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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 Master of Science in Manufacturing.

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

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DIRECT RECYCLING OF ALUMINIUM ALLOY 6061 AND 7075 EMPLOYING
CYCLIC EXTRUSION COMPRESSION BACK PRESSURE TECHNIQUE

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TABLE OF CONTENTS

	Page
DECLARATION	
TITLE PAGE	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
ABSTRAK	iv
TABLE OF CONTENTS	v
LIST OF TABLES	ix
LIST OF FIGURES	xi
LIST OF SYMBOLS	xii
LIST OF ABBREVIATIONS	xiii
CHAPTER 1 INTRODUCTION	
1.1 Research Motivation	1
1.2 Problem Statement	3
1.3 Aim and Objectives	4
1.4 Research Scope	5
1.5 Thesis Organisation	6
CHAPTER 2 LITERATURE REVIEW	
2.1 Introduction	8
2.2 Aluminium and Aluminium Alloy	8
2.3 Aluminium Production	11
2.3.1 Primary Production	11
2.3.2 Secondary Production	13
2.4 Direct Recycling Process	15
2.4.1 Chip Preparation Process	16
2.4.2 Cold Compaction Process	18
2.4.3 Hot Deformation Process	21

2.4.4	Summary Direct Recycling Process	22
2.5	Taguchi Method	25
2.6	Application Severe Plastic Deformation (SPD) to Direct Recycling Process	28
2.7	Summary	32

CHAPTER 3 PRELIMINARY STUDIES: EFFECT OF COOLING STRATEGIES

3.1	Introduction	34
3.2	Chip Preparation in Maching Aluminium Alloy	35
3.2.1	Material Selection	35
3.2.2	Lubrication Strategy in Machining	35
3.2.3	Cutting Parameters in Machining Operation	38
3.3	Direct Compaction Experiment	39
3.4	Measurement of Direct Billet Density and Porosity	42
3.5	Results for Cold Compaction Experiment For AA6061 and AA7075	44
3.5.1	The Effect of Chip Geometry with Different Lubrication Strategies	44
3.5.2	Direct Billets Density and Porosity	48
3.6	Discussion on Cold Compaction Results of AA6061 and AA7075	52
3.7	Summary	54

CHAPTER 4 DEVELOPMENT OF CYCLIC EXTRUSION COMPRESSION BACK PRESSURE (CECBP) TECHNIQUE

4.1	Introduction	55
4.2	Die Development	56
4.2.1	Cyclic Extrusion Compression Back Pressure	56
4.2.2	Hot Forging	58
4.3	Experimental Method	59

4.3.1	Cold Compaction using CECBP Technique	60
4.3.2	Hot Forging Process	56
4.4	Method of Measurement	68
4.4.1	Chip Size Measurement with Different Sample Cyclic Billets (SCYB)	69
4.4.2	Density Measurement by Archimedes Principle	70
4.4.3	Hardness Measurement by Vickers Microhardness Machine	72
4.4.4	Microstructural Analysis by Light Optical Microscope (LOM)	73

CHAPTER 5 RESULTS AND DISCUSSIONS

5.1	Results for AA6061 and AA7075	75
5.2	Cyclic Billet Density and Porosity Results	75
5.2.1	Main Effect Analysis of Cyclic Billets Density	78
5.2.2	Analysis of Variance of Cyclic Billets Density	80
5.3	Cyclic Specimens Density Results	81
5.3.1	Main Effect Analysis of Cyclic Specimens Density	84
5.3.2	Analysis of Variance of Cyclic Specimens Density	85
5.4	Cyclic Specimens Hardness Results	87
5.4.1	Main Effect Analysis of Cyclic Specimens Hardness	89
5.4.2	Analysis of Variance of Cyclic Specimens Hardness	90
5.5	Chip Size Results	92
5.6	Microstructural of Chip Boundaries Results	97
5.7	Discussion on CECBP Technique	100
5.7.1	Improvement of Billets Density	100
5.7.2	Main Effect CECBP Factors	101
5.7.3	Comparison Density and Hardnes CECBP with Original	101
5.7.4	Effect of Chip Size	104
5.8	Summary	106

