

Experimental Modelling of Gripper Arm Using CAD Fusion 360 and Fused Deposition Modelling 3D Printing Process of Polymer

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Abstract

The use of Fusion 360 CAD technology and Fused Deposition Modelling (FDM) 3D printing process enables the development of complex and efficient gripper arm designs. This study explores the effect of mesh and infill density parameters on the print time, weight, and strength of parts printed using ABS material. The results show that a 40% mesh with 40% infill is optimal for lightweight applications due to material and time efficiency. In contrast, a 60% mesh with 80% infill is more suitable for heavy loads due to higher strength. With this design approach, components that meet the needs of robotics-based industries are produced, reinforcing the contribution of FDM technology in modern manufacturing.

Kata kunci: CAD, 3D printing, ABS, Infill density, Meshing

1. Introduction

In the era of increasingly advanced technology, design and development are becoming innovative in producing mechanical components. Especially the development of gripper arm design in robotics is one of the main focuses in engineering and manufacturing as a complex prototype. Modelling the gripper arm in robotics is a very complex process that involves a large modelling and simulation effort [1]. One technology that supports such component development is Computer-Aided Design (CAD)-based design software [2], [3], such as Fusion 360. Fusion 360 offers the ability to design and analyse various mechanical components, including gripper arms, with high precision and reduced design defects [4].

The development of the gripper arm involves a multidisciplinary approach, incorporating design, engineering and advanced manufacturing technologies. The integrated features of Fusion 360 as a Computer-Aided Design (CAD) design with the help of computer media bring rapid progress to the conventional manufacturing process, where the work is time- ineffective and difficult to be a solution to the current problems [2]. Fused Deposition Modeling technology is popular as the extrusion of thermoplastic material that undergoes melting through a nozzle tip that processes in layers horizontally to build model parts by utilising 3D Computer-Aided Design [5], [6].

This technology is the latest resolution in the industry because it is cost-efficient in producing highly complex geometry designs [7], [8] Choosing the right material for the gripper arm is crucial in determining its performance. One of the increasingly popular materials in the polymer class is Acrylonitrile butadiene styrene (ABS) due to the material's properties of high strength and ductility against impact, corrosion resistance, and the ability to get complex geometry products fulfilled [9].

Hassan et al., (2017) their study proposed a process of modelling the design of robot gripper components by optimising their structure, especially in geometric models carried out to determine the efficiency and performance of the gripper on rigid objects [1]. In contrast, Syamsir et al, (2022) conducted simulation and experimental research on the gripper arm by combining the FDM 3D Printing process on PLA polymer, in their research concluded that mesh parameters affect all measured responses, namely print time, weight, and product bending load and said that infill density has a significant impact on the response of time, weight and bending loading that occurs [4].

Based on the current problems that are limitations in obtaining optimal product components both in terms of strength and efficient use of time and materials, this study focuses on determining the optimum design of FDM 3D printing process parameters. In addition, the optimised design approach is expected to improve the gripper's ability to handle various shapes and sizes of objects.

2. Research Method

2.1 Material and Tools

The study involves simulation of the design modelling of a gripper arm using CAD software Fusion 360 along with its supporting tools, Figure 1. The material used in this simulation is ABS (filament with a diameter of 1.75 mm, a weight of 1 kg, and a blue colour. The filament is manufactured by Shenzhen Esun Industrial Co., Ltd, as shown in Figure 2 and the properties of the material, in Table 1. Then, Figure 3 shows in 3D printing Anyubic Mega-S type using a design printing gripper.

