

INFLUENCE OF 3D PRINTING
PARAMETERS ON MECHANICAL
BEHAVIOUR OF POLYLACTIC ACID (PLA)
SPECIMEN UTILIZING FDM TECHNIQUE

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ABSTRAK

Pencetakan 3D adalah teknologi yang mampu secara langsung menghasilkan model fizikal 3D bersama-sama dengan model matematik yang dimasukkan dalam sifat tambahan, di mana bahan-bahan tersebut ditambah untuk membentuk produk, tidak seperti kaedah pembuatan tradisional. Kemunculan pencetakan 3D telah memperoleh masa kitaran yang lebih pendek untuk mereka bentuk dan mengembangkan produk inovatif. Salah satu teknologi pencetakan 3D ialah pemodelan pemendapan (FDM). FDM telah digunakan secara meluas untuk pemodelan konsep dan visualisasi, bentuk, dan analisis fungsian. Walaubagaimanapun, potensi pencetak 3D murah masih kabur kerana menjejak kaki dalam perniagaan ini. Kajian ini bertujuan untuk melakukan penilaian eksperimen terhadap kesan parameter percetakan ke arah sifat mekanik Polylactic Acid (PLA) yang dicetak dengan menggunakan pemodelan pemendapan dengan menjalankan empat jenis ujian mekanikal iaitu ujian tegangan, mampatan, lenturan dan impak. Semua spesimen telah dicetak mengikut kehendak yang dinyatakan di dalam ASTM D638, ASTM D695, ASTM D690 dan ASTM D256 masing-masing. Dua parameter yang dipilih untuk diubah dalam penyediaan spesimen dalam kajian ini adalah sudut raster dan ketumpatan bahan, dengan nilai 0° , 45° , 90° dan 10%, 50%, 99% masing-masing. Penilaian eksperimen mendedahkan bahawa semua ciri spesimen sangat dipengaruhi oleh peratusan infill, di mana semua tindak balas mekanikal meningkat dengan ketumpatan bahan, iaitu yang tertinggi berada pada 99% ketumpatan. Sudut raster menunjukkan kesan bervariasi berhubung dengan ujian mekanikal yang dijalankan. Untuk sifat tegangan, kekuatan tegangan muktamad dan ketegangan retak adalah tertinggi pada sudut 45° raster, manakala modulus elastik dan kekuatan hasil tinggi tertinggi pada sudut 0° raster. Sifat mampatan tidak terjejas dengan ketara dengan variasi sudut raster. Ciri fleksural dan kesan adalah tertinggi pada sudut 0° dan 45° raster masing-masing. Untuk mengesahkan data eksperimen, analisis statistik dijalankan menggunakan pendekatan Design of Experiment (DOE) dengan metodologi permukaan respon. Kesalahan purata dikira membandingkan nilai eksperimen dan ramalan yang dijangkakan, di mana akauntabiliti data uji eksperimen telah disahkan dengan peratusan ralat di bawah 10%. Pengoptimuman tindak balas telah digunakan untuk memaksimumkan tindak balas mekanikal secara keseluruhan berkaitan dengan kombinasi parameter percetakan. Sifat tegangan optimum didapati pada gabungan parameter 99% infill dengan 36.36° raster angle. Sifat mampatan dan lentur menunjukkan tindak balas optimum pada peratus 99% infill dengan sudut 0° raster. Akhirnya, sifat impak didapati optimum pada peratus 99% infill dengan sudut 50° raster. Penilaian eksperimen dilakukan sekali lagi untuk mengesahkan akauntabiliti kombinasi parameter yang diperolehi. Ini akan menjadi panduan untuk pengguna pencetak 3D untuk menentukan kesesuaian pencetak 3D murah untuk mengarang produk yang diinginkan dengan tahap sifat mekanikal yang diperlukan untuk mematuhi faktor ekonomi. Seperti yang dicadangkan, kerja penyelidikan ini perlu diperluaskan dengan memasukkan parameter seperti kelajuan percetakan, suhu penyemperitan, jurang udara dan ketebalan lapisan supaya potensi pencetak 3D kos rendah dapat diterokai sepenuhnya bersamaan dengan pelbagai parameter percetakan.

