EFFECT OF SELECTIVE LASER MELTING PROCESS PARAMETERS ON PROPERTIES OF 316L STAINLESS STEEL

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT’S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Peleburan Laser Selektif (SLM) mampu menghasilkan komponen metalik dengan sifat-sifat yang setanding dengan bahan pukal. Sifat anisotropik, parameter proses dan tekanan interfacial yang ketara mempengaruhi sifat akhir komponen akhir yang direka. Penyelidikan ini menitikberatkan kesan parameter proses SLM iaitu kepadatan tenaga yang rendah dan reka bentuk orientasi bangunan; serta rawatan haba terhadap sifat-sifat kelakuan kakisan sampel keluli tahan karat 316L yang dihasilkan oleh SLM. Penyelidikan ini menyiasat kesan kepadatan tenaga yang berlainan (60 dan 65 J / mm^3) dan orientasi bangunan 0 °, 45 ° dan 90 ° pada sifat fizikal dan mekanikal; serta kesan pada suhu rawatan haba (650, 950 dan 1100 ° C) pada sifat mekanik dan kelakuan kakisan sampel keluli tahan karat 316L yang dihasilkan oleh SLM. Ketepatan dimensi dan ketumpatan relatif menurun dengan penurunan kepadatan tenaga dan orientasi bangunan. Perubahan ubah bentuk yang ketara diperhatikan untuk orientasi binaan 0 ° yang menyumbang ketumpatan relatif terendah dari orientasi binaan 0 ° berbanding dengan orientasi binaan 45 ° dan 90 °. Walau bagaimanapun, kepadatan relatif tinggi (98-99.2%) dicapai untuk semua keadaan sampel yang dibina. Jumlah dan saiz keliangan adalah sejajar dengan ketumpatan relatif. Pengurangan kekerasan dan kekuatan ketumpatan tenaga rendah (60 J/mm^3) sampel dikaitkan dengan jumlah keliangan yang tertinggi. Untuk orientasi bangunan, kekerasan dan kekuatan sampel keluli tahan karat SLM-ed 316L adalah kemungkinan dipengaruh oleh gabungan liang dan tekanan sisa yang tinggi. Jenis sempadan kolam cair (MPBs) tergelincir dalam ciri-ciri mikrostruktur berbeza dengan orientasi bangunan kecenderungan dan ketara mempengaruhi kemuluran. Pemanjangan yang tinggi pada patah dari sekitar 40% hingga 85% telah dicapai selepas rawatan haba pada 950ºC dan ke atas untuk ketumpatan tenaga Rendah (60 J/mm^3) sampel keluli tahan karat SLM-ed 316L. Di samping itu, kekerasan, kekuatan hasil dan kekuatan tegangan muktamad merosot selepas rawatan haba berikutan pengurangan ketumpatan kehelan, melegakan tekanan tekanan, dan peningkatan bilangan dan saiz ciri-ciri seperti lubang kecil. Peningkatan suhu rawatan haba menyebabkan sedikit pengurangan potensi kakisan yang dipengaruhi oleh keliangan, ketumpatan kehelan dan tekanan sisa. Hasil orientasi bangunan dan ketumpatan tenaga menunjukkan bahawa sampel yang dibina sehingga orientasi binaan 0º dan 90º pada ketumpatan tenaga yang tinggi (65 J/mm^3) mempunyai kualiti produk tertinggi keseluruhan. Meningkatkan suhu haba mengurangkan kekerasan dan kekukuhan tetapi membantu meningkatkan kemuluran dan potensi kakisan bagi sampel tahan karat SLM-ed 316L.

ABSTRACT

Selective laser melting (SLM) is capable of producing metallic components with comparable properties as bulk material. Anisotropic properties, process parameters and notable interfacial stresses influence the final properties of a final fabricated component. This research concerns about the effect SLM process parameters –low value of energy density and design of building directions; as well as heat treatments on the properties of fabricated SLM-ed 316L stainless steel. This research investigate the effects of different energy densities (60 and 65 J/mm^3) and building orientations of 0°, 45° and 90° on the physical and mechanical properties; as well as effects on heat treatment temperatures (650, 950 and 1100 °C) on mechanical properties and corrosion behaviour of 316L stainless steel samples fabricated by SLM. The dimensional accuracy and relative density decrease with the decrease of energy densities and building orientations. Significant deformation is observed for 0° build orientation which contributes the lowest relative density of 0° build orientation compares to 45° and 90° build orientations. However, high relative densities (98-99.2%) are achieved for all as-built samples condition. The amount and size of porosity are aligned with the relative density. Reduction of hardness and strength of the low energy density (60J/mm^3) samples are associated with the highest amount of porosity. For building orientation, hardness and strength of as-built SLM-ed 316L stainless steel samples are influenced by the combination of pores and high residual stress. Types of molten pool boundaries (MPBs) slipping in the microstructure features varies with the inclination building orientations and may significantly affect the ductility. High elongation at fracture from around 40% to 85% was reached after the heat treatment at 950ºC and above for Low energy density (60 J/mm^3) of SLM-ed 316L stainless steel samples. In addition, the hardness, yield strength and ultimate tensile strength declined after heat treatment due to a decrease in dislocation density, compress stress relief, and an increase in number and size of small pits-like features. The increased heat treatment temperatures cause a slight reduction of corrosion potential influenced by porosity, dislocation density and residual stress. The outcomes of building orientation and energy density show that as-built samples built up 0º BO and 90º BO at high energy density (65J/mm3) have the overall highest product quality. Increasing the heat temperatures reduced the hardness and strength but helped to improve the ductility and corrosion potential of the SLM-ed 316L stainless samples.

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LIST OF SYMBOLS

A_0	Original cross-sectional area of the specimen
d	Diagonal length for Vickers hardness test (mm)
L_f	Final length of the specimen
L_0	Original length of the specimen
P	External axial tensile load
P_{HV}	Applied load for Vickers hardness test (kg)
α	Angle between the opposite faces of the diamond) = 136°
$\alpha°$	Deformation angle occurred for 30 μm sample
$\beta°$	Deformation angle occurred for 50 μm sample
σ	Engineering stress
ε	Engineering strain
δ	Specimen’s gauge length
ρ_{water}	Density of water (g/cm^3)
ρ_{316L}	Density of 316L stainless steel (g/cm^3)
ρ	Relative density (%)
M_{air}	Mass in air (g)
M_{water}	Mass in water (g)
ΔM	Mass difference
T_{H2O}	Temperature of water (°C)
V	Volume of water (cm^3)

LIST OF ABBREVIATIONS

316L SS	316L Stainless Steel
ALM	Additive Layer Manifacturing
AM	Additive Manifacturing
BCC	Body-centred Cubic
BO	Build Orientation
CAD	Computer Aided Design
DM	Direct Manifacturing
EBM	Electron-Beam Melting
FCC	Face-centred Cubic
FDM	Fused Deposition Modelling
HT	Heat Treatment
SLM	Selective Laser Melting
SLS	Selective Laser Sintering
STL	Standard Tessellation Language
UTS	Ultimate Tensile Strength
YS	Yield Strength

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