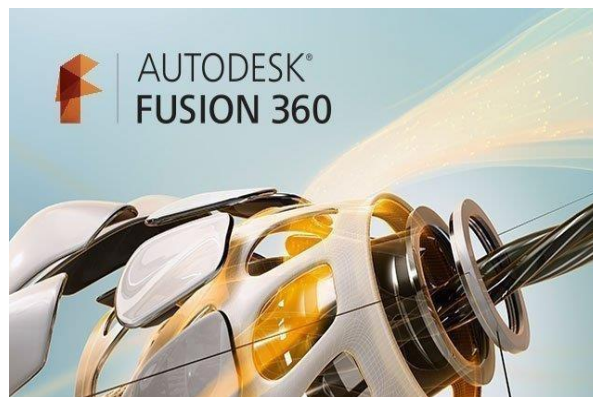


Figure 1. Computer-Aided Design Fusion 360



Figure 2. ABS Material

2.3 Printing Parameters

In the simulation and printing design using Autodesk Fusion 360 and FDM 3D printing, the parameters used to print the gripper arm design can be seen in Table 2.

Table 2. Parameters used in research

Parameters	Range
Target Mesh (%) Infill	40, 50, and 60
Density (%)	40, 60, 80
Material	ABS

3. Result and Discussion

Based on the research that has been done, data is obtained in the form of 3D design optimisation results and physical printing of gripper arm products through the FDM 3D printing process. Figure 5 shows the basic element geometry without any mesh optimisation which is used as the initial design. In contrast to Figure 6, the representation of 3D design that has been optimised with a mesh of only 40%, then Figure 9a shows the results of 3D printing with the same mesh, from the picture there is no difference which means that the ability of 3D printing can print complex geometric designs. The 40% mesh shows the print design results are more efficient in terms of filament filling and printing process time because the design structure has more cavities, so it is quite prone to be applied with high loads.

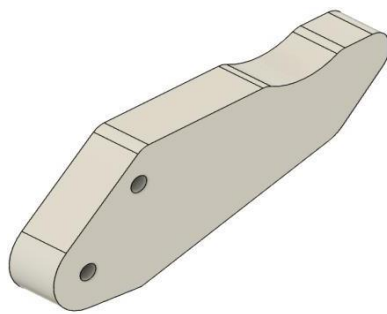


Figure 5. Initial design



Figure 6. Design view with 40% mesh optimization

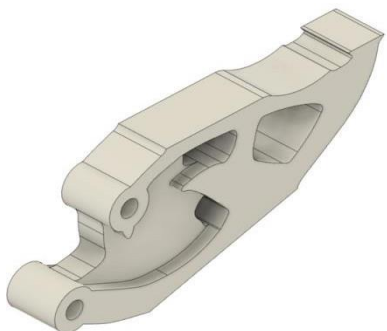


Figure 7. Design view with 50% mesh optimization

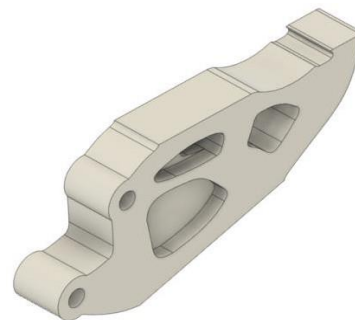


Figure 8. Design view with 60% mesh optimization

In contrast to the 50% mesh shown in Figure 7, the optimised design is stronger and denser in structure, providing a balanced combination of strength and efficiency in time and materials used with the 3D physical print, Figure 9b. However, with a high mesh of 60% shown in Figure 8 the design

optimisation with a denser structure provides better strength and durability while for the physical 3D printing of the gripper arm, the resulting product shape looks fuller and only a few voids are formed. This significantly affects the increase in print time and material.

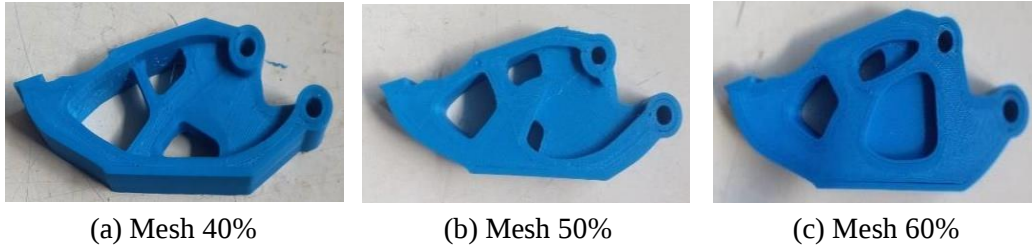


Figure 9. Printout of gripper arm using FDM 3D printing method

The results of testing each mesh parameter and infill density for the same material, ABS, were taken replicative to get a response that has a major effect on the FDM 3D printing process method, which is presented in Table 3.