ABSTRACT

Additive manufacturing is a technology capable to directly manufacture 3D physical model alongside with their inserted mathematical model in an additive nature, where the materials are fused together to form a product, unlike the traditional manufacturing method. The emergence of 3D printing has secured a shorter cycle time for designing and developing innovative products. One of the most common additive manufacturing technologies is Fused deposition modelling (FDM). FDM has been used widely for concept modelling and visualization, fit, form, and functional analysis and rapid manufacturing. The unavailability of extensive printer parameter information which directly reflects the mechanical properties of the 3D printed products has been a barrier for the low-cost 3D printer users to identify the connection between printing parameter, intended application and 3D printer used which becomes the key for reliability and economical factor. Moreover, the potential of a low-cost 3D printer remains blurry since high-end FDM machines are commonly used compared to low-cost FDM machines that just debuted into this business. This research work aims to perform an experimental evaluation on the effects of printing parameter towards the mechanical property of Polylactic Acid (PLA) printed using Fused Deposition Modelling Technique by conducting four types of mechanical tests namely tensile, compression, flexural and impact test. All the specimens were printed according to the requirement stated in ASTM D638, ASTM D695, ASTM D690, and ASTM D256 respectively. Two parameters chosen to be varied in specimen preparation in this research are raster angle and infill density, with value of 0°, 45°, 90°, and 10%, 50%, 99% respectively. Experimental evaluation revealed that all the specimen properties are highly influenced by infill percentage, whereby all the mechanical responses increases with the infill density, making the highest is at 99%. Raster angle showed varied effect with regards to the conducted mechanical test. For tensile properties, ultimate tensile strength and fracture strain were highest at 45° raster angle, while elastic modulus and yield strength were highest at 0° raster angle. Compression properties were not significantly affected by the variation of raster angle. Flexural and impact properties were highest at 0° and 45° raster angle respectively. To validate the experimental data, statistical analysis was carried out using Design of Experiment (DOE) approach with response surface methodology. The average error was calculated comparing experimental and predicted response value, whereby the accountability of obtained experimental data was confirmed with the percentage of error below 10%. Response optimizer was used to maximize the overall mechanical response with regards to the printing parameter combinations. It was determined that the optimum tensile properties were found at parameter combination of 99% infill percentage with 36.36° raster angle. Compression and flexural properties showed an optimum response at 99% infill percentage with 0° raster angle. Finally, impact properties were found to be optimum at 99% infill percentage with 50° raster angle. Experimental evaluation was carried out again to validate the accountability of obtained parameter combinations. This will serve as a guide for 3D printer users to decide on the suitability of low-cost 3D printer to fabricate intended products with needed mechanical property level to comply with the economic factor. As for recommendation, this research work should be extended by including parameters such as printing speed, extrusion temperature, air gap, and layer thickness so that the potential of the low-cost 3D printer can be fully explored.

TABLE OF CONTENT

DECLARATION	
TITLE PAGE	
ACKNOWLEDGEMENTS	ii
ABSTRAK	iii
ABSTRACT	iv
TABLE OF CONTENT	v
LIST OF TABLES	viii
LIST OF FIGURES	x
LIST OF SYMBOLS	xiii
LIST OF ABBREVIATIONS	xiv
CHAPTER 1 INTRODUCTION	1
1.1 Project Background	1
1.2 Problem Statement	3
1.3 Objective	5
1.4 Project Scope	5
1.5 Thesis Outline	6
CHAPTER 2 LITERATURE REVIEW	7
2.1 3D Printing Overview	7
2.2 Polylactic Acid	9
2.3 Types of Additive Manufacturing	11
2.3.1 Vat Photopolymerization	11
2.3.2 Material Jetting	12

2.3.3	Binder Jetting	13
2.3.4	Material Extrusion	14
2.3.5	Powder Bed Fusion	15
2.3.6	Sheet Lamination	17
2.3.7	Direct Energy Deposition	18
2.4	Fused Deposition Modelling	19
2.4.1	3D Modelling to Prototype	20
2.4.2	Effect of Build Parameters on FDM Parts	22
2.5	Applications of 3D Printing	24
2.6	Limitations and Advantages	25
2.7	Mechanical Testing	26
2.7.1	Tensile Test	26
2.7.2	Compression Test	26
2.7.3	Flexural Test	34
2.7.4	Impact Test	36
2.8	Previous Researches Done Using PLA	38
2.9	Summary	41
CHAPTER 3 METHODOLOGY		42
3.1	Flow Chart	42
3.2	3D Printer Selection	44
3.3	Calibration Process	45
3.4	Specimen Printing	45
3.5	Design of Experiment	47
3.6	Machine Parameters	48
3.7	Tensile Testing Procedure	48

