Faculty of Mechanical Engineering

IMPROVEMENT ON MECHANICAL PROPERTIES AND STUDY OF MANUFACTURABILITY OF PRINTED PART FABRICATED VIA OPEN SOURCE 3D PRINTER

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in fulfillment of the requirements for the degree of Master of Science
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DECLARATION

I declare that this thesis entitled “Improvement on Mechanical Properties and Study of Manufacturability of Printed Part Fabricated Via Open Source 3D Printer” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : …….....

Name : …….....

Date : …….....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Mechanical Engineering.

Signature : …….....

Supervisor Name : …….....

Date : …….....

DEDICATION

To my beloved mother and father, thank you for strengthen me whenever I felt down and giving up to finish my Master's Degree. Thank you for your endless support including financial, moral, and everything. I am dedicated this study to both of you who I loves so much with all my heart. For my supervisor, Ir. Dr. Mohd Rizal bin Alkahari, thank you so much for believing in me and always help me to finish the study. Thank you for everything.

ABSTRACT

3D printing or also known as additive manufacturing (AM) has been introduced to fabricate the prototypes in shorter time and cost-effective. AM also capable to fabricate complex part geometry without any additional tooling and jigs required. One of the most well-known techniques in AM is fused deposition modeling (FDM). However, the main bottleneck of FDM is its design manufacturabillity and printed part quality in terms of surface roughness, tensile strength and dimensional accuracy. In this research, the 3D printing processing methods using FDM were discussed to study the effect of pre-process, in-process and post-processing technique on mechanical properties and manufacturability of open source 3D printed parts. As for pre-processing, Taguchi analysis was conducted to find the optimum printing parameter settings. Meanwhile, for in-processing method, inert gas assisted 3D printing was evaluated. Then, the post-processing method which involves improvement of fully completed printed part was analyzed. The laser post-treatment and blow cold acetone vapor is used for post-processing method. Based on the comparison made, inert gas assisted 3D printing technique was selected as the best improvement method because of its capability to improve the overall part's quality including surface roughness, tensile strength and dimensional accuracy. In order to identify the design limitation for FDM, the manufacturability and design attributes were studied. The manufacturability study involves some of the difference features of overhang, bridges, wall thickness, small hole diameter and wire diameter. Based on the information, test model 1, 2 and 3 was fabricated using inert gas assisted 3D printer machine. The dimensional accuracy for the test model was compared to original 3D printing technique. In general, it was found that, the 3D printed part's surface roughness was improved by 45% for inert gas assisted method, 63% for laser post-treatment and 94% for blow cold acetone vapor. For tensile strength, 36% improvement made using inert gas assisted method, while for the other post-processing method, the tensile strength is significantly reduces. The dimensional accuracy was also improved for the test model structure up to 39% improvement when using inert gas assisted method. The study has successfully identified the design limitation, and developed design guideline for open source 3D printer. The information can be useful to all 3D printer users to avoid the laborious and time consuming trials during manufacturing process of the prototype.

