

THE EFFECT OF PROCESSING PARAMETERS
ON MICROSTRUCTURE AND MECHANICAL
PROPERTIES OF ALUMINIUM 6061 SEMISOLID
METAL BILLET

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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

Tesis ini mempersembahkan dapatan kerja kajian mengenai kesan parameter Pemprosesan Logam Separa Pepejal (PLSP) pada aluminium bilet yang dihasilkan dengan menggunakan Kaedah Haba Langsung (KHL)). Gabungan suhu tuangan telah ditetapkan pada suhu 640 °C, 660 °C dan 680 °C dengan masa pegangan 20 s, 40 s dan 60 s. Tiga sampel dihasilkan untuk setiap kombinasi pemprosesan. Logam aluminium lebur dituangkan ke dalam acuan tembaga silinder dengan kombinasi suhu tuangan dan masa pegangan yang berbeza sebelum dilindapkejutkan ke dalam air yang bersuhu bilik. Ketumpatan, kekuatan tegangan utama dan kekuatan Vickers bilet PLSP setelah melalui proses KHL diperiksa. Nilai ketumpatan untuk setiap sampel yang dihasilkan diantara 2.527 g/cm³ dan 2.701 g/cm³. Sampel 6 dengan suhu tuangan 660 °C dan masa pegangan 60 s mempunyai nilai ketumpatan tertinggi iaitu 2.701 g/cm³. Ini menunjukkan bahawa sampel 6 mempunyai kandungan keliangan terendah dalam bilet PLSP. Hasil ujian tegangan juga menunjukkan bahawa nilai ujian tegangan utama adalah diantara 65.39 MPa dan 146.797 MPa, sementara nilai ujian kekuatan vickers adalah diantara 65.85 HV dan 86.5 HV. Sampel dengan suhu tuangan di atas sedikit suhu lebur aluminium 6061 mengakibatkan kandungan keliangan menurun, manakala kekuatan tegangan dan nilai kekerasan meningkat. Sampel 4 dengan suhu tuangan 660 °C dan masa pegangan 20 s menghasilkan ukuran struktur bulat dan kecil dari kawasan fasa primer iaitu 2547.87 μm². Hasil kajian menunjukkan bahawa akibat daripada proses penyejukan secara pantas bagi aloi aluminium 6061, lebih banyak struktur bulat diperolehi. Kecepatan haba yang keluar dari aloi akan merencatkan pembentukan struktur dendritik sehingga mengubahnya menjadi struktur bulat untuk pemprosesan PLSP. Suhu tuangan yang lebih rendah meningkatkan pembentukan nukleasi semasa proses penyejukan, sehingga menghasilkan struktur bulat yang lebih banyak dan ukuran butiran yang lebih kecil. Penemuan kajian ini meningkatkan pemahaman yang lebih baik mengenai tingkah laku bilet aluminium 6061 PLSP. Penemuan ini boleh memberi kefahaman sifat aluminium 6061 yang lebih baik terutamanya dalam industri pembuatan.

ABSTRACT

This thesis presents the experimental works on the effects of the semisolid metal (SSM) processing parameters on the aluminium feedstock billets produced by the direct thermal method (DTM). The combinations of pouring temperatures were fixed at 640 °C, 660 °C, and 680 °C with holding times of 20 s, 40 s, and 60 s, respectively. Three samples were produced for each of the combinations. The SSM feedstock billets were prepared by using DTM, in which 6061 molten metal was poured into a cylindrical copper mould with a different combination of pouring temperature and holding time before being solidified into room temperature water. The porosity content, ultimate tensile strength, and Vickers hardness were examined for the feedstock billets after the DTM process. There were differences in density value for each sample which occurred between 2.527 g/cm³ and 2.701 g/cm³. Sample 6 with a pouring temperature of 660 °C and holding time of 60 s has the highest density value, which was 2.701 g/cm³. This indicated that sample 6 has the lowest porosity content within the feedstock billets. The tensile test results showed that the ultimate tensile test values were between 65.39 MPa and 146.797 MPa, while the Vickers hardness test values were between 65.85 HV and 86.5 HV. In the sample with pouring temperature slightly above the aluminium 6061 liquidus temperature, the porosity content had decreased; tensile strength and hardness values had increased. Sample 4 with a pouring temperature of 660 °C and holding time of 20 s produced globular and small grain size for the primary phase area, which was 2547.87 μm². Results show that, due to the rapid cooling condition of the molten 6061 inside the copper mould, more globular microstructures were obtained. The faster the heat is convected out from the molten alloy will retard the formation of dendritic microstructure, thus transforming it into globular microstructure for SSM processing. The lower pouring temperature enhances the formation of nucleation during the solidification process, thus producing more globular microstructure and smaller grain size. The findings of this experimental works enhance a better understanding of the behaviour of aluminium alloy 6061 SSM feedstock billets. These findings could lead to better information on the formability behaviour of aluminium alloy 6061, mainly in the manufacturing industry.