3.8	Compression Testing Procedure	50
3.9	Flexural Testing Procedure	51
3.10	Impact Testing Procedure	52
3.11	Validation of Printing Process and Precautions	52
3.12	Design of Experiment Analysis Using Response Surface Methodology	53
3.13	Summary	54
CHAPTER 4 RESULTS AND DISCUSSION		55
4.1	Physical Representation of Printed Sample	55
4.2	Mechanical Testing Result	56
4.2.1	Tensile Testing Result	58
4.2.2	Compression Testing Result	61
4.2.3	Impact Testing Result	64
4.2.4	Flexural Testing Result	66
4.3	Overall Discussion	68
4.4	Statistical Analysis	70
4.4.1	Tensile Result	71
4.4.2	Compression Result	83
4.4.3	Flexural Result	90
4.4.4	Impact Result	96
4.4.5	Optimization of Overall Response Using Response Optimizer	103
4.5	Summary	105
CHAPTER 5 CONCLUSIONS		106
5.1	Conclusion	106
5.2	Recommendation	108
REFERENCES		110

LIST OF TABLES

Table 2.1	Summary of available maximum PLA tensile results	30
Table 2.2	Summary of available maximum PLA compression results	34
Table 2.3	Summary of available maximum PLA flexural results	36
Table 2.4	Summary of available maximum PLA impact results	38
Table 2.5	Table of previous researches done on PLA using FDM with ASTM standards	39
Table 3.1	Specification of Flying Bear P905H	44
Table 3.2	Printing parameter combination	47
Table 3.3	Printing parameters that were kept constant and their values	48
Table 3.4	Dimensions of the Type 1 specimen geometry according to ASTM D638 standard	49
Table 4.1	Overall results for tensile properties	59
Table 4.2	Overall results for compressive properties	62
Table 4.3	Overall results for impact properties	64
Table 4.4	Overall results for flexural properties	66
Table 4.5	ANOVA (estimated regression coefficients) for ultimate tensile strength	71
Table 4.6	ANOVA table for ultimate tensile strength	72
Table 4.7	Comparative test between the experimental and predicted value of ultimate tensile strength	73
Table 4.8	ANOVA (estimated regression coefficients) for elastic modulus	74
Table 4.9	ANOVA table for elastic modulus	75
Table 4.10	Comparative test between the experimental and predicted value of elastic modulus	76
Table 4.11	ANOVA (estimated regression coefficients) for fracture strain	77
Table 4.12	ANOVA table for fracture strain	78
Table 4.13	Comparative test between the experimental and predicted value of fracture strain	79
Table 4.14	ANOVA (estimated regression coefficients) for yield strength (0.2% offset)	80
Table 4.15	ANOVA table for yield strength (0.2% offset)	81
Table 4.16	Comparative test between the experimental and predicted value of yield strength (0.2% offset)	82
Table 4.17	ANOVA (estimated regression coefficients) for compressive strength	84
Table 4.18	ANOVA table for compressive strength	85

Table 4.19	Comparative test between the experimental and the predicted value of compression strength	85
Table 4.20	ANOVA (estimated regression coefficients) for compression modulus	87
Table 4.21	ANOVA table for compression modulus	88
Table 4.22	Comparative test between the experimental and the predicted value of compression modulus	88
Table 4.23	ANOVA (estimated regression coefficients) for flexural strength	90
Table 4.24	ANOVA table for flexural strength	91
Table 4.25	Comparative test between the experimental and predicted value of flexural strength	92
Table 4.26	ANOVA (estimated regression coefficients) for flexural modulus	93
Table 4.27	ANOVA table for flexural modulus	94
Table 4.28	Comparative test between the experimental and predicted value of flexural modulus	95
Table 4.29	ANOVA (estimated regression coefficients) for energy absorbed	97
Table 4.30	ANOVA table for energy absorbed	98
Table 4.31	Comparative test between the experimental and predicted value of energy absorbed	98
Table 4.32	ANOVA (estimated regression coefficients) for impact strength	100
Table 4.33	ANOVA table for impact strength	101
Table 4.34	Comparative test between the experimental and predicted value of impact strength	101
Table 4.35	Summary of the significance of factors on each mechanical property based on p-value	103
Table 4.36	Comparison between predicted and experimental value of optimized tensile properties	103
Table 4.37	Comparison between predicted and experimental value of optimized compression properties	104
Table 4.38	Comparison between predicted and experimental value of optimized flexural properties	104
Table 4.39	Comparison between predicted and experimental value of optimized impact properties	105
Table 5.1	Summary of comparison in between mechanical properties of low-cost 3D printed PLA, high-cost 3D printed PLA and bulk PLA	108

