Journal of Advanced Research in Applied Sciences and Engineering Technology 48, Issue 2 (2025) 10-15

SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage: https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

3D Printing Parameters Optimization of ABS Probe Holder for Ultrasonic Scanner

Muhammad Nur Farhan Saniman[1], Muhammad Ibrahim Yahya[1], Nurul Nadiah Mahmud[2,*], Mohd Khairul Anuar Abd Wahid[1], Khairul Azhar Mohammad[1], Noor Faizah Che Harun[1], Mohd Helmy Sakir[3], Moh Khairudin[4]

1 Mechanical Engineering Section, Malaysia France Institute, Universiti Kuala Lumpur, Section 14, Jalan Teras Jernang, 43650 Bandar Baru Bangi, Selangor, Malaysia
2 Japanese Collaboration Program Section, Malaysia France Institute, Universiti Kuala Lumpur, Section 14, Jalan Teras Jernang, 43650 Bandar Baru Bangi, Selangor, Malaysia
3 Clifden Solution Sdn Bhd, Kawasan Perindustrian Hi-Tech 6, 43500 Semenyih, Selangor, Malaysia
4 Department of Electrical Engineering, Universitas Negeri Yogyakarta, Karangmalang, Yogyakarta, Indonesia

ARTICLE INFO

Article history:
Received 9 October 2023
Received in revised form 19 April 2024
Accepted 15 June 2024
Available online 15 July 2024

Keywords:
3D printing; ABS; design of experiment; CAD; STL

ABSTRACT

In recent years, 3D printing technology has received a lot of attention. The use of 3D printing technology in many industries is widely accepted due to its low cost of production and capacity to manufacture complex and geometrical shapes. This paper presents the fabrication of probe holder by using 3D printing technology for ultrasonic scanner application. The fabrication of 3D printed probe holder began with the Taguchi technique design of experiment (DOE). Three major effects were identified: printing temperature, layer thickness and infill density. Solidworks software was employed to build the computer-aided design (CAD) model of the probe holder. Subsequently, the CAD model file is converted to Standard Tessellation Language (STL) file for 3D printing process. The probe holder was successfully fabricated using 3D printer without any defects visible on the outside surface of the 3D printed products. Based on bending test results, it can be concluded that the strength of probe holder was attributed by the layer thickness.

1. Introduction

A recently well accepted an additive manufacturing (AM) process, 3D printing, refers to a process used to make 3D objects by forming successive layers of material under computer control. 3D printing process starts with the fundamental design of the objects or parts created on a computer software and attach to the 3D printers later on for printing process [1]. In comparison to other fabrication technology, 3D printing has the advantage of minimal material waste and is useful for producing complex and geometrical parts [1]. Furthermore, 3D printing can manufacture a wide range of complicated and geometrical shapes without require special moulds like other manufacturing

* *Corresponding author.*
E-mail address: nurulnadiah@unikl.edu.my

https://doi.org/10.37934/araset.48.2.1015

technologies. As a result of the advantages of making products with unlimited shapes, 3D printing is attracting a wide range of industries.

In order to satisfy the need for 3D printing, methods of AM have been developed such as laminated object manufacturing (LOM), laser metal deposition (LMD), selective laser sintering (SLS), stereolithography (SLA) and fused deposition modelling (FDM) [1]. The FDM process is the most effective and common technique of polymeric AM, create 3D prototypes from computer-aided design (CAD) data designs [2]. Not only that, FDM technology able to produce products in a short period of time without wasting raw materials [3]. The basic concept of FDM technique is that FDM construct a structural design layer by layer. The molten materials are melted through an extruder at a particular temperature and deposited on the platform layer by layer [3]. The layers will be bonded together by state bonding due to molecular interaction when one layer remains molten and is bound to the solid layer while solidifying [4]. Despite FDM's usually used in rapid prototyping, it has numerous advantages, such as its simplicity and ability to produce complicated thermoplastic parts, making it a popular technology in advanced manufacturing.