Table 3. Result test of ABS material

Target Mesh (%)	Infill Density (%)	Time (minutes)	Weight (grams)
40%	40%	96	14,2
40%	60%	100	15,1
40%	80%	104	15,8
50%	40%	110	17,3
50%	60%	117	19,1
50%	60%	116	19,2
50%	60%	118	19,1
50%	80%	126	20,7
60%	40%	114	19,1
60%	60%	122	21,0
60%	80%	133	23,2

Figure 10 and Figure 11 present graphs of the experimental testing of mesh and infill density parameters in response to the moulding time and weight of the gripper components. Based on Figure 9, the highest percentage obtained is 60% mesh with an infill density of 80%, confirming that the moulding time will increase significantly with an increase in the infill and mesh density values. Similarly, Figure 10 shows that the results obtained are the same as in Figure 9 showing a linear graph increasing. While the lowest is at a small mesh of 40% with a filling percentage of 40% infill density material.

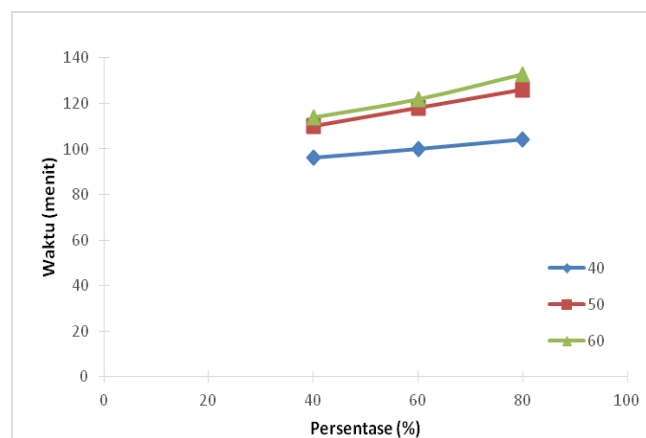


Figure 10. Graph against time of ABS

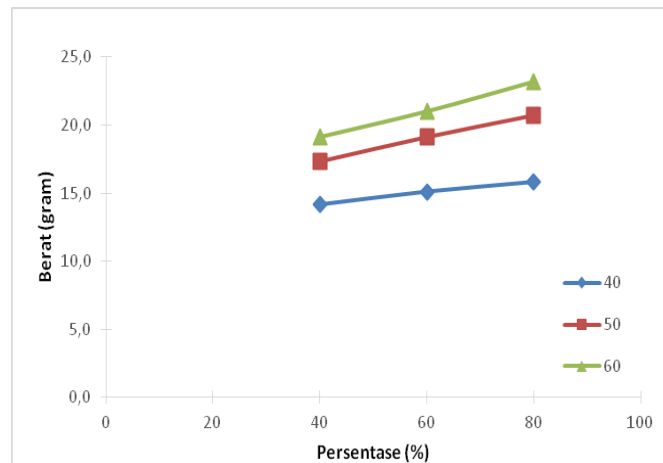


Figure 10. Graph against weight of ABS

Both graphs show a direct relationship between manufacturing parameters and production time efficiency, high infill density filling makes the structure of product components have high strength and durability because of the large amount of material that is filled in the object during the process. In addition, the weight response also increases as the infill density increases, as can be seen from the comparison of the printout at various levels of mesh parameters and infill density. It should be understood that a small percentage of infill density decreases the strength performance of the object making it very prone to damage despite being efficient in terms of time and material. This is in line with the study of Fernandez-Vicente et al, (2016) which states the effect of infill density on the strength of 3D printing, justifying that a large infill density can produce high strength [10].