LIST OF FIGURES

Figure 2.1	Schematic of a bath configuration SLA printer with a direct write curing process	12
Figure 2.2	Material jetting mechanics	13
Figure 2.3	Binder jetting schematics	14
Figure 2.4	Working mechanism of fused filament printer	15
Figure 2.5	Selective laser melting (SLM) system schematics	16
Figure 2.6	Selective laser sintering (SLS) system schematics	17
Figure 2.7	Laminated object manufacturing (LOM) system schematics	18
Figure 2.8	Generic illustration of the powder feed system	19
Figure 2.9	Generic illustration of the wire feed system	19
Figure 2.10	Solid work 3D model and 3D printed prototype	21
Figure 2.11	Triangulated surface of a STL file	21
Figure 2.12	Fused deposition modelling process of a product	22
Figure 2.13	Graphical representation of the different tensile test specimen specified in the ASTM standard D638-10	27
Figure 2.14	Stress concentration area of D638 specimen	28
Figure 2.15	Different build orientations	29
Figure 2.16	Compression tool	31
Figure 2.17	Build direction of the specimen for compression test	31
Figure 2.18	Break behaviour of specimen built in x, y and z-direction	32
Figure 2.19	Failure of compression specimens under compression loading	33
Figure 2.20	Two building direction of the cylindrical specimen	33
Figure 2.21	3-point bending test mechanism	34
Figure 2.22	Specimen under 3-point flexural loading	35
Figure 2.23	Schematic of Izod impact test	37
Figure 3.1	Process flow chart	43
Figure 3.2	Fully assembled Flying Bear P905H DIY 3DPrinter	44
Figure 3.3	Steps to prepare specimens	46
Figure 3.4	Repetier host software used for slicing the tensile specimen to be printed	47
Figure 3.5	Type 1 specimen geometry according to ASTM D638 standard	49
Figure 3.6	Specimen is in a clamped position with threaded grips	50
Figure 3.7	Compression specimen undergoing compression test	51
Figure 3.8	Humidity and temperature detected in the printing environment	53

Figure 4.1	Fully printed tensile specimen	55
Figure 4.2	Fully printed compression specimen	55
Figure 4.3	Fully printed bending specimen	56
Figure 4.4	Fully printed impact specimen	56
Figure 4.5	Stress-strain curve of a PLA 3D printed specimen upon tensile stress	57
Figure 4.6	Stress-strain curve of specimens acted upon tensile stress	58
Figure 4.7	Bar chart of overall ultimate tensile strength versus raster angle	59
Figure 4.8	Bar chart of overall elastic modulus versus raster angle	60
Figure 4.9	Bar chart of overall fracture strain versus raster angle	60
Figure 4.10	Bar chart of overall yield strength versus raster angle	61
Figure 4.11	Stress-strain curve of specimens acted upon compressive stress	62
Figure 4.12	Bar chart of overall compression strength versus raster angle	63
Figure 4.13	Bar chart of overall compression modulus versus raster angle	63
Figure 4.14	Bar chart of overall energy absorbed versus raster angle	65
Figure 4.15	Bar chart of overall impact strength versus raster angle	65
Figure 4.16	Stress-strain curve of specimens acted upon flexural stress	66
Figure 4.17	Bar chart of overall flexural strength versus raster angle	67
Figure 4.18	Bar chart of overall flexural modulus versus raster angle	68
Figure 4.19	Pareto chart of standardized effects on ultimate tensile strength ($\alpha= 0.05$)	72
Figure 4.20	Average experimental ultimate tensile strength and predicted ultimate tensile strength versus the combination of raster angle and infill density	73
Figure 4.21	Contour plot of ultimate tensile strength (UTS) against raster angle and infill percentage	74
Figure 4.22	Pareto chart of standardized effect on the elastic modulus ($\alpha=0.05$)	75
Figure 4.23	Average experimental elastic modulus and predicted elastic modulus versus the combination of infill density and raster angle	76
Figure 4.24	Contour plot of elastic modulus (EM) against raster angle and infill percentage	77
Figure 4.25	Pareto chart of standardized effect on fracture strain ($\alpha=0.05$)	78
Figure 4.26	Average experimental fracture strain and predicted fracture strain versus the combination of infill density and raster angle	79
Figure 4.27	Contour plot of fracture strain (FS) against raster angle and infill percentage	80
Figure 4.28	Pareto chart of standardized effect on yield strength ($\alpha=0.05$)	81
Figure 4.29	Average experimental yield strength and predicted yield strength versus the combination of infill density and raster angle	82