CHAPTER 6 CONCLUSION AND RECOMMENDATION

6.1	Summary of Thesis	108
6.2	Research Summary and Conclusion	109
6.3	Future Work and Recommendation	110
REFERENCES		111
APPENDICES		116
APPENDIX A1:	Drawing cyclic extrusion compression back pressure (CECBP) die	116
APPENDIX A2:	Drawing hot forging die	117
APPENDIX B1:	Height of cyclic billets (CYB) for AA6061 and AA7075	118
APPENDIX B2:	Calculation chip size area for AA6061	119
APPENDIX B3:	Calculation chip size area for AA7075	121
APPENDIX B4:	Mass water (m_{wtr}) reading of cyclic specimens (CYS) for AA6061	123
APPENDIX B5:	Mass water (m_{wtr}) reading of cyclic specimens (CYS) for AA7075	124
APPENDIX B6:	Cyclic specimens hardness reading for AA6061 and AA7075	125
APPENDIX B7:	Average of chip boundaries measurement for AA6061 and AA7075	126
APPENDIX C1:	International manufacturing engineering conference (IMEC), February 2013	127
APPENDIX C2:	Malaysia University Conference Engineering Technical (MUCET), December 2013	128

LIST OF TABLES

Table No.	Title	Page
2.1	Element alloying in aluminium.	9
2.2	Factors effect on compaction stages	22
2.3	Factors Effect on Solid State Stages	23
2.4	Review direct recycling process	25
3.1	Material composition of AA6061 and AA7075	36
3.2	Romi C420 Specifications	39
3.3	Manual press hydraulic specifications	41
3.4	Adam PGW 753e weight balance specifications	43
3.5	Mitutoyo absolute digimatic caliper 500 series specification	44
3.6	Direct billet density of AA6061 and AA7075	44
3.7	Height of direct billets for direct compaction process	49
4.1	Factor and level selection for experimental	61
4.2	Cold compaction experiment using L ₂₅	65
4.3	Ching Fong OCP-60 specification	66
4.4	Density for reference specimen AA6061 and AA7075	71
4.5	Wilson Vickers 402 MVD specifications	73
4.6	Result for hardness for reference specimen AA6061 and AA7075	73
5.1	Cyclic billets density and S/N ratio results for AA6061 and AA7075	77
5.2	ANOVA of cyclic billet density for AA6061	81
5.3	ANOVA of cyclic billet density or AA7075	81
5.4	Cyclic specimen density and S/N ratio result for AA6061 and AA7075	82
5.5	ANOVA of cyclic specimen density for AA6061	86
5.6	ANOVA of cyclic specimen density for AA7075	86
5.7	Cyclic specimen hardness and S/N ratio results for AA6061 and AA7075	88
5.8	ANOVA of cyclic specimen hardness for AA6061	91
5.9	ANOVA of cyclic specimen hardness for AA7075	91
5.10	Percentage improvement of CECBP technique	101

LIST OF FIGURES

Figure No.	Title	Page
1.1	Comparison between conventional recycling and direct recycling technique	2
1.2	Thesis Organization	7
2.1	World aluminium production from 2003 to 2012	12
2.2	Primary Production of aluminium	12
2.3	Secondary Aluminium Production	14
2.4	Metal losses in secondary aluminium processes	14
2.5	A comparison of secondary process and direct recycling process of aluminium alloy chips	16
2.6	Two technique of direct recycling process	16
2.7	Chip aluminium preparation	17
2.8	Temperature Distribution during cutting operation	19
2.9	Chip Formation from different lubricant strategy	19
2.10	Types of cold compaction in direct recycling technique	20
2.11	Comparison between direct and indirect technique for relative green density and mechanical properties	20
2.12	Performance of Hot and Cold Compaction Process	21
2.13	Severe Plastic Deformation Technique	30
2.14	Back Pressure in ECAP	31
2.15	Direct recycling by using back equal pressure channel angular pressing (BP-ECAP)	31
2.16	Direct recycling by using Equal Chanel Angular Pressing (ECAP)	32
2.17	Chip boundaries on hot deformation process	32
3.1	Experiment of cold compaction process using direct technique	35
3.2	Dimension of billet AA6061 and AA7075 before machining	36
3.3	Cooling strategy in machining	37
3.4	MQL concept and mixture regulator	37
3.5	Romi C420 lathe machine	38
3.6	Flow process direct compaction	40
3.7	Manual press hydraulic machine and direct die set	40
3.8	Direct compaction die	41
3.9	Total mass aluminium chip by Adam PGW 753e Weight balance	43
3.10	Diameter and height for direct billet	43
3.11	Types of chips on different lubricant strategies for AA6061	46
3.12	Type of chips on different lubricant strategies for AA7075	47
3.13	Direct billets for direct compaction process	49
3.14	Direct billets density results for AA6061	50
3.15	Direct Billets density results for AA7075	50
3.16	Percentage of direct billets porosity results for AA6061	51
3.17	Percentage of direct billets porosity results for AA7075	51
3.18	Length of chips change on maximum number depth of cut	52
4.1	Cyclic Extrusion Compression Back Pressure die	57
4.2	Design of die part	57
4.3	Part components of hot forging die	58
4.4	Flow Experimental Process	59
4.5	Procedure for cyclic compression extrusion back pressure technique	60
4.6	Manual hydraulic press machine with (CECBP) die	61