The design that will produce components from FDM 3D printing results in the selection of optimal parameters which depend on the needs of the application. For gripper arms used in robots with light workloads, 40% mesh with 40% density is the best choice. In contrast, for heavy industrial applications, 60% mesh with 80% density provides more reliable performance.

4. Conclusion

The utilisation of Fusion 360 CAD and FDM 3D Printing is effective in producing more complex designs, efficiency and functional value. The mesh parameters and infill density affect the moulding time, weight and strength of the product; 40% mesh and 40% infill are more material and moulding process efficient, while 60% mesh and 80% infill are stronger.

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Reference

- [1] A. Hassan and M. Abomoharam, "Modeling and design optimization of a robot gripper mechanism," *Robot Comput Integr Manuf*, vol. 46, pp. 94–103, Aug. 2017, doi: 10.1016/j.rcim.2016.12.012.
- [2] Y. G. Jeong, W. S. Lee, and K. B. Lee, "Accuracy evaluation of dental models manufactured by CAD/CAM milling method and 3D printing method," *Journal of Advanced Prosthodontics*, vol. 10, no. 3, pp. 245–251, Jun. 2018, doi: 10.4047/jap.2018.10.3.245.

- [3] T. Sher Wen and A. Professor Mohd Salman Abu Mansor, "FINAL DESIGN IMPROVEMENT OF REPLICA TROPHY FROM PROTOTYPE TO MASS PRODUCTION," 2022.
- [4] N. Syamsir, R. Nur, and A. Salam, "Analyzing and modelling gripper arm using shape optimization of fusion 360 and 3D printing of polylactic acid," *AIP Conf Proc*, vol. 2543, Nov. 2022, doi: 10.1063/12.0010284.
- [5] A. Jaisingh Sheoran and H. Kumar, "Fused Deposition modeling process parameters optimization and effect on mechanical properties and part quality: Review and reflection on present research," in *Materials Today: Proceedings, Elsevier Ltd*, 2020, pp. 1659–1672. doi: 10.1016/j.matpr.2019.11.296.
- [6] T. D. Ngo, A. Kashani, G. Imbalzano, K. T. Q. Nguyen, and D. Hui, "Additive manufacturing (3D printing): A review of materials, methods, applications and challenges," Jun. 15, 2018, *Elsevier Ltd*. doi: 10.1016/j.compositesb.2018.02.012.
- [7] K. E. Aslani, D. Chaidas, J. Kechagias, P. Kyratsis, and K. Salonitis, "Quality performance evaluation of thinwalled PLA 3D printed parts using the taguchi method and grey relational analysis," *Journal of Manufacturing and Materials Processing*, vol. 4, no. 2, Jun. 2020, doi: 10.3390/jmmp4020047.
- [8] F. Rayegani and G. C. Onwubolu, "Fused deposition modelling process parameter prediction and optimization using group method for data handling and differential evolution (de)," *International Journal of Advanced Manufacturing Technology*, vol. 73, no. 1–4, pp. 509–519, 2014, doi: 10.1007/s00170-014-5835-2.
- [9] D. P. Cole, J. C. Riddick, H. M. Iftekhar Jaim, K. E. Strawhecker, and N. E. Zander, "Interfacial mechanical behavior of 3D printed ABS," *J Appl Polym Sci*, vol. 133, no. 30, Aug. 2016, doi: 10.1002/app.43671.
- [10] M. Fernandez-Vicente, W. Calle, S. Ferrandiz, and A. Conejero, "Effect of Infill Parameters on Tensile Mechanical Behavior in Desktop 3D Printing," *3D Print Addit Manuf*, vol. 3, no. 3, pp. 183–192, Sep. 2016, doi: 10.1089/3dp.2015.0036.