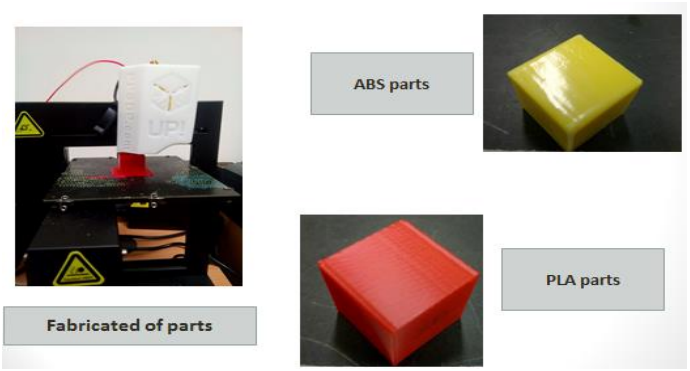


Figure 9 Fabrication Process

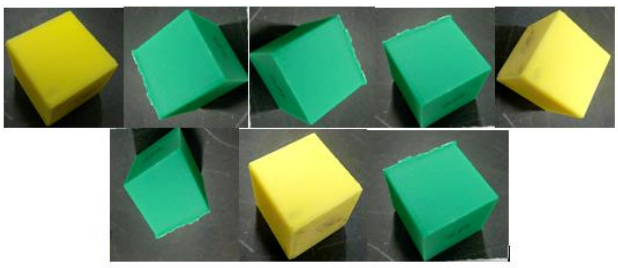
4.2 Chemical Treatment

The parts are divided into 2 different experiments which is 8 parts for experiment by time until 5 minutes and another 8 parts for experiment within 5 minutes. Each experiment consists of 4 ABS parts and 4 PLA parts. The first experiment was conducted for different time and second experiment were conducted within 5 minutes. The chemical used was added with the water in order to reduce the reaction of chemical while it immersed. The chemical was used by different percentage of acetone and water. The percentage of the acetone are 85%, 90%, 95% and 100%, while for the water used are 15%, 10% and 5%. The clear Acetone turns cloudy after second minutes and the parts become sticky as shown in Figure 10. Then, the parts are taken out and dry.

Figure 10 The Acetone turn cloudy after the part immersed after second minute

The visual observation of the parts for before and after the chemical treatment for ABS specimen are shown in Figure 11 (a) (b) and 12 (a) (b) for PLA material.

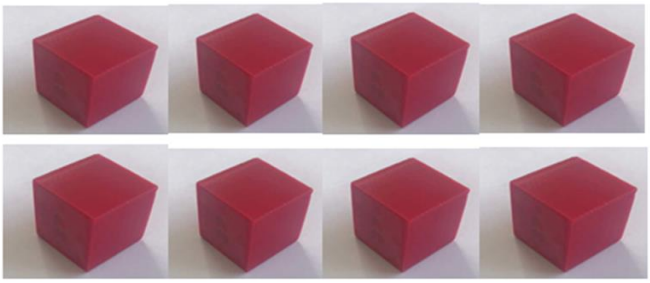
From Figure 11 (a) and (b), we can roughly observe that the specimens that had undergone chemical treatment have better surface area and shinny surface compared to the before chemical treatment ones. However, due to the sticky effects of ABS material after the immersed to the Acetone, the tool that carry out the specimen through the chemical bath had affected some section of the part in terms of surface finish. For the PLA material, the chemical bath does not give the effect on the surface roughness instead the surface becomes worse for the high percentage. Figure 12 (a) and (b) shows the visual observation of untreated and treated specimens under the chemical bath. It also shows the chemical reaction to PLA material it eroded the material and the colour of PLA material becomes dull after it treated.



(a)

(b)

Figure 11 (a) The visual observation before chemical treatment for ABS specimen; (b) The visual observation after chemical treatment for ABS specimen



(a)

(b)

Figure 12 (a) The visual observation before chemical treatment for PLA specimens; (b) The visual observation after chemical treatment for PLA specimens

4.3 Chemical Treatment Procedure

Chemical treatment is one of important method for post processing to improve the surface finish quality. By selecting the method of chemical bath in order to immerse the specimens in the different percentage of Acetone added with water to make the chemical bath. There are some processes needed to be conducted before and during the experiment. Table I shows the processes and equipment used for conducting this experiment.

