

Influence of inert gas assisted 3D printing machine on the surface roughness and strength of printed component

Siti Nur Humaira Mazlan¹, Mohd Rizal Alkahari^{1,2,*}, Nurul Ain Maidin³, Faiz Redza Ramli^{1,2}, Mohd Nizam Sudin^{1,2}, Lim Guo Dong¹, Imran Syakir Mohamad^{1,2}

¹) Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

²) Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

³) Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 71600 Durian Tunggal, Melaka, Malaysia.

*Corresponding e-mail: rizalalkahari@utem.edu.my

Keywords: Fused deposition modeling (FDM); 3D printing; additive manufacturing

ABSTRACT – The constraint of 3D printing system is its manufacturability and printed part quality in terms of surface roughness and tensile strength. In this experiment, the 3D printing processing method was discussed to study the effect of inert gas assisted 3D printing on mechanical properties and quality of 3D printed parts. Based on the experiment, it was found that through inert gas assisted 3D printing, the surface roughness and tensile strength of the 3D printed parts were improved.

1. INTRODUCTION

Fused deposition modeling (FDM) is an AM technology and is a popularly known by a low-cost 3D printer technique [1]. 3D printing/additive manufacturing (AM) is a term used to describe the technologies that build 3D objects utilizes a layer-by-layer additive fabrication [2]. This technology enables the physical creation of models and prototype parts in almost in any shape through computer aided design (CAD) data. The technique has enormous impact on how products are manufactured in the future. However, the limitation of the technique is the quality of the parts produced due to porosity, warping, surface finish and strength [3-5].

Thus, in this study, in-processing technique uses inert gas assisted in 3D printing machine was performed. During the FDM process, the polymer filament is under influence of high temperature which is between 200 to 280 C. Furthermore, printing occurs on a heated printing bed. Consequently, during the FDM process, the polymer surface of each layer is degrading which may influence the mechanical properties of the printed part. Several researchers attribute the coloration of ABS to thermal aging, and this degradation of ABS lead to the loss of mechanical properties. Thus, due to the factors of ABS degradation, an inert gas has been used in the 3D printer system to slow down the process of ABS degradation so that the mechanical properties in ABS material is maintained. Therefore, the strength of printed part can be improved slightly [6]. Hence, the objective of this study is to investigate the influences of inert gas 3D printing on strength and surface roughness of printed part.

2. METHODOLOGY

In this study, the 3D printer was placed in the enclosed chamber. Figure 1 shows the schematic diagram of inert gas assisted 3D printing. The parameter condition is shown Table 1.

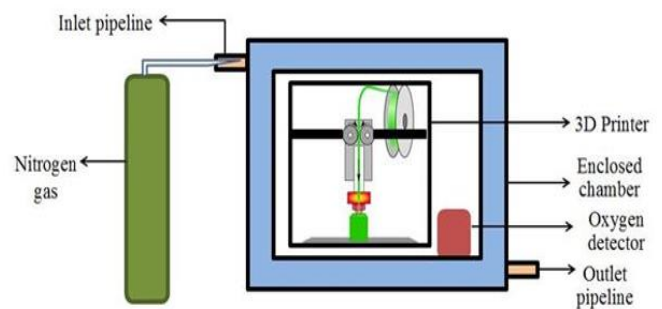


Figure 1 Schematic diagram for in-processing treatment using nitrogen gas, N₂.

Table 1 FDM parameter for inert gas assisted 3D printer.

Specimen number	Layer thickness (mm)	Infill density %	Raster angle
1	0.18	30	45
2	0.18	50	60
3	0.18	70	90
4	0.25	30	60
5	0.25	50	90
6	0.25	70	45
7	0.35	30	90
8	0.35	50	45
9	0.35	70	60

The chamber was made from mild steel and chrome-coated to prevent corrosion. The chamber is sealed to avoid release of inert gas to the atmosphere. The chamber is equipped with an inlet for gas in-flow, and an outlet for gas discharge from the chamber. An oxygen detector model UYIGAO UA6070B was placed in the chamber to measure the concentration of O₂ in % volume after N₂ gas was released inside the chamber. In the setup, N₂ flushed the O₂ out from the chamber through outlet pipeline so that the environment in the chamber was fully filled with N₂ gas.

3. RESULTS AND DISCUSSION

3.1 Surface roughness analysis

One of the limiting factor in the application of plastic at high temperature is their tendency to not become softer but also thermally degrade. Thermal degradation can lead to the possibility of loss in mechanical properties.