The mechanical properties of 3D printed products are influenced primarily by variables such as the build orientations, the filament flow rate, extrusion temperature, infill density, raster angles, layer thickness, and air gaps [5-8]. The mesostructures obtained from infill density and infill pattern, play an important role in maintaining an appropriate balance of stress intensity and controlling crack propagation, meanwhile a smooth surface with good dimension accuracy can be achieved with small layer thickness [6,9,10]. In addition, based on ANOVA analysis carried out by Beniak *et al.,* [11] printing temperature showed influence in dimensional accuracy of 3D printed products. However, at higher temperature of 260°C, bubbles were formed which resulted in dimensional defects [12].

The current study aims to fabricate a probe holder for ultrasonic scanner, made up from acrylonitrile butadiene styrene (ABS) thermoplastic material by 3D printing technology. ABS thermoplastic is the most common filament used in FDM method due to its characteristics of toughness, stiffness, chemical and resistance to heat [13-16]. The influence of printing factors, such as infill density, layer thickness, and printing temperature, on the physical and mechanical properties of 3D printed probe holder were evaluated.

2. Methodology

2.1 Material

Materials used in the printing production influence their quality, functions, and strength. Thermoplastic materials such as polypropylene (PP), acrylonitrile butadiene styrene (ABS), polyethylene (PE), and polylactic acid (PLA) are commonly used in extrusion techniques. ABS thermoplastics are commonly employed in the FDM process due to their dimensional stability and low glass transition temperature. ABS material is also widely known for its durability, hardness, heat resistance, chemical resistance, and capacity to perform functional testing on sample material. Hence, this study used ABS filament to fabricate 3D printed probe holder.

2.2 Taguchi Method Design of Experiment (DOE)

Design of experiment (DOE) is widely used in many fields, including engineering, manufacturing, biology, and social sciences, to improve product quality while lowering production costs through systematic investigation prior to a process by providing a relationship between variables and outcome. In this current study, Taguchi method based on orthogonal arrays (OA) was employed to optimize process parameters, thus reduces the number of overall trials. The OA technique involves selecting level combinations of the input design variables for each trial [17,18]. This current study employs Minitab software to carry out Taguchi method design of experiment, which is similar to that employed by other researchers [18,19]. There were nine specimens were prepared in this current study. Table 1 shows the number of specimens and its parameters level.

Table 1
Number of specimens and its parameters level

Specimen	Printing Temperature [°C]	Layer Thickness [mm]	Infill Density [%]
1	220	0.20	15
2		0.25	25
3		0.30	35
4	230	0.20	25
5		0.25	35
6		0.30	15
7	240	0.20	35
8		0.25	15
9		0.30	25

2.3 Model Development

CAD model of probe holder was designed by using SolidWorks software. Figure 1 shows the probe holder design that will be used for the next step.

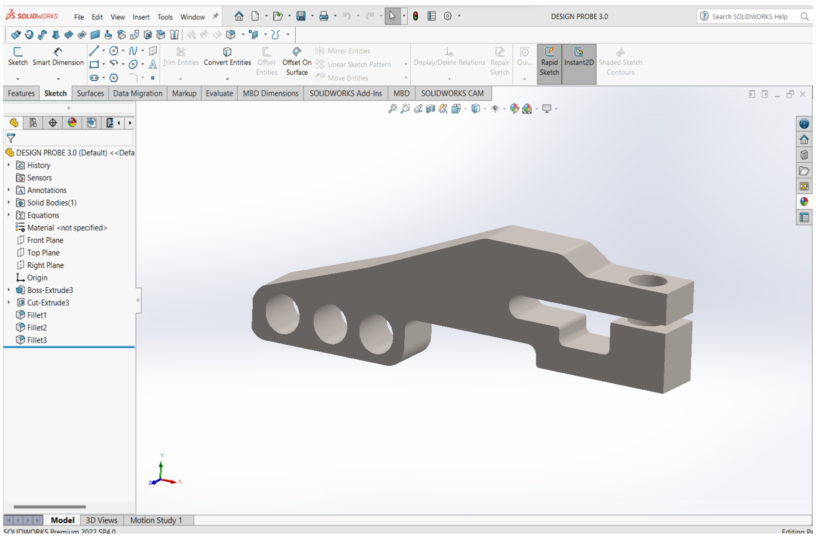

Fig. 1. CAD model of probe holder design

After the CAD model was completed, the Standard Tessellation Language (STL) file was generated. The file subsequently imported into slicing software, which acts as a bridge between the 3D model and the 3D printer. Slicing software or slicers separate models into thin layers and generate G-code files that commands the 3D printers. Ultimaker Cura, a slicing software was employed in this study. The fabrication of probe holder made up from ABS material was performed by using a 3D printer (Creality Enders 3).