4.7	Back pressure system in CECBP die	62
4.8	Complete One of cycle for cycle time	63
4.9	Holding time Process	63
4.10	Flow chart of design of experiment	64
4.11	Hot Forging Process	67
4.12	Measurement analysis flow	68
4.13	Particle of aluminium chip after crush back of CYB	69
4.14	FESEM image for particle aluminium chip size using CECBP technique for experiment 25 (AA6061)	70
4.15	Measurement of reference specimen by Archimedes concept	71
4.16	Cyclic specimen hardness 21 by microhardness Vickers machine for AA6061	72
4.17	Microstructural analysis by Light Optical Microscope (LOM)	74
4.18	Chip boundaries cyclic specimen	74
5.1	Cyclic billets for AA6061	76
5.2	Cyclic billets for AA7075	76
5.3	Main effect factors of billets density for AA6061	79
5.4	Main effect factors of billets density for AA7075	80
5.5	Cyclic specimens after Hot Forging Process	82
5.6	Main effect factors of cyclic specimen density for AA6061	85
5.7	Main effect factors of cyclic specimen density for AA7075	85
5.8	Cyclic specimens Hardness	87
5.9	Main effect factors of cyclic specimen hardness for AA6061	90
5.10	Main effect factors of cyclic specimen hardness for AA7075	90
5.11	Chip size on different sample cyclic billet for AA6061	93
5.12	Average of chip size graph for AA6061	94
5.13	Distribution of chip size on different sample cyclic billet for AA7075	95
5.14	Average of chip size graph for AA7075	96
5.15	Chip boundaries with different cyclic specimen (AA6061)	98
5.16	Chip boundaries with different cyclic specimens (AA7075)	99
5.17	Relative cyclic billets density comparison between direct billets density and previous cold compaction techniques	101
5.18	Contribution CECBP factors by using Main Effect analysis for AA6061 and AA7075	102
5.19	Contribution of CECBP factors by using Anova for AA6061 and AA7075	102
5.20	Density comparison between CECBP technique and reference for AA6061/AA7075	103
5.21	Hardness comparison between CECBP technique and reference for AA6061/AA7075	103
5.22	Correlation between chip size and cyclic billet density	105
5.23	Relation chip size and chip boundaries	105
5.24	Correlation between chip boundaries and cyclic specimens hardness	106

LIST OF SYMBOLS

%	Percentage
ϕ	Porosity
$^{\circ}\text{C}$	Degree Celsius
dB	Decibel
GJ/t	Giga Joule per Ton
kN	Kilo Newton
ρ_{cyb}	Cyclic billets density, g/cm^3
ρ_{cys}	Cyclic specimens density, g/cm^3
ρ_{dcb}	Direct billets density, g/cm^3
H_{cys}	Cyclic specimens hardness, HV
μm	Micro meter
P	Pressure, MPa
P_{b}	Back Pressure, KPa
t_{c}	Cycle Time
t_{h}	Holding Time, s
s	Second
m_{cp}	Mass Chip, g
v_{dcb}	Volume direct billets, cm

LIST OF ABBREVIATIONS

AA	Aluminium Alloy
ANOVA	Analysis of Variance
CECBP	Cyclic Extrusion Compression Back Pressure
CB	Chip Boundaries
CL	Chip Length
CS	Chip Sizes
CYB	Cyclic billets
CYS	Cyclic specimens
DCB	Direct Billets
DOC	Depth of Cut
DOE	Design of Experiment
ECAP	Equal Chanel Angular Pressing
EDM	Electrical Discharge Machine
FR	Feed Rate
GD	Green Density
HV	Hardness Vickers
MAG	Magnification
MQL	Minimum Quantity Lubricant
SEM	Scanning Electron Microscopy
S/N	Signal Noise
SPD	Severe Plastic Deformation
SS	Spindle Speed
SCYB	Sample cyclic billets