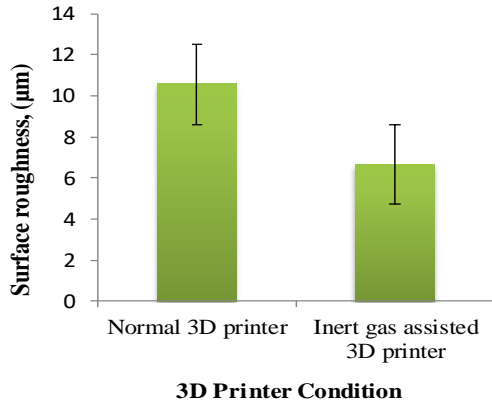


Figure 2 Surface roughness comparison between normal 3D printer and inert gas assisted 3D printer.

Figure 2 shows the comparison of surface roughness when the printing under normal condition and assisted by inert gas. Generally, the surface was slightly better when there was no oxygen in the chamber. The degradation of polymer occurs from variety of causes such as from heat, thermal degradation and thermal oxidative degradation when in the presence of oxygen. In this experiment, there is two factors involve which are heat and the presence of oxygen because the low-cost 3D printer was placed in an open air. The chemical reactions in thermal degradation led to physical changes that involve color changes and cracking. However, from the present experiments, the cracking effect was not obvious, but the part's surface was rough due to the bubble formation on the top surfaces.

3.2 Tensile strength analysis

Mechanical strength is one of the qualities that need to be taken into consideration when fabricating FDM part. However, FDM technique produced low quality in strength compared to other AM technique. Figure 3 shows the tensile strength comparison between the normal 3D printer and inert gas assisted 3D printer.

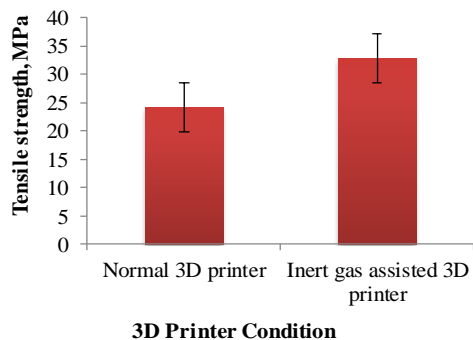


Figure 3 Tensile strength data comparison of normal 3D printer and inert gas assisted 3D printer.

When printing using normal 3D printer, there was a general reduction in the physical properties of the filament because it underwent thermal degradation and affected the strength produced from 3D printed part. However, by using an inert gas assisted 3D printer, the tensile strength was improved because the filament is now freely from oxidation process.

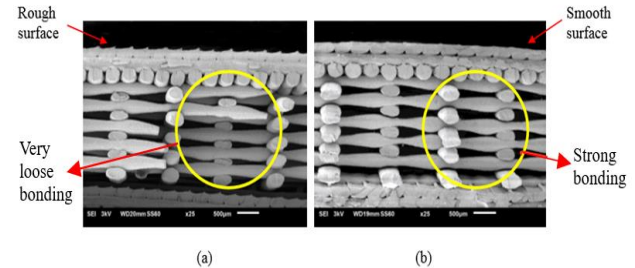


Figure 4 (a) Cross section of 3D printed part by normal 3D printer and (b) cross section of 3D printed part by inert gas assisted 3D printer.

4. CONCLUSION

The improvement in 3D printed part quality has been achieved and discussed. Inert gas assisted 3D printer is able to improve the surface roughness and tensile strength of the printed part.

ACKNOWLEDGEMENT

The research was supported by research grant RAGS/1/2015/2016/TK0/FTK/03/B00113.

REFERENCES

- [1] Tymrak, B. M., Kreiger, M., & Pearce, J. M. (2014). Mechanical properties of components fabricated with open-source 3-D printers under realistic environmental conditions, *Material & Design*, 58, 242–246.
- [2] Majid, S. N. A., Alkahari, M. R., Ramli, F. R., Maidin, S., Tan, C. F., & Sudin, M. N. (2017). Influence of integrated pressing during fused filament fabrication on tensile strength and porosity, *Journal of Mechanical Engineering*, 2, 185-195.
- [3] Habeeb, H. A., Alkahari, M. R., Ramli, F. R., Hasan, R., & Maidin S. (2016). Strength and porosity of additively manufactured PLA using a low cost 3D printing. *Proceedings of Mechanical Engineering Research Day, 2016*, 69-70.
- [4] Nazan, M. A., Ramli, F. R., Alkahari, M. R., Sudin, M. N., & Abdullah, M. A. (2016). Optimization of warping deformation in open source 3D printer using response surface method. *Proceedings of Mechanical Engineering Research Day, 2016*, 71–72.
- [5] Ramli, F. R., Jailani, M. I., Unjar, H., Alkahari, M. R., & Abdullah, M. A. (2015). Integrated recycle system concept for low cost 3D-printer sustainability, *Proceedings of Mechanical Engineering Research Day, 2015*, 77-78.
- [6] Blom, H., Yeh, R., Wojnarowski, R., & Ling, M. (2006). Detection of degradation of ABS materials via DSC. *Journal of Thermal Analysis and Calorimetry*, 83(1), 113-115.