2.4 Bending Test

Cantilever bend test was performed by using Universal Testing Machine. In this test, 3D printed probe holder was fixed at one end and a load is applied to the other end. The flexural load was obtained for all specimens of 3D printed probe holder.

3. Results

3.1 3D Printed ABS Probe Holder

Figure 2 depicts nine specimens that were successfully fabricated utilising 3D printer for probe holder shapes by using ABS material. There were no flaws on the exterior surface of any of the specimens. It may be inferred that the parameters and levels are appropriate for the ABS material and geometrical shape of the probe holder.

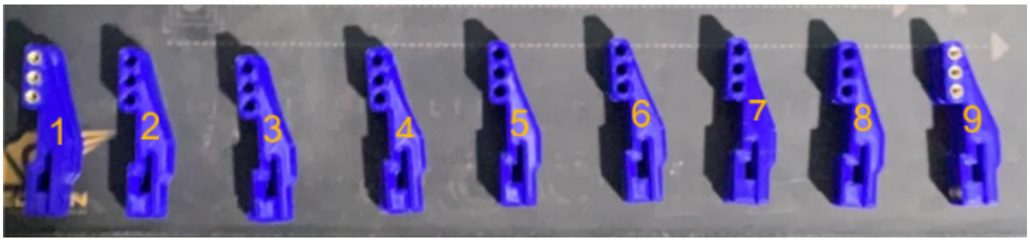

Fig. 2. 3D printed ABS probe holder

3.2 Bending Test

Table 2 displays the flexural load from bending test for each specimen. The bending test results show that, the flexural load increases from specimen 1 to 3 as layer thickness and infill density increase while the printing temperature remains constant at 220°C. Following that, for specimens 5 to 7, flexural load improves as layer thickness increases and was unaffected by infill density. This study found that layer thickness had an effect on the flexural properties of 3D printed ABS probe holder. In other studies, smaller layer thickness was associated with better ultimate tensile strength, whereas bigger layer thickness was associated with higher Young Modulus, which is similar to previously reported study when the layer thickness was increased from 0.06 to 0.10 mm, the ultimate tensile strength also increased [16,20]. On the other hand, Dezaki *et al.,* [3] concluded that infill density influenced the tensile properties of 3D-printed products. As the infill density increased from 95% to 105%, the ultimate tensile strength, yield strength as well as Young modulus of ABS parts also increased [16,21]. However, at the higher temperature of 240°C, layer thickness and infill density appear to have no effect on strength. The bending results show that the flexural load was lower at 240°C than at 230°C. The warping issue or distortion that impairs the dimensional accuracy of products has been documented as a result of high printing temperatures caused by thermal reaction that happens when ABS material expands and cools during solidification processes between layers [22]. It is related to the current investigation, where the unpredictability in strength at high printing temperature could be attributed to the shrinkage and cooling between the solidifying layer and the deposited layer, which affects the bonding between layers and hence influenced its flexural properties. Furthermore, the formation of bubbles during high-temperature fabrication, might also attribute to the instability of mechanical properties [12]. This is because as the formation of bubbles weaken the bonding between layers as well as diminishes its density, and thus influenced the flexural properties.

Table 2
Flexural load for 3D printed ABS probe holder

Specimen	Printing Temperature [°C]	Layer Thickness [mm]	Infill Density [%]	Flexural Load [N]
1	220	0.20	15	315.03
2		0.25	25	348.82
3		0.30	35	552.17
4	230	0.20	25	682.95
5		0.25	35	759.00
6		0.30	15	792.43
7	240	0.20	35	674.32
8		0.25	15	679.10
9		0.30	25	643.83

4. Conclusions

The fabrication of probe holder for ultrasonic scanner application by using AM technology were presented. Taguchi method design of experiment helps in contributing in minimize the study duration as the optimum parameters were obtained at the beginning of study. There were nine specimens were successfully produced by 3D printer with different printing temperature, layer thickness as well as infill density. Based on the bending test results for all nine specimens, it can be concluded that the flexural properties of 3D printed probe holder were affected by the layer thickness. However, the effect of infill density and layer thickness on flexural load was less significant at high printing temperature of 240°C. This could be linked to the formation of bubbles as well as the instability of bonding between layers during solidification of layers and deposition of new layer, which impact the flexural properties. In the future, SEM analysis and simulation analysis will be used to investigate the bonding condition between layers as well as the formation of bubbles.

