



**Study of Microstructure and Ageing Characteristic
of Aluminium Alloy Reinforced with
Glass Particulates**

By

Josef Hadipramana
0630410117

A thesis submitted
In fulfillment of the requirements for the degree of
Master of Science

MATERIALS ENGINEERING
UNIVERSITI MALAYSIA PERLIS

2009

ACKNOWLEDGMENT

Alhamdulillah and praise to Allah the Almighty Who gave me the strength in completion of this thesis. In the name of Allah, The Most Gracious and The Most Merciful, I would like to take this opportunity to express my gratitude for those helping hands upon completing this thesis.

My appreciation goes to Prof. Dr. Shamsul Baharin Jamaludin as my main supervisor, who has given me the opportunity of searching my potential for his advice and guidance. I extend my gratitude to my second supervisor En. Mohd. Fitri Mohd. Wahid for his supports and encouragement.

I record my gratitude to PLV and all technicians, En. Azmi Kamardin, En. Mohd. Nasir Ibrahim, Norzaidi Zainol, Ku Hazrin, Hadzrul, Azmi, Rosmawadi Othman and the others who have been involved in providing assistance and give their best cooperation.

I am grateful to my wife Fetra Venny Riza and my children Fadhilah Athhar Fauzi Avicenna and Fatharani Mazaya Azka for their forbearance, unconditional support and patience in putting up with the inconveniences when I was engaged in the preparation of this thesis. Also I owe a considerable debt of gratitude to my father Zamanhuri and my mother in law Risnidar Chan for their understanding and patience during the long periods of family neglect while I worked on this thesis. And not to forget thank to all my beloved siblings of their best wishes for me.

My special appreciation goes to the School of Materials Engineering, for providing me the required facilities and to everyone who contributed in this master research. Last but not least, also to all colleagues in postgraduate for inspiring discussions, thank you.

Josef Hadipramana

CONTENT

TITLE	
ACKNOWLEDGMENT	i
CONTENT	ii
LIST OF TABLE	v
LIST OF FIGURE	vi
GLOSSARY	xi
LIST OF ABBREVIATION, SYMBOLS and SPECIALISED NOMENCLATURES	xii
ABSTRAK	xiv
ABSTRACT	xv
CHAPTER 1 INTRODUCTION	1
1.1 Research background	1
1.2 Problem statement	2
1.3 Objectives of the research	3
1.4 Scope of the research	3
CHAPTER 2 LITERATURE REVIEW	6
2.1 Introduction	6
2.2 Strengthening mechanism in metals	8
2.2.1 Solid solution strengthening	8
2.2.1.1 Formation of solid solution	10
2.2.1.2 Effect of solid solution strengthening on properties	12
2.2.2 Strain or work hardening	13
2.2.3 Grain boundary strengthening	15
2.2.4 Dispersion strengthening	16

2.2.5	Precipitation hardening	18
2.3	Hardening in composite	19
2.3.1	Classification of composites	20
2.3.2	Fabrication of metal matrix composites (MMCs)	20
2.3.3	Particle hardening / dispersion strengthened composites	22
2.4	Precipitation strengthening of Al - 4 wt. % Cu alloys	25
2.4.1	Guinier-Preston Zone (G.P. Zone)	25
2.4.2	Ageing behaviour aluminium-copper alloy	26
2.4.3	Ageing behaviour on Aluminium MMC's (accelerating ageing kinetic on aluminium MMC's)	28
CHAPTER 3	METHODOLOGY	32
3.1	Raw materials	32
3.1.1	Pure aluminium powders characteristics	32
3.1.2	Pure copper powder characteristics	33
3.1.3	Glass particulates characteristics	33
3.2	Composite fabrication	35
3.2.1	Development aluminium-copper alloy	36
3.2.2	Mixing process of aluminium-copper alloy with glass particulates	37
3.2.3	Compacting	38
3.2.4	Sintering	40
3.3	Heat treatment	41
3.3.1	Solution heat treatment of composite	41
3.3.2	Ageing process	42
3.4	Characterisation of powder and composite	42
3.4.1	Particle size analysis	42
3.4.2	Microstructure characterisation	43
3.4.3	X-ray diffraction (XRD)	43

