PERFORMANCE EVALUATION OF AlSi10Mg MOULD INSERT MATERIAL FABRICATED BY SELECTIVE LASER MELTING PROCESS

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A thesis report submitted in
fulfilment of the requirement for the award of the
Doctor of Philosophy.

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FEBRUARY 2019

Special dedication to my beloved parents, wife and family.....

Thanks for the love, support and memories

ACKNOWLEDGEMENT

In the name of the Almighty ALLAH, the most gracious and merciful, with his grace and blessing has led to the success in completing this thesis. Peace be upon the Prophet Muhammad (pbuh), may Allah bless him.

First and foremost, I would like to express my heartfelt gratitude to my supervisor, Assoc. Prof. Ir. Dr. Md Saidin Wahab for his patience, encouragement, excellent advice and great concern to my work. Sincere thanks to my co-supervisors, Assoc. Prof. Dr. Mustaffa Ibrahim for his helpful comments, ideas and advices.

I also wish to express my appreciation to Dr. Shayfull Zamree Bin Abd Rahim from UniMAP, all lab technicians from CIAST Shah Alam and also IKTBN Sepang for their help, guidance, encouragement and friendship throughout my research progress. Their assistance made it possible for me to carry out the experiments with minimal problem.

I would like to take this opportunity to thank the faculty administration and departments staff particularly the staff of AMMC lab for their constant support along doing my research experiments.

Finally, I acknowledge the people who mean a lot to me, my dear wife, for her patience along years that she stayed with me away from her parents. I would never be able to pay back the love and affection showered upon by my wife; Siti Hadijah. And my lovely kids; Liyana, Nurhanis, Iman, and my little angels; Nurdini, Amilin and Umar. And not to forget my friends.

May Allah bless us all!

ABSTRACT

In this thesis the physical properties, mechanical properties, different profile building feasibility and dimension accuracy of AlSi10Mg samples fabricated by selective laser melting (SLM) technique, as well as novel fabrication strategies as an alternative to conventional methods in order to produce of plastic injection mould (PIM) tools was investigated. Response surface method (RSM) and variance analysis (ANOVA) are utilized to optimize the SLM parameters and develop the mathematical models. The optimum values input parameters for laser power, scan speed and hatch distance recommended to achieve optimum value of relative density and ultimate tensile strength (UTS) were 348.14 Watt, 1483.25 mm/s and 0.1207 mm, respectively. Other than almost full density achievement with the value of 99.3547% from the experiment, the experimental value of UTS (411.881MPa) was higher compared to A360F and A360T6 HDPC alloys. The feasibility and accuracy results indicate that the benchmark model fabricated by SLM technique revealed the potential of producing near net shape parts. Only 0.5mm offset was added in the normal direction during the fabrication of PIM tool inserts for post-processing purpose. The total time reduction in fabricating the PIM tool inserts using the combination of SLM and high speed machining (HSM) strategy was 34 hours. By introducing square fin conformal cooling channel (SFCCC) in PIM tool inserts has shorten the cycle time and improved the injected product quality due to uniform and faster heat dissipation during the moulding cycle. Whereas the total impact of conformal cooling channel and AlSi10Mg as PIM tool insert materials led to almost 32% reduction on cycle time during the moulding cycle compared to the reference PIM tool. Although with the reduction of fabrication time and cycle time, still the cost modelling result highlights that, in order the SLM AlSi10Mg fabricated PIM with square fin conformal cooling to be cheaper than the reference PIM, an endurance of at least 40 000 cycles is required.