Acknowledgement
This research was funded by a grant from Universiti Kuala Lumpur (STRG str19015). Technical assistance from Clifden Plantech Sdn Bhd is acknowledged.

References
[1] Jandyal, Anketa, Ikshita Chaturvedi, Ishika Wazir, Ankush Raina, and Mir Irfan Ul Haq. "3D printing-A review of processes, materials and applications in industry 4.0." *Sustainable Operations and Computers* 3 (2022): 33-42. https://doi.org/10.1016/j.susoc.2021.09.004

[2] Nabipour, Mojtaba, and Behnam Akhoundi. "An experimental study of FDM parameters effects on tensile strength, density, and production time of ABS/Cu composites." *Journal of Elastomers & Plastics* 53, no. 2 (2021): 146-164. https://doi.org/10.1177/0095244320916838

[3] Dezaki, Mohammadreza Lalegani, Mohd Khairol Anuar Mohd Ariffin, Ahmad Serjouei, Ali Zolfagharian, Saghi Hatami, and Mahdi Bodaghi. "Influence of infill patterns generated by CAD and FDM 3D printer on surface roughness and tensile strength properties." *Applied Sciences* 11, no. 16 (2021): 7272. https://doi.org/10.3390/app11167272

[4] Syrlybayev, Daniyar, Beibit Zharylkassyn, Aidana Seisekulova, Mustakhim Akhmetov, Asma Perveen, and Didier Talamona. "Optimisation of strength properties of FDM printed parts-A critical review." *Polymers* 13, no. 10 (2021): 1587. https://doi.org/10.3390/polym13101587

[5] Saniman, Muhammad Nur Farhan, Muhammad Fadhli Bidin, Rashid Meseret Nasir, Jamilah Mohd Shariff, and M. A. Harimon. "Flexural Properties Evaluation of Additively Manufactured Components with Various Infill Patterns." *International Journal of Advanced Science and Technology* 29, no. 8s (2020): 4646-4657.

[6] Saniman, M. N. F., M. H. M. Hashim, K. A. Mohammad, K. A. Abd Wahid, W. M. Wan Muhamad, and N. H. Noor Mohamed. "Tensile characteristics of low density infill patterns for mass reduction of 3D printed polylactic parts." *International Journal of Automotive and Mechanical Engineering* 17, no. 2 (2020): 7927-7934. https://doi.org/10.15282/ijame.17.2.2020.11.0592

[7] Kristiawan, Ruben Bayu, Fitrian Imaduddin, Dody Ariawan, Ubaidillah, and Zainal Arifin. "A review on the fused deposition modeling (FDM) 3D printing: Filament processing, materials, and printing parameters." *Open Engineering* 11, no. 1 (2021): 639-649. https://doi.org/10.1515/eng-2021-0063

[8] Agrawal, Anant Prakash, Virendra Kumar, Jitendra Kumar, Prabhu Paramasivam, Seshathiri Dhanasekaran, and Lalta Prasad. "An investigation of combined effect of infill pattern, density, and layer thickness on mechanical properties of 3D printed ABS by fused filament fabrication." *Heliyon* 9, no. 6 (2023). https://doi.org/10.1016/j.heliyon.2023.e16531

[9] Chohan, Jasgurpreet Singh, Rupinder Singh, and Kamaljit Singh Boparai. "Effect of process parameters of fused deposition modeling and vapour smoothing on surface properties of ABS replicas for biomedical applications." *Additive Manufacturing of Emerging Materials* (2019): 227-249. https://doi.org/10.1007/978-3-319-91713-9_7

[10] Nancharaiah, T. R. D. R. V., D. Ranga Raju, and V. Ramachandra Raju. "An experimental investigation on surface quality and dimensional accuracy of FDM components." *International Journal on Emerging Technologies* 1, no. 2 (2010): 106-111.