Figure 4.30	Contour plot of yield strength (YS) (0.2% offset) against raster angle and infill percentage	83
Figure 4.31	Pareto chart for standardized effect on compression strength ($\alpha=0.05$)	84
Figure 4.32	Average experimental compression strength and predicted compression strength versus the combination of infill density and raster angle	86
Figure 4.33	Contour plot of compression strength (CS) against raster angle and infill percentage	86
Figure 4.34	Pareto chart of the standardized effects on compression modulus ($\alpha=0.05$)	87
Figure 4.35	Average experimental compression modulus and predicted compression modulus versus the combination of infill density and raster angle	89
Figure 4.36	Contour plot of compression modulus (CM) against raster angle and infill percentage	89
Figure 4.37	Pareto chart of standardized effect on flexural strength ($\alpha=0.05$)	90
Figure 4.38	Average experimental flexural strength and predicted flexural strength versus the combination of infill density and raster angle	92
Figure 4.39	Contour plot of flexural strength (FS) against raster angle and infill percentage	93
Figure 4.40	Pareto chart of standardized effects on the flexural modulus ($\alpha=0.05$)	94
Figure 4.41	Average experimental flexural modulus and predicted flexural modulus versus the combination of infill density and raster angle	95
Figure 4.42	Contour plot of flexural modulus (FM) against raster angle and infill percentage	96
Figure 4.43	Pareto chart of standardized effects on energy absorbed ($\alpha=0.05$)	97
Figure 4.44	Average experimental energy absorbed and predicted energy absorbed versus the combination of infill density and raster angle	99
Figure 4.45	Contour plot of energy absorbed (EA) against raster angle and infill percentage	99
Figure 4.46	Pareto chart of standardized effects on impact strength ($\alpha=0.05$)	100
Figure 4.47	Average experimental impact energy and predicted impact strength versus the combination of infill density and raster angle	102
Figure 4.48	Contour plot of impact strength (IS) against raster angle and infill percentage	102

LIST OF SYMBOLS

W_c	Gauge width
W_o	Overall width
L_o	Overall length
a	Alpha value

LIST OF ABBREVIATIONS

3D	Three Dimensional
PLA	Polylactic Acid
ABS	Acrylonitrile Butadiene Styrene
PEI	Polyetherimide
FDM	Fused Deposition Modelling
CAD	Computer-Aided Design
CAM	Computer Aided Manufacturing
ASTM	American Society for Testing and Materials
AM	Additive Manufacturing
STL	Stereolithography
USB	Universal Serial Bus
2D	Two Dimensional
UV	Ultra Violet
DOD	Drop On Demand
VP	Vat Photopolymerization
PBF	Powder Bed Fusion
SLA	Stereolithography
SLM	Selective Laser Melting
EBM	Electron Beam Melting
SLS	Selective Laser Sintering
DMLS	Direct Metal Laser Sintering
DLP	Digital Light Processing
EBM	Electron Beam Melting
LOM	Laminated Object Manufacturing
DED	Direct Energy Deposition
LENS	Laser Engineered Net Shaping
EBW	Electron Beam Welding
SEM	Scanning Electron Microscope
UTS	Ultimate Tensile Strength
EM	Elastic Modulus
FS	Fracture Strain
YS	Yield Strength
CS	Compression Strength
CM	Compression Modulus

FS	Flexural Strength
FM	Flexural Modulus
EA	Energy Absorbed
IS	Impact Strength
T	Tensile
C	Compression
Fl	Flexural
Fa	Fatigue
I	Impact

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