TABLE OF CONTENTS

DECLARATION	
TITLE PAGE	
ACKNOWLEDGEMENT	ii
ABSTRAK	iii
ABSTRACT	iv
TABLE OF CONTENTS	v
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF SYMBOLS	xiii
LIST OF ABBREVIATIONS	xiv
CHAPTER 1 INTRODUCTION	1
1.1 Research Background	1
1.2 Problem Statement	3
1.3 Research Objectives	4
1.4 Scope of Study	5
CHAPTER 2 LITERATURE REVIEW	6
2.1 Introduction to Semisolid Metal Processing.	6
2.1.1 Thixoforming Process	7
2.1.2 Rheoforming Process	8
2.1.3 Advantages of Semisolid Metal Process	9
2.1.4 Primary Phase Morphology and Particle Size Distribution	9
2.1.5 Alloy Composition	12
2.1.6 Defects and Imperfections of Aluminium Alloy	14

2.2	Methods in Semisolid metal Processing	17
2.2.1	Magnetohydrodynamic Stirring	18
2.2.2	New Rheocasting	19
2.2.3	Swirled Enthalpy Equilibrium Device (SEED)	19
2.2.4	Spray Casting	20
2.2.5	Chemical Grain Refining	22
2.2.6	Cooling Slope	23
2.2.7	New MIT	24
2.2.8	Mechanical Stirring	25
2.2.9	Ultrasonic Vibration	26
2.2.10	Serpentine Channel Process	28
2.2.11	Distributary-confluence Channel Process.	29
2.2.12	Direct Thermal Method	30
2.3	Solidification	33
2.3.1	Heat Extraction	35
2.3.2	Conditions for Nucleation	36
2.4	Quenching Theory	36
2.5	Aluminium Alloy	39
2.5.1	Aluminium Alloy 6061	40
2.5.2	Properties of Aluminium 6061	41
2.6	Mechanical Test	42
2.6.1	Density Measurement	42
2.6.2	Tensile Test	43
2.6.3	Fractography	44
2.6.4	Hardness Test	45
2.7	The Effect of Processing Parameters on Microstructure Formation	45

CHAPTER 3 METHODOLOGY	52
3.1 Introduction	52
3.1.1 Aluminium Alloy 6061 Material Preparation and Composition Analysis	53
3.2 Direct Thermal Method	54
3.2.1 Copper Mould Preparation	54
3.2.2 Direct Thermal Method Experimental Setup	55
3.2.3 DTM feedstock billets	56
3.3 Mechanical Properties Assessment	58
3.3.1 Density Measurement	58
3.3.2 Ultimate Tensile Strength	59
3.3.3 Fractography	61
3.3.4 Hardness Test	61
3.4 Microstructure Sample Preparation and Analysis	63
3.5 Energy-dispersive X-ray Spectroscopy Analysis	66
CHAPTER 4 RESULTS AND DISCUSSION	67
4.1 Introduction	67
4.2 Mechanical Properties Assessment	67
4.2.1 Density Measurement	67
4.2.2 Ultimate Tensile Strength	69
4.2.3 Fractography	73
4.2.4 Hardness Test	77
4.3 DTM Feedstock Billets Microstructure Formation	79
4.3.1 The effect of pouring temperature on the microstructure formation	84
4.3.2 The effect of holding time on the microstructure formation	85
4.4 Energy-dispersive X-ray Spectroscopy Analysis	85