3.5	Mechanical testing	43
3.5.1	Hardness	43
3.6	Differential scanning calorimetry (DSC)	44

CHAPTER 4 RESULTS AND DISSCUSION 46

4.1	Raw material charactersation	46
4.1.1	Particle size analysis of raw materials	46
4.1.2	Microstructure analysis of raw materials	48
4.1.3	XRD analysis of raw materials	50
4.2	Composites characterisation	53
4.2.1	Microstructure of composites after sintering	53
4.2.2	Hardness after sintering	56
4.3	XRD analysis after solution heat treatment	57
4.4	Differential scanning calorimetry (DSC) analysis of composites	63
4.5	Microstructure of composite after solution heat treatment	71
4.6	Age hardening at 160° C	85

CHAPTER 5 CONCLUSION AND SUGGESTION FOR FURTHER RESEARCH WORK 88

5.1	Conclusion	88
5.2	Suggestion for further research works	89

REFFERENCES 90

APPENDIX A

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX E

LIST OF TABLE

Table 2.1	Maximum solubility of succeeding atomic numbered metals in copper.	11
Table 3.1	Composition aluminium powder (<i>Sigma-Aldrich Laborchemikalien GmbH Seelze</i>).	32
Table 3.2	Composition of copper powder (<i>Fluka Chemie GmbH CH-9471 Buchs, Sigma-Aldrich, Steinheim, Switzerland</i>).	33
Table 3.3	Composition of soda lime glass for window.	34
Table 3.4	Physical properties of soda lime glass.	35
Table 3.5	Composition Al-Cu Alloy reinforced by glass particulate.	38
Table 3.6	Weight and pressure of the compact samples.	40
Table 4.1	DSC results for Al-4 wt.% Cu reinforced with 0, 5, 10, 15, 20 and 25 wt. % glass particulates.	70

© This item is protected by original copyright

LIST OF FIGURE

Figure 1.1	Phase diagram Al-Cu Alloy.	2
Figure 1.2	Flowchart of research of methodology	4
Figure 2.1	Formation of composite material using fibres and resin.	7
Figure 2.2	The effect of several alloying element on the yield strength of copper, nickel and zinc atoms are about the same size as copper atoms, but beryllium and tin atoms are much different from copper atoms. Increasing both atomic size difference and amount of alloying element increasing solid solution strengthening.	9
Figure 2.3	The effect of additions of zinc to copper on the properties of the solid solution-strengthening alloy. The increase in % elongation with increasing zinc content is not typical of solid-solution strengthening.	12
Figure 2.4	Relationship of strain hardening to stress-strain curve.	14
Figure 2.5	Dislocation in metallic atoms arrange.	15
Figure 2.6	Disperse phase should be hard, strong and discontinuous. Matrix phase should be continuous and ductile.	17
Figure 2.7	The disperse phase particle should be small and numerous. A larger amount of disperse phase increasing strengthening.	17
Figure 2.8	Disperse phase particle should be round rather than needlelike.	18
Figure 2.9	Phase diagram for precipitation hardening.	19
Figure 2.10	(a) incoherent precipitate has no relationship with the crystal structure of the surrounding matrix. (b) A coherent precipitate forms so that there is definite relationship between the precipitate's and the matrix's crystal structure.	23
Figure 2.11	Three types of interphase boundary (IPBs): (a) a coherent or ordered IPB exist between α and β phases, The atoms match up one to one along such a boundary. Owing to different lattice parameters of the phases, a coherency strain energy is associated with this type of boundary. (b), a fully disordered IPB is shown, here there are no coherency strains. A dislocation can penetrate an ordered IPB, but not a disordered one. (c) An intermediate type of IPB (a partially ordered one). Here, coherency strain are partially relieved by the periodic.	24
Figure 2.12	Correlation of structure and hardness of Al - 4% Cu alloy aged at 130°C and 190°C.	27