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ABSTRACT

The direct recycling process is an alternative method of recycling waste of chip aluminium without melting the materials as compared to conventional recycling technique (secondary production). The cold compaction stage is the most crucial process of the direct recycling process. The billets density, ρ_b achieved through the cold compaction stage significantly influences the hardness (mechanical properties) and chip boundaries (microstructural properties). The problem of conventional compaction (direct compaction) presents low of ρ_b . The objective of this study is to develop the Cyclic Extrusion Compression Back Pressure (CECBP) technique to improve the ρ_b which influences the hardness and chip boundaries of aluminium alloy 6061 and 7075 chips in the direct recycling process. Taguchi Method was used as a tool to analyse and optimise the CECBP factors namely the pressure, P back pressure, P_b cycle time, t_c and holding time, t_h . Different lubricant strategy techniques (flood, dry and minimum quantity lubricant (MQL) were used to obtain different types of aluminium chips. Conventional compaction (direct compaction technique) was used to get ρ_b value. The MQL showed the highest ρ_b results compared to flood and dry technique. The experimental results suggested that the CECBP technique is able to improve cyclic billets density ρ_{cyb} to 12.11% (AA6061) and 5.45 % (AA7075) compared to direct compaction technique. It is also established that the cyclic specimen hardness, H_{cys} and chip boundaries for both aluminium alloys improved when ρ_{cyb} value increased by using regression analysis. Pressure is identified to be the most significant factor in influencing the properties of ρ_{cyb} , ρ_{cys} and H_{cys} . In conclusion, CECBP technique had successfully improved the cold compaction stage for a direct recycling process and can used as direct recycling process of aluminium in industry.

ABSTRAK

Proses kitar semula langsung adalah satu kaedah alternatif kitar semula sisa cip aluminium tanpa lebur bahan berbanding teknik kitar semula konvensional (pengeluaran menengah). Peringkat pemadatan sejuk adalah proses yang paling penting dalam proses kitar semula langsung. Ketumpatan bilet, ρ_b dicapai melalui peringkat pemadatan sejuk ketara mempengaruhi kekerasan (sifat mekanikal) dan sempadan cip (sifat mikrostruktur). Masalah pemadatan konvensional (pemadatan langsung) membentangkan rendah ρ_b . Objektif kajian ini adalah untuk membangunkan Cyclic penyemperitan Mampatan Kembali Tekanan (CECBP) teknik untuk meningkatkan ρ_b yang mempengaruhi kekerasan dan cip sempadan aloi aluminium 6061 dan 7075 cip dalam proses kitar semula langsung. Taguchi Kaedah digunakan sebagai alat untuk menganalisis dan mengoptimumkan faktor CECBP iaitu tekanan, tekanan P kembali, P_b masa kitaran, t_c dan memegang masa, t_h . Teknik strategi pelincir yang berbeza (banjir, kering dan minimum kuantiti pelincir (MQL)) telah digunakan untuk mendapatkan pelbagai jenis cip aluminium. Pemadatan konvensional (teknik pemadatan langsung) telah digunakan untuk mendapatkan nilai ρ_b . The MQL menunjukkan hasil ρ_b tertinggi berbanding dengan banjir dan teknik kering. Keputusan eksperimen menunjukkan bahawa teknik CECBP ini mampu meningkatkan kitaran ρ_{cyb} ketumpatan bilet kepada 12.11% (AA6061) dan 5.45% (AA7075) dan juga berbanding dengan teknik pemadatan langsung. Ia juga menetapkan bahawa kekerasan spesimen kitaran, H_{cys} dan cip sempadan untuk kedua-dua aloi aluminium meningkat apabila nilai ρ_{cyb} ditambah dengan menggunakan analisis regresi. Tekanan dikenal pasti sebagai faktor yang paling penting dalam mempengaruhi sifat-sifat ρ_{cyb} , ρ_{cys} dan H_{cys} . Kesimpulannya, teknik CECBP telah berjaya meningkatkan tahap pemadatan sejuk untuk proses kitar semula langsung.

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