ABSTRAK

Percetakan 3D atau juga dikenali sebagai pembuatan secara tambahan telah diperkenalkan untuk mengurangkan masa pembuatan prototaip dan mengurangkan kos secara efektif. Selain itu, percetakan 3D juga mampu untuk menghasilkan produk dengan reka bentuk kompleks geometri tanpa menggunakan sebarang kaedah peralatan dan jig tambahan. Salah satu teknik yang terkenal dalam percetakan 3D adalah pemodelan secara pemendapan ataupun "fused deposition modeling" (FDM). Walaubagaimanapun, kaedah ini mempunyai sedikit kelemahan dimana kualiti produknya tidak terlalu baik berbanding dengan teknik percetakan 3D yang lain. Oleh itu, dalam kajian ini, kaedah memprosesan percetakan 3D secara FDM telah dibincangkan untuk mengkaji kesan secara teknik pra-proses, semasa proses dan pasca-proses terhadap kualiti produk yang dihasilkan. Kajian ini adalah untuk menguji kualiti produk yang dihasilkan dari segi sifat-sifat mekanikal seperti kekuatan produk, dan kualiti bahagian permukaan produk. Bagi pra-pemprosesan, analisa Taguchi telah dijalankan untuk mendapatkan nilai optima untuk parameter mesin 3D cetak yang sesuai sepanjang eksperimen dijalankan. Sementara itu, untuk kaedah pemprosesan, percetakan 3D yang dibantu dengan penglibatan gas lengai telah dinilai. Kemudian, pasca-pemprosesan melibatkan proses seperti rawatan pasca menggunakan laser dan menggunakan kaedah tiupan wap aseton sejuk telah digunakan. Berdasarkan perbandingan yang telah dibuat, teknik yang menggunakan gas lengai telah dipilih sebagai kaedah penambahbaikan yang terbaik kerana mampu untuk meningkatkan mutu produk secara keseluruhannya. Untuk mengenal pasti kekangan reka bentuk untuk FDM, kebolehpembuatan dan kebolehan FDM menghasilkan bentuk-bentuk tertentu dikaji.Berdasarkan maklumat tersebut, model ujian telah dibangunkan dengan menggunakan model ujian 1, 2 dan 3 dicetak menggunakan mesin pencetak 3D yang menggunakan gas lengai. Ketepatan dimensi untuk model ujian yang dicetak menggunakan 3D cetak secara gas lengai telah dibandingkan dengan 3D cetak secara normal. Berdasarkan eksperimen yang dijalankan, didapati bahawa dengan menggunakan kaedah secara gas lengai, permukaan kasar produk dapat ditingkatkan sehingga 45%, manakala 63% secara rawatan laser dan 94% dengan menggunakan kaedah tiupan wap aseton sejuk. Untuk ujian ketepatan dimensi, peningkatan secara 39% dengan menggunakan kaedah bantuan gas lengai telah dijalankan. Kajian ini berjaya mengenal pasti kekangan reka bentuk produk, serta membangunkan rujukan ketika rekabentuk untuk percetakan 3D. Maklumat ini boleh digunakan untuk semua pengguna mesin percetakan 3D untuk mengelakkan berlakunya susah payah di makmal dan dapat menjimatkan masa semasa proses pembuatan prototaip.

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LIST OF ABBREVIATIONS

FDM	-	Fused deposition modeling
DFM	-	Design for Manufacture
AM	-	Additive manufacturing
N_2	-	Nitrogen gas
O_2	-	Oxygen gas
SLS	-	Selective laser sintering
LOM	-	Laminated object manufacturing
SLA	-	Stereolithography
VOL	-	Volume
%	-	Percentage
S/N	-	Signal to noise ratio
CAD	-	Computer aided design

LIST OF APPENDICES

LIST OF PUBLICATIONS

1 **S.N.H.Mazlan**., M.R.Alkahari., F.R. Ramli. and M.N.Sudin.,2018. Manufacturability of mechanical structure fabricated using entry level 3D printer, *Journal of Mechanical Engineering*, 5(3), pp. 98-122.

2 **S.N.H.Mazlan**, M.R.Alkahari, F.R. Ramli, N.A.Maidin, M.N.Sudin, 2018. Surface finish and mechanical properties of parts after blow cold vapor treatment, *Journal of Advanced Research in Fluid Mechanics and Thermal Science*, 48(2), pp.148-155.

3 **S.N.H.Mazlan**, M.R.Alkahari, F.R. Ramli, N.A.Maidin, Inert gas assisted 3D printing machine, *Proceedings of Mechanical Engineering Research Day 2018,* Accepted.

4 M.R.Alkahari, **S.N.H.Mazlan,** F.R. Ramli, N.A.Maidin, M.N.Sudin, "Manufacturability of overhang structure using open source 3D printer," *Proceedings of Mechanical Engineering Research Day 2017*, 158-159 (2017).

5 **S.N.H.Mazlan**, M.R.Alkahari, F.R. Ramli, N.A.Maidin, M.N.Sudin, "Effect of Laser post-processing on surface roughness of fused deposition modeling (FDM)," *Proceedings of Innovative Research and Industrial Dialogue*, 101-102 (2016).