Figure 2.13	Microhardness with time of ageing after solutionising at 495°C.	30
Figure 3.1	Process to obtain glass particulates from (a) pieces of disposal window glass (b) coarse glass (c) glass particulates.	37
Figure 3.2	(a) Hand Press (b) Scale shows 400 MPa or 11.091 Metric Ton to compress the sample.	39
Figure 3.3	Surface of compression die.	39
Figure 3.4	Sintering of composite at 548° C for 2 hours then furnace cooled.	41
Figure 3.5	Solution heat treatment of composite at 510° C for 2 hours and quenched rapidly into cold water.	41
Figure 3.6	Composite and unreinforced alloy are quenched after one hour of ageing time.	42
Figure 3.7	Vickers hardness with microindenter type <i>Mitutoyo AVK-C21</i> series.	44
Figure 3.8	DSC machine type TA instruments model <i>Q10 V8.2</i> .	45
Figure 4.1	Particle size distribution of aluminium particles.	47
Figure 4.2	Particle size distribution of copper particles.	47
Figure 4.3	Particle size distribution of glass particulates.	48
Figure 4.4	SEM micrograph of pure aluminium powder.	48
Figure 4.5	SEM micrograph of pure copper powder.	49
Figure 4.6	SEM micrograph of glass particulates.	50
Figure 4.7	XRD pattern of pure aluminium.	51
Figure 4.8	XRD pattern of pure copper.	51
Figure 4.9	XRD pattern of glass powder.	52
Figure 4.10	Flowchart of samples studied.	53
Figure 4.11	Microstructure of Al – 4 wt. % Cu with 5 wt. % glass particulates after sintering.	54
Figure 4.12	Microstructure of Al – 4 wt. % Cu with 10 wt. % glass particulates after sintering.	54
Figure 4.13	Microstructure of Al – 4 wt. % Cu with 15 wt. % glass particulates after sintering.	55

Figure 4.14	Microstructure of Al – 4 wt. % Cu with 20 wt. % glass particulates after sintering.	55
Figure 4.15	Microstructure of Al – 4 wt. % Cu with 25 wt. % glass particulates after sintering.	56
Figure 4.16	Microhardness of Al – 4 wt. % Cu reinforced with glass particulates after sintering.	57
Figure 4.17	XRD pattern of Al - 4 wt.% Cu alloy after solution treatment without ageing.	58
Figure 4.18	XRD pattern of aged unreinforced Al – 4 wt. % Cu alloy for 6 hours.	59
Figure 4.19	XRD pattern of Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates after solution treatment without ageing.	60
Figure 4.20	XRD pattern of Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates for 8 hours ageing time.	60
Figure 4.21	XRD pattern of Al - 4 wt.% Cu alloy reinforced with glass particulate 25 wt.% glass particulates after solution treatment without ageing.	61
Figure 4.22	XRD pattern of Al - 4 wt.% Cu reinforced with glass particulate 25 wt.% with 7 hours ageing time.	61
Figure 4.23	DSC result of Al - 4 wt. % Cu alloy after solution heat treated.	63
Figure 4.24	DSC result of aluminium reinforcement with 5 wt. % glass particulates.	65
Figure 4.25	DSC results for Al - 4 wt. % Cu reinforced with 10 wt. % glass particulates.	66
Figure 4.26	DSC results for Al - 4 wt. % Cu reinforced with 15 wt. % glass particulates.	67
Figure 4.27	DSC results for Al - 4 wt. % Cu reinforced with 20 wt. % glass particulates	68
Figure 4.28	DSC results for Al - 4 wt. % Cu reinforced with 25 wt. % glass particulates.	69
Figure 4.29	Microstructure of the unreinforced Al – 4 wt. % Cu alloy after solution heat treatment.	71
Figure 4.30	Microstructure of cross section unreinforced Al - 4 wt. % Cu alloy after solution heat treatment.	72
Figure 4.31	SEM micrograph between Al and Cu in unreinforced Al – 4 wt. % Cu alloy after solution heat treatment.	73