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS	89
5.1 Introduction	89
5.2 Conclusions	89
5.2.1 The Influence of Pouring Temperature and Holding Time on DTM Feedstock	89
5.2.2 DTM Feedstock Billet Microstructure Formation and Chemical Composition	90
5.2.3 Processing Parameters for High-Quality Components	91
5.3 Future Work Recommendation	91
REFERENCES	93
APPENDIX A ALUMINIUM ALLOY 6061 COMPOSITION	104
APPENDIX B LIST OF PUBLICATIONS AND SEMINAR	105

LIST OF TABLES

Table 2.1	Four-digit system list of wrought composition families.	39
Table 2.2	Chemical Composition of Aluminium 6061.	41
Table 2.3	Physical Properties of Aluminium 6061.	42
Table 2.4	Mechanical Properties of Aluminium 6061.	42
Table 3.1	Processing parameters for SSM feedstock billets.	58
Table 4.1	Compositions of Aluminium 6061.	67
Table 4.2	Average density and porosity level of SSM feedstock billets.	68
Table 4.3	Comparison between ultimate tensile strength, yield strength, and elongation from the experimental works and the literature.	70
Table 4.4	Average Ultimate Tensile strength, Yield strength and Elongation of feedstock billet.	70
Table 4.5	Average hardness value for each SSM sample.	78
Table 4.6	The primary phase chemical composition of DTM feedstock billets.	86
Table 4.7	The secondary phase chemical composition of DTM feedstock billets.	87

LIST OF FIGURES

Figure 1.1	Comparison of (a) dendritic structure by the conventional casting process and (b) near-globular semisolid microstructure of aluminium A357.	2
Figure 2.1	Thixocasting process.	8
Figure 2.2	Rheocasting Process.	9
Figure 2.3	Columnar and equiaxed dendritic structure.	10
Figure 2.4	Calculated apparent viscosity versus Fraction solid for the sample sheared continuously.	12
Figure 2.5	The relationship between apparent viscosity and fraction solid for various chemical compositions.	13
Figure 2.6	Macro-shrinkage with (a) Macrograph and (b) corresponding micrograph.	15
Figure 2.7	Interdendritic shrinkage with (a) schematic view of metal flow and (b) micrograph dendritic shrinkage (Fiorese et al., 2015).	15
Figure 2.8	SEM images for (a) air entrapment porosity and (b) hydrogen porosity within the components.	16
Figure 2.9	Examples of filling related defects with (a) surface lamination and (b) cold shot.	17
Figure 2.10	Schematic diagram of three modes in MHD process.	18
Figure 2.11	New Rheocasting stages for SSM processing.	19
Figure 2.12	Schematic diagram of SEED process.	20
Figure 2.13	The microstructure of aluminium 356 achieved by the SEED process.	20
Figure 2.14	Schematic diagrams of the semisolid stream on the preform surface.	21
Figure 2.15	Schematic diagram of spray casting setup.	22
Figure 2.16	Schematic diagram of the cooling slope process.	23
Figure 2.17	Stages in New MIT process.	24
Figure 2.18	Mechanical Stirring apparatus.	26
Figure 2.19	Ultrasonic vibration schematic diagram.	27