Table 1 Experiment procedure

Procedure	Explanation
	• Wearing a proper attire while conducting the experiment • Wearing glove and a face mask to prevent exposing from the chemical
	• Pour the chemical treatment into the beaker • Calculation of percentage: 85/100 X 250 =212.5 • The value of 212.5 is the measurement of Acetone that pour in the beaker.
	• Pour the water in the Acetone for the mixing the chemical bath
	• Immersed the specimens into the chemical bath by using a wire as a tool to hold the specimens from moving in a chemical bath. • Time was taken by minute until 5 minutes and within 5 minutes
	• After finishing the chemical treatment, the wire usd as a tool to carry out the specimens from chemical bath
	• Then, the specimens were drying using a small fan before take the reading of surface roughness analysis.
	• After the specimens dry, the result of surface roughness was taken from the surface roughness tester by taken 10 reading for each surface of specimens.

4.4 Result Surface Roughness

The result of surface roughness had been taken by different percentage and different time in order to get the minimum value of surface finish for the treated specimens.

4.4.1 Result surface finish taken by time until 5 min

The bar chart from Figure 13 shows the result of surface roughness of ABS material from a different percentage of Acetone and water. The reading for untreated mostly has a same reading of 14 above. After the specimens treated with chemical treatment, the reading of 90%, 95% and a 100% drop dramatically as seen in the bar chart. The reading from maximum 14.87 drops until minimum value 0.34 as shown in the figure. Therefore, it can be concluded that the Acetone has a good chemical resistance towards the ABS material. The surface becames smooth starting 90% of Acetone at the time 4 minutes, which is the reading have a low result rather than the 3 minutes. For the 95% of Acetone, at the time 3 minutes the surface becomes smooth by the reading is decreasing from 9.31 to 0.34 and after the 3 minutes the surface become rough a little bit due to material become eroded. For 100% of Acetone that is purely used chemical give an impact at the time 2 minutes to 5 minutes. This because, the reaction of chemical is strong and eroded the material for the time being and have a small hole at the surface due to chemical reaction while immersed in a chemical bath. The small hole is the cause of the small bubble at the surface of specimens.

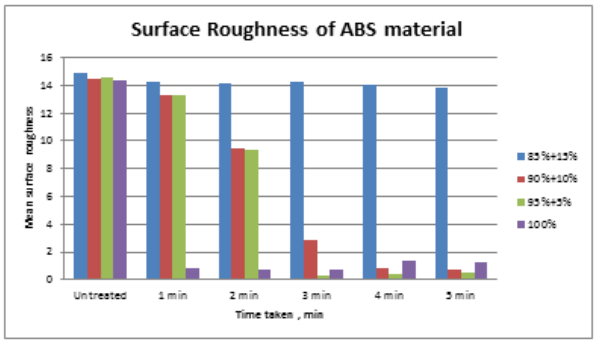


Figure 13 Bar chart of surface roughness of ABS material taken by time

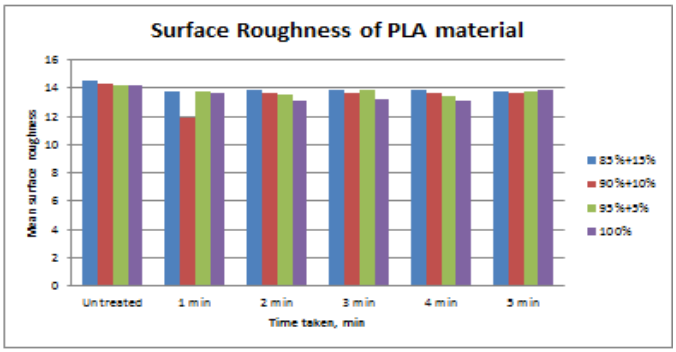


Figure 14 Bar chart of surface roughness of PLA material taken by time

From the bar chart that shown in Figure 14, the result of PLA material does not achieve the objective that is Acetone does not influence to the PLA material because the PLA material have a high chemical resistance. From the bar chart above, there is no different reading after it was treated. It also becomes worse after 100% of Acetone due to the purely chemical used. In addition, the specimens also become rougher and the color has changed while the chemical bath from the red color of PLA becomes dull due the reaction.