Figure 4.32	SEM micrograph between Al and Cu of unreinforced Al - 4 wt. % Cu alloy after solution heat treatment.	73
Figure 4.32a	EDS spectrum taken from figure 4.33. point 001, EDS indicated diffusion of Al-Cu in unreinforced Al – 4 wt. % Cu alloy after solution heat treatment.	74
Figure 4.32b	EDS spectrum taken from figure 4.33. point 003, EDS detected aluminium in unreinforced Al – 4 wt. % Cu alloy after solution heat treatment.	74
Figure 4.32c	EDS spectrum taken from figure 4.33. point 002, EDS detected copper in unreinforced Al – 4 wt.% Cu alloy after solution heat treatment.	75
Figure 4.33	Microstructure of Al – 4 wt. % Cu alloy reinforced with 5 wt. % glass particulates after solution heat treatment.	76
Figure 4.34	Microstructure of Al – 4 wt. % Cu alloy reinforced with 10 wt. % glass particulates after solution heat treatment.	76
Figure 4.35	Microstructure of Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates after solution heat treatment.	77
Figure 4.36	Microstructure of aluminium alloy reinforced with 20 wt. % glass particulates after solution heat treatment.	77
Figure 4.37	Microstructure of aluminium alloy reinforced with 25 wt. % glass particulates after solution heat treatment.	78
Figure 4.38	SEM micrograph of interface between aluminium, copper and glass particulate in Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates and aged for 3 hours.	79
Figure 4.38a	EDS spectrum taken from figure 4.39, point 004 EDS has been detected aluminium oxide in Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates and aged for 3 hours.	79
Figure 4.38b	EDS spectrum taken from figure 4.39, point 005 EDS has been detected copper in Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates and aged for 3 hours.	80
Figure 4.38c	EDS spectrum taken from figure 4.39, point 006 EDS has been detected aluminium in Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates and aged for 3 hours.	80
Figure 4.38d	EDS spectrum taken from figure 4.39, point 007 EDS has been detected elements of glass in Al – 4 wt. % Cu alloy reinforced with 15 wt. % glass particulates and aged for 3 hours.	81
Figure 4.39	SEM micrograph shows the interaction between Cu and glass particulates in Al – 4 wt. % Cu alloy reinforced with 10 wt. % glass particulates after ageing 8 hours.	82

Figure 4.40	SEM micrograph at 4000X magnification (a) glass particulates as reinforcement in aged Al - 4 wt. % Cu alloy reinforced with 10 wt. % glass particulates for 8 hours (b) aged glass (only) for 8 hours.	83
Figure 4.41	Glass particulate interfere interface bond between copper and aluminium in Al – 4 wt. % Cu alloy reinforced with 10 wt. % glass particulates after solution treatment.	84
Figure 4.42	Al - 4 wt. % Cu reinforced with 15 wt. % aged for 1 hour which the glass particulate is interfere interface bond between copper and aluminium and disturbing solution formation.	84
Figure 4.43	Interface bonding between matrix and copper in Al - 4 wt. % Cu reinforced with 25 wt. % glass particulates aged for 7 hours.	85
Figure 4.44	Microhardness of unreinforced Al – 4 wt.% Cu alloy and composites as a function of ageing times (aged at 160° C).	86

© This item is protected by original copyright

Glossary

Ageing hardening	=	A special dispersion-strengthening heat treatment. By solution treatment, quenching and ageing. A coherent precipitate forms that provides a substantial strengthening effect.
Discontinuous reinforced	=	Reinforced which is particle or whisker shapes
Endothermic	=	Endothermic reaction is one reaction that absorb energy/heat.
Eutectic	=	A three phase invariant reaction in which one liquid phase solidifies to produce two phases
Exothermic	=	Exothermic reaction is one reaction that release energy/heat.
GP zones	=	Guinier-Preston zone is tinny cluster of atom that precipitate from the matrix in the early stages of the age hardening process.
Hardness (test)	=	Measures the resistance of material to penetration by sharp object. Common hardness test include the Brinnel test, Rockwel test, Knop Test and Vickers test.
Matrix	=	The continuous solid phase in a complex microstructure. Solid dispersed phase particles may form within the matrix.
Particulate	=	The materials powder that have more than one shape of particles.
Precipitation formation	=	A solid phase that forms from the original matrix phase when solubility limit is exceeded.
Quenching	=	Rapidly cooled after the solution heat treatment.
Reflectivity	=	The percentage of incident radiation that is reflected.
Silicide		Compound of silicon that have more electropositive
Solubility	=	The amount of one material that will completely dissolve in a second material without creating a second phase.
Solutionising	=	The first step of the precipitation strengthening heat treatment.
Thermal conductivity	=	A microstructure-sensitive property that measures the rate at which heat is transferred through material.