Figure 2.20	The SCP schematic diagram with (a) Molten alloy; (b) Semisolid slurry preparation; and (c) Cooling.	29
Figure 2.21	The globular microstructure produced from the DTM process.	31
Figure 2.22	Schematic diagram for DTM.	32
Figure 2.23	Phase diagram of temperature versus composition.	34
Figure 2.24	The fracture surface of the tensile sample with (a) ductile fracture and (b) brittle fracture.	45
Figure 2.25	Principle of the Vickers hardness test method.	46
Figure 2.26	Microstructure formation with different pouring temperature on the Al-Si 356 alloy with (a) pouring temperature of 695 °C, (b) pouring temperature of 675 °C, (c) pouring temperature of 645 °C, and (d) pouring temperature of 615 °C	47
Figure 2.27	Dendritic microstructure formed with the pouring temperature of 665 °C.	48
Figure 2.28	Microstructure from holding time of 45 s and pouring temperature of (a) 630 °C, (b) 650 °C and (c) 680 °C.	49
Figure 2.29	Microstructure from holding time of 60 s and pouring temperature of (a) 630 °C, (b) 650 °C and (c) 680 °C.	50
Figure 3.1	Overall project flow chart.	53
Figure 3.2	Foundry-Master UV spectrometer.	54
Figure 3.3	Design of copper mould.	55
Figure 3.4	Schematic diagram of DTM experimental works apparatus setup.	56
Figure 3.5	Samples of feedstock billets produced by DTM.	57
Figure 3.7	Extensometer attached to the tensile sample to measure the sample elongation.	60
Figure 3.9	Indentation point on the sample with a pouring temperature of 660 °C and a holding time of 20 s.	62
Figure 3.10	Indentation points near the pores.	62
Figure 4.1	The average result of (a) Ultimate Tensile Strength, (b) Yield Strength, and (c) Elongation for DTM samples.	71
Figure 4.2	Porosity content within the feedstock billets during the density test.	73

Figure 4.3	Scanning Electron Microscopic (SEM) images for (a) tensile sample fracture surface for pouring temperature of 660 °C and holding time of 40 s with the arrows indicated pores; (b) fracture image with 200x magnification power, (c) fracture image with 250x magnification power; and (d) fracture image with 500x magnification power.	74
Figure 4.4	Scanning Electron Microscopic (SEM) images for (a) tensile sample fracture surface for pouring temperature of 660 °C and holding time of 60 s with the arrows indicated pores; (b) fracture image with 200x magnification power, (c) fracture image with 250x magnification power; and (d) fracture image with 1000x magnification power.	76
Figure 4.6	Average Vickers Hardness value for DTM feedstock billets.	78
Figure 4.7	Microstructure with combination pouring temperature of 660 °C and holding time of 20 s for three samples a, b and c.	80
Figure 4.8	Microstructure with combination pouring temperature of 660 °C and holding time of 40 s for three samples a, b and c.	81
Figure 4.9	Microstructure with combination pouring temperature of 660 °C and holding time of 60 s for three samples a , b and c.	82
Figure 4.10	Average grain size measurement with (a) grain size; (b) circularity; and (c) aspect ratio	83
Figure 4.11	Selected primary Phases area for (a) combination pouring temperature of 660 °C and holding time of 40 s; and (b) combination pouring temperature of 660 °C and holding time of 60	86
Figure 4.12	Selected secondary Phases area for (a) combination pouring temperature of 660 °C and holding time of 40 s, and (b) combination pouring temperature of 660 °C and holding time of 60 s	87

LIST OF SYMBOLS

°C	degree Celsius
s	Second
%	Percentage
Mg ₂ Si	Magnesium Silicide
Mg	Magnesium
Si	Silicon
Cu	Copper
Cr	Chromium
Al	Aluminium
Mn	Manganese
HB	Brinell Hardness
MPa	Mega Pascal
µm	Micro meter
ρ_f	Density of feedstock
W _f	Weight of feedstock
W _w	Weight of water
ρ_w	Density of water
SiC	Silica Carbide
HV	Vickers Hardness
rpm	Revolutions per minute

LIST OF ABBREVIATIONS

SSMP	Semi Solid Metal Processing
SSM	Semi Solid Metal
MIT	Massachusetts Institute of Technology
DTM	Direct Thermal Method
MHD	Magnetohydrodynamic
HPDC	High Pressure Die Casting
ITT	International Telephone and Telegraph
NRC	New Rheocasting
DAQ	data acquisition
ASTM	American society for testing and materials
SEM	Scanning Electron Microscope
EDXS	Energy-dispersive X-ray Spectroscopy
CNC	Computer numerical control

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