4.4.2 Result surface finish taken within 5 min

In this analysis, this experiment is different from the experiment before which is require the time taken until 5 minutes as shown in Figure 15. So that the surface of specimens can be used one time of treated. Once it immersed in the one time, the surface of specimens becomes shining

and more smooth compared to the experiment that taken by time. It can be seen that the difference between 5 minute surface and by time surface while the 5 minutes surface looks more shine and smooth. So that in order to cut off the time while doing the post treatment, the time of 5 minutes is suggested in order to get the surface look smooth.

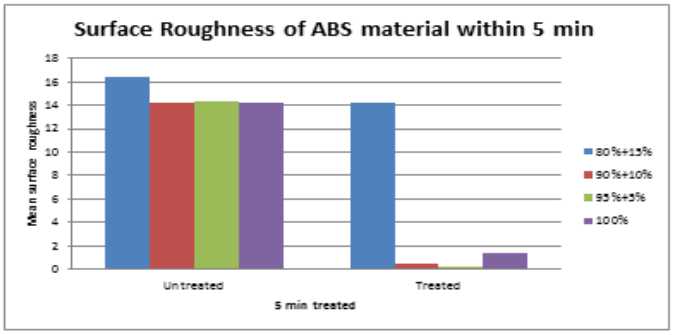


Figure 15 Bar chart of surface roughness of ABS material taken within 5 minutes

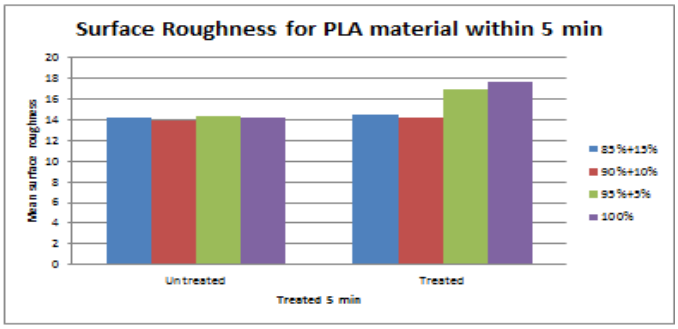


Figure 16 Bar chart of surface roughness of PLA material taken within 5 minutes

The result from the bar chart as shown in Figure 16 has an increasing from 90%, 95% and 100% of Acetone. From the chart also it can be concluded that the surface has a rough in surface finish after it treated. The surface becomes worse and missing layer happened at PLA material due the strongly the attraction of chemical used. The surface does not have a good surface quality in order to be used. The mechanical properties also can be effected due to lack of surface finish by using chemical bath.

4.4.3 Physical Properties

In order to determine the effect of the Acetone to the FDM parts, some dimension of the specimens is measured for the before and after the chemical treatment by using digital vernier calipers. Table 2 and Table 3 show the measurement of the parts for both experiments before treatment and after chemical treatment.

Table 2 Measurement of the dimension of specimens taken by different time

Aceton + Water	ABS		PLA	
	Untreated	Treated	Untreated	Treated
85%+15%	20.00	20.00	20.00	20.00
90%+10%	20.00	19.96	20.00	19.98
95%+5%	20.00	19.94	20.00	19.96
100%	20.00	19.92	20.00	19.96

From the Table 2, we can clearly observe that there are have a minor change of ABS and PLA material in term of the physical dimensions. In general, the dimension of ABS and PLA have same of minor changing the dimension from before it treated. For 85% Acetone added with 15% water does not have impact of chemical towards the material. Therefore, it can conclude that the high percentage of chemical used, the stronger the reaction between the chemical and materials. In addition, the time taken of each minute until 5 minute also give impact to the chemical reaction due to the long time to immerse. So that, it gives the minor change of the dimension of specimens.