ABSTRAK

Dalam tesis ini, sifat fizikal, sifat mekanik, kebolehlentukan pembinaan profil yang berlainan dan ketepatan dimensi sampel AlSi10Mg yang dihasilkan oleh teknik peleburan laser selektif (SLM), serta strategi fabrikasi novel sebagai alternatif kepada kaedah konvensional untuk menghasilkan suntikan plastik alat acuan (PIM) telah disiasat. Kaedah permukaan tindak balas (RSM) dan analisis varians (ANOVA) digunakan untuk mengoptimumkan parameter SLM dan membangunkan model matematik. Parameter input nilai optimum untuk kuasa laser, kelajuan imbasan dan jarak menetas yang disyorkan untuk mencapai nilai optimum ketumpatan relatif dan kekuatan tegangan muktamad (UTS) adalah masing-masing 348.14 Watt, 1483.25 mm / s dan 0.1207 mm. Selain pencapaian kepadatan hampir penuh dengan nilai 99.3547% daripada eksperimen, nilai eksperimen UTS (411.881MPa) lebih tinggi berbanding aloi A360F dan A360T6 HDPC. Keputusan kebolehlaksanaan dan ketepatan menunjukkan bahawa model penanda aras yang direka oleh teknik SLM mendedahkan potensi menghasilkan bentuk produk hampir tepat. Hanya 0.5mm offset yang telah ditambah dalam arah normal semasa pembuatan alat PIM untuk tujuan pemprosesan akhir. Pengurangan jumlah masa dalam membuat alatan PIM menggunakan kombinasi SLM dan strategi pemesinan kelajuan tinggi (HSM) adalah 34 jam. Dengan memperkenalkan saluran penyejukan conformal fin persegi (SFCCC) dalam alatan PIM telah memendekkan masa kitaran dan meningkatkan kualiti produk yang disuntik kerana pelesapan haba yang seragam dan lebih cepat semasa kitaran pengacuan. Manakala kesan keseluruhan saluran penyejukan conformal dan AlSi10Mg sebagai bahan alatan PIM menyebabkan pengurangan hampir 32% pada masa kitaran semasa kitaran acuan berbanding dengan alatan PIM sedia ada. Walaupun dengan pengurangan masa fabrikasi dan masa kitaran, namun hasil pemodelan kos menunjukkan bahawa, agar alatan PIM AlSi10Mg dengan penyejukan conformal persegi yang lebih murah daripada PIM sedia ada, penyuntikan plastik sekurang-kurangnya 40 000 kitaran diperlukan.

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LIST OF SYMBOLS AND ABBREVIATIONS

2D		2 Dimensional
3D	-	3 Dimensional
AA6061	-	Aluminium 6061
ABS	-	Acrylonitrile Butadiene Styrene
Adeq. precision	-	Adequate precision
Adj. R^2	-	Adjusted R^2
AlSi10Mg	-	Aluminium Silicon Magnesium
AM	-	Additive manufacturing
ANOVA	-	Analysis of Variance
ASTM	-	American Society for Testing and Materials
C.V. %	-	Coefficient of variation
CAD	-	Computer aided design
CCD	-	Central composite design
CI	-	Chemically induced melting
CIAST	-	Centre for Instructor and Advance Skill Training
CNC	-	Computer Numerical Control
CO2	-	Carbon Dioxide
Cor. total	-	Totals of all information corrected for the mean

d.f.	-	Degrees of freedom
DMLS	-	Direct metal laser sintering
DOE	-	Design of experiment
EBM	-	Electron beam melting
EDM	-	Electrical discharge machining
EDS	-	Energy-dispersive spectroscopy
EDX	-	Energy dispersive X-ray
F	-	Force
FEM	-	Finite element method
FM	-	Full melting
HAZ	-	Heat affected zone
HPDC	-	High pressure die cast
HV	-	Hardness Vickers
LENS	-	Laser Engineered Net Shaped
LPS	-	Liquid Phase Sintering
MFI	-	Moldflow Insight
MGSS	-	Milled groove square shape
MSDS	-	Material Safety Data Sheets
OFAT	-	One Factor at a Time
OM	-	Optical Microscopy
PIM	-	Plastic Injection Moulding
Pred. R^2	-	Predicted R^2
PRESS	-	Predicted residual error sum of squares
POM	-	Precision Optical Manufacturing
R^2	-	Coefficient of determination
RD	-	Relative Density

RM	-	Rapid Manufacturing
RP	-	Rapid Prototyping
RSM	-	Response Surface Methodology
RT	-	Rapid Tooling
Std. Dev.	-	Square root of the residual mean square
STL	-	Stereolithography
SEM	-	Scan electron microscopy
SFCCC	-	Square fin conformal cooling channel
SLA	-	Stereo-lithography
SLM	-	Selective laser melting
SSS	-	Solid State Sintering
T	-	Temperature
t	-	Holding Time
Ti-6Al4V	-	Titanium 6% aluminium 4% vanadium
UniMap		University Malaysia Perlis
UTHM		Universiti Tun Hussein Onn Malaysia
UTS	-	Ultimate Tensile Strength
XRD	-	X-ray diffraction

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