LIST OF ABBREVIATIONS, SYMBOLS and SPECIALISED NOMENCLATURES

Al	Aluminium
Al ₂ Cu	Aluminium Cupri
Al ₂ O ₃	Alumina
ASM	American Society for Metals
ASTM	American Standard for Testing Materials
Be	Beryllium
C	Composition
CaO	Calcium oxide
Cd	Cadmium
Cl	Chlorine
Co	Cobalt
Cr	Chromium
CTE	Coefficient Thermal Expansion
Cu	Cuprum
D	Diameter
DSC	Differential Scanning Calorimetry
EDS	Energy Dispersive Spectrum
F	Fluorine
Fe	Ferro/Iron
Fe ₂ O ₃	Feri oxide
Ga	Gallium
Ge	Germanium
GP	Guinier-Preston
GP zones	Guinier-Preston zone
HV	Hardness Value
ICDD	International Centre for Diffraction Data
IPB	Interphase boundary
K	Constant
K ₂ O	Potassium oxide
K ₂ O ₃	Potassium trioxide
Mg	Magnesium
MgO	Magnesium oxide
Mg ₂ Sn	Mangan stransium

mm	Milimeter
MMC	Metal matrix composite
Na	Sodium
Na ₂ O	Sodium oxide
Ni	Nickel
Pb	Lead
P/M	Powder Metallurgy
RPM	Round per minute
SEM	Scanning Electron Microscope
Si	Silicon
SiC	Silica
SiO ₂	Silicon oxide
Sn	Tin
SSS	Supersaturated solid solution
T	Temperature
TiO ₂	Titanium dioxide
V	Vanadium
W-Mo	Tungsten-Molybdenum
wt	Weight
XRD	X-ray diffraction
Zn	Zinc
α	Alpha
σ	Tow

© This item is protected by original copyright

KAJIAN MIKROSTRUKTUR DAN SIFAT PENUAAN ALOI ALUMINIUM YANG DITETULANGI DENGAN ZARAH KACA

ABSTRAK

Kajian mikrostruktur dan sifat penuaan telah dilakukan pada aloi aluminium yang ditetulang dengan zarah kaca. Komposit aluminium - 4 % berat kuprum dihasilkan dengan kaedah metalurgi serbuk. Kandungan 0, 5, 10, 15, 20 dan 25 % berat zarah kaca dicampurkan ke dalam aloi aluminium - 4 wt. % kuprum. Semua komposit dibuat dengan kaedah pembuatan meliputi : pencampuran, penekanan, dan pensinteran. Pensinteran dijalankan pada suhu 548° C. Penuaan komposit dilakukan dengan cara rawatan haba pada 510° C, diikuti dengan lindap kejut dengan cepat ke dalam air sejuk dan penuaan buatan selama 10 jam dalam suhu 160° C.

Analisis XRD dan DSC menunjukkan pembentukan mendakan di dalam Al - 4 % berat Cu aloi dan komposit. Al - 4 % berat Cu aloi yang tidak ditetulang menunjukkan mendakan Al₂Cu semasa pensinteran, tetapi setelah perawatan larutan, Al₂Cu dikesan mempunyai puncak yang kecil pada graf XRD. Hal ini menunjukkan bahawa Al₂Cu tidak melarut dengan sempurna. Selanjutnya, semasa pensinteran, ada terjadinya mendakan Al₂Cu pada Al - 4 % berat Cu aloi yang tidak ditetulang dengan zarah kaca, tetapi setelah perawatan larutan, mendakan Al₂Cu tidak larut telah diperhatikan pada antara muka zarah kaca dengan aluminium matrik. Hal ini telah menunjukkan bahawa Al₂Cu tidak melarut dengan sempurna. Penuaan telah mempengaruhi pembentukan mendakan di dalam komposit kerana Al₂Cu telah menunjukkan keamatan tertinggi pada graf XRD dibandingkan dengan komposit tanpa penuaan.

Mikrostruktur pada komposit menunjukkan bahawa zarah kaca tertabur dengan homogen di dalam matrik. Walaupun demikian zarah kaca pada kadar 10, 15, 20 dan 25 % berat mengasingkan diri dekat kuprum. Pembentukan fasa AlCu and Al₂Cu telah dihalangi oleh kehadiran zarah kaca. Lapisan aluminium oksida di dalam matrik dihasilkan di antara aluminium, kuprum dan zarah kaca. Ianya lebih keras daripada matrik yang ditunjukkan dengan keretakan mikro pada lapisan aluminium oksida yang terjadi di antara muka lapisan aluminium oksida dengan aluminium. Selanjutnya, lapisan aluminium oksida meningkatkan kekerasan pada matrik dan bahawa ianya bertanggungjawab terhadap mekanisme kekerasan komposit.