Table 3 Measurement of the dimension of specimens taken within 5 min

Aceton + Water	ABS		PLA	
	Untreated	Treated	Untreated	Treated
85%+15%	20.00	20.00	20.00	20.00
90%+10%	20.00	19.98	20.00	19.98
95%+5%	20.00	19.96	20.00	19.97
100%	20.00	19.94	20.00	19.96

From the Table 3, we can observe that the dimension also has a minor change in dimension of specimens. For the ABS, within the 5 minute the chemical treatment gives a changing dimension to the material. The high percentage of chemical Acetone used like as 90%, 95% and 100% give a different measurement of dimension the specimens. It clearly observes, the ABS and PLA has a changing the dimension due to chemical reaction of the chemical. Hence, we can conclude that the chemical treatment of Acetone does not affect much on the physical dimension of the parts. Buts, the chemical treatment cut away material, the ABS and PLA taken off is balanced by the absorption and hence creates an uneven distribution in terms of dimension.

4.4.4 Visual Observation

The visual observation can clearly show the microscopic level of the behavior of the parts. This observation is used in obtaining the surface finish and deformation behavior.

From the Figure 17, the surface of untreated part has a rough surface with texture of parallel line due to filament joins during Additive Manufacturing. On the other hand, the surface of treated parts has a smoother surface with “bubble like” image on the surface as shown in Figure 18. This effect may due to the filaments had joined together after the reaction with Acetone. For untreated specimens, it is clearly observing that there is a same building pattern which seems like parallel lines of the specimens. Meanwhile, for the treated specimens, the Acetone bath dissolves the filaments that subsequently join together and reducing the roughness.

Figure 17 Surface behavior of untreated part under microscope

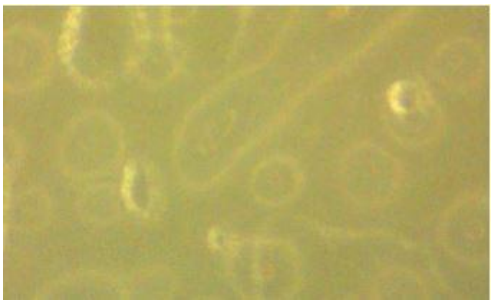


Figure 18 Surface behavior of treated part under microscope

5. Conclusion

In study the influence of the chemical treatment by using the chemical of acetone to treat the FDM parts have been analyzed. The chemical was used with different percentage of acetone and water in order to get the result. As a result, the surface roughness ware taken by different percentage of chemical was used as 85% acetone + 15% water, 90% acetone + 10% water, 95% acetone + 5% water and 100% of acetone. In this experiment, the data was taken each 1 minute to 5 minutes. Before starting the experiment, the data for the untreated part was taken in order to get the result for comparing the treated and untreated of surface roughness. In addition, the experiment also had done for time taken up to 5 minutes for four different percentages as mention before.

References

Galantucci, L. M., Bodi, I., Kacani, J., & Lavecchia, F. 2015. Analysis of Dimensional Performance for a 3D Open-source Printer Based on Fused Deposition Modeling Technique. Procedia CIRP, Vol. 28, pp. 82–87. http://doi.org/10.1016/j.procir.2015.04.014

Gebhardt, A. 2016. Additive Manufacturing, Hanser Publisher, Munich. http://doi.org/10.3139/9783446431621

Krolczyk, G., Raos, P., & Legutko, S. 2014. Experimental Analysis of Surface Roughness and Surface Texture of Machined and Fused Deposition Modelled Parts. Tehnički Vjesnik-Technical Gazette, Vol. 21, No. 1, pp. 217–221.

Kuo, C. C., & Su, S. J. 2013. A simple method for improving surface quality of rapid prototype. Indian Journal of Engineering and Materials Sciences, Vol. 20, No. 6, pp. 465–470.

Raja, K. 2016. A review on chemical processes for plastics substrates used in engineering industries. International Journal of ChemTech Research, Vol. 9, No. 7, pp. 354–365.

Singh Bual, G., & Kumar, P. 2014. Methods to Improve Surface Finish of Parts Produced by Fused Deposition Modeling. Manufacturing Science and Technology, Vol. 2, No. 3, pp. 51–55. http://doi.org/10.13189/mst.2014.020301

Wong, K. V., & Hernandez, A. 2012. A Review of Additive Manufacturing. ISRN Mechanical Engineering, 2012, pp. 1–10. http://doi.org/10.5402/2012/208760