[11] Beniak, J., P. Križan, Ľ. Šooš, and M. Matúš. "Research on shape and dimensional accuracy of FDM produced parts." In *IOP Conference Series: Materials Science and Engineering*, vol. 501, p. 012030. IOP Publishing, 2019. https://doi.org/10.1088/1757-899X/501/1/012030

[12] Chung, Michael, Norbert Radacsi, Colin Robert, Edward D. McCarthy, Anthony Callanan, Noel Conlisk, Peter R. Hoskins, and Vasileios Koutsos. "On the optimization of low-cost FDM 3D printers for accurate replication of patient-specific abdominal aortic aneurysm geometry." *3D Printing in Medicine* 4 (2018): 1-10. https://doi.org/10.1186/s41205-017-0023-2

[13] Shabana, R., J. Sarojini, K. Arun Vikram, and V. Lakshmi. "Evaluating the mechanical properties of commonly used 3D printed ABS and PLA polymers with multi layered polymers." *International Journal of Engineering and Advanced Technology* 8, no. 6 (2019): 2351-2356. https://doi.org/10.35940/ijeat.F8646.088619

[14] Perez, Angel R. Torrado, David A. Roberson, and Ryan B. Wicker. "Fracture surface analysis of 3D-printed tensile specimens of novel ABS-based materials." *Journal of Failure Analysis and Prevention* 14 (2014): 343-353. https://doi.org/10.1007/s11668-014-9803-9

[15] Gibson, Ian, David Rosen, and Brent Stucker. *Additive Manufacturing Technologies-Rapid Prototyping to Direct Digital Manufacturing*. Springer Nature, 2010. https://doi.org/10.1007/978-1-4419-1120-9

[16] Vicente, Carlos MS, Tomás S. Martins, Marco Leite, António Ribeiro, and Luís Reis. "Influence of fused deposition modeling parameters on the mechanical properties of ABS parts." *Polymers for Advanced Technologies* 31, no. 3 (2020): 501-507. https://doi.org/10.1002/pat.4787

[17] Uttarwar, P. B., S. K. Raini, and D. S. Malwad. "Optimization of process parameter on Surface Roughness (Ra) and Wall Thickness on SPIF using Taguchi method." *International Research Journal of Engineering and Technology* 2, no. 9 (2015): 781-784.

[18] Ahmad, Mohd Nazri, Mohd Hidayat Ab Rahman, Nurul Ain Maidin, Mohd Hairizal Osman, Mohammad Khalid Wahid, Hussin Mohamed Saiful Firdaus, and Nur Afifah Abd Aziz. "Optimization on Surface Roughness of Fused Deposition Modelling (FDM) 3D printed parts using taguchi approach." In *Intelligent Manufacturing and Mechatronics: Proceedings of the 2nd Symposium on Intelligent Manufacturing and Mechatronics-SympoSIMM 2019*, 8 July 2019, Melaka, Malaysia, pp. 230-243. Springer Singapore, 2020. https://doi.org/10.1007/978-981-13-9539-0_24

[19] Eguren, José Alberto, Aritz Esnaola, and Gorka Unzueta. "Modelling of an additive 3d-printing process based on design of experiments methodology." *Quality Innovation Prosperity* 24, no. 1 (2020): 128-151. https://doi.org/10.12776/qip.v24i1.1435

[20] Shergill, Kietan, Yao Chen, and Steve Bull. "An investigation into the layer thickness effect on the mechanical properties of additively manufactured polymers: PLA and ABS." *The International Journal of Advanced Manufacturing Technology* 126, no. 7 (2023): 3651-3665. https://doi.org/10.1007/s00170-023-11270-y

[21] Yankin, Andrei, Yerassyl Alipov, Ali Temirgali, Gaini Serik, Saniya Danenova, Didier Talamona, and Asma Perveen. "Optimization of Printing Parameters to Enhance Tensile Properties of ABS and Nylon Produced by Fused Filament Fabrication." *Polymers* 15, no. 14 (2023): 3043. https://doi.org/10.3390/polym15143043

[22] Daly, Mohamed, Mostapha Tarfaoui, Manel Chihi, and Chokri Bouraoui. "FDM technology and the effect of printing parameters on the tensile strength of ABS parts." *The International Journal of Advanced Manufacturing Technology* 126, no. 11 (2023): 5307-5323. https://doi.org/10.1007/s00170-023-11486-y