Setelah pensinteran, nilai kekerasan menunjukkan bahawa komposit dengan kadar 25 % berat zarah kaca mempunyai nilai kekerasan tertinggi iaitu 34.87 HV daripada aloi aluminium tanpa tetulang iaitu 15.83 HV. Nilai kekerasan bertambah dengan penambahan kandungan zarah kaca di dalam aloi aluminium. Kinetik penuaan pada komposit lebih lambat daripada aloi aluminium yang tidak ditetulang. Lambatnya kinetik penuaan dijangka kerana kehadiran zarah kaca yang mengganggu pembentukan mendakan aluminium-kuprum dan melambatkan pembentukan zon G.P..

STUDY OF MICROSTRUCTURE AND AGEING CHARACTERISTIC OF ALUMINIUM ALLOY REINFORCED WITH GLASS PARTICULATES

ABSTRACT

Study on microstructure and ageing characteristics has been done on the aluminium alloy reinforced with glass particulates. Aluminium - 4 wt. % copper composites were produced by powder metallurgy technique. Composition of 0, 5, 10, 15, 20 and 25 wt. % glass particulates was mixed into aluminium - 4 wt. % copper alloy. All composites were fabricated by mixing, pressing and sintering. The sintering was performed at 548° C. Ageing of the composites was done by solution heat treatment at 510° C followed by quenched rapidly into cool water and artificial aged for 10 hours at 160° C.

XRD and DSC analysis showed the precipitation formation in unreinforced and reinforced Al - 4 wt. % Cu alloy. Unreinforced Al - 4 wt. % Cu alloy showed the precipitation of Al₂Cu during sintering, but after solution treatment Al₂Cu detected as small peak by XRD. It is indicated that Al₂Cu did not completely dissolved. In addition, reinforced Al - 4 wt. % Cu alloy with glass particulates showed precipitation of Al₂Cu during sintering but after solution treatment, undissolved precipitates were observed at the interface between glass particulates and the aluminium matrix. It showed incomplete dissolution. Ageing has influenced the precipitation formation in the composite because Al₂Cu indicated higher intensity of XRD pattern as compared to the composite without ageing.

The microstructures of the composites showed that the glass particulates were homogenously distributed in the matrix. However, glass particulates with the composition of 10, 15, 20 and 25 wt. % were found segregated near copper. The formation of AlCu and Al₂Cu phases was interfered by the presence of glass particulates. The aluminium oxide layer in the matrix is produced between aluminium, copper and glass particulate. It is harder than matrix that indicated by micro cracks in aluminium oxide layer and at interface between aluminium oxide layer and aluminium. Furthermore, it was found an increase in the hardness of matrix and that is found responsible for hardening mechanism.

After sintering, hardness value indicated that the composite with 25 wt. % glass had highest hardness i.e. 34.87 HV than unreinforced aluminum alloy i.e. 15.83 HV. The hardness value increased with increasing the glass composition in the aluminium alloy. Ageing kinetic of the composites was slower than unreinforced aluminium alloy. The slow ageing kinetic was expected due to the presence of glass particulates which disturbed precipitate formation of aluminium-copper and delay the G.P. zone formation.

CHAPTER 1

INTRODUCTION

1.1. Research background

Production of aluminium is the most abundant metallic element in the earth's crust and it is ranked only second to iron and steel in the metals market. The rapid growth of the aluminium industry is attributed to a unique combination of properties which makes it one of the most versatile of engineering and construction materials. Aluminium can be cast and worked into almost any form and can be given a wide variety of surfaces finishes (Smith, 1993).

Aluminium is light in weight, some of its alloys have good strength, and it has good electrical and thermal conductivities and high reflectivity to both heat and light. It is highly corrosion-resistant under a great many service conditions and is non-toxic (Smith, 1993, Kissell and Ferry, 2002). Because of these outstanding properties, it is not surprising that aluminium alloys have come to be of prime importance as engineering materials, one of them is aluminium - copper alloy.

Copper is one of the most important alloying elements for aluminium since it produces considerable solid solution strengthening that provides greatly increased strength by precipitate formation. The maximum solid solubility of copper in aluminium is 5.65 wt. % at the eutectic temperature of 548°C. The solubility of copper in aluminium decreases rapidly with decreasing temperature from 5.65 wt. % Cu to less than about 0.1 wt. % Cu at room temperature as shown in Figure 1.1 (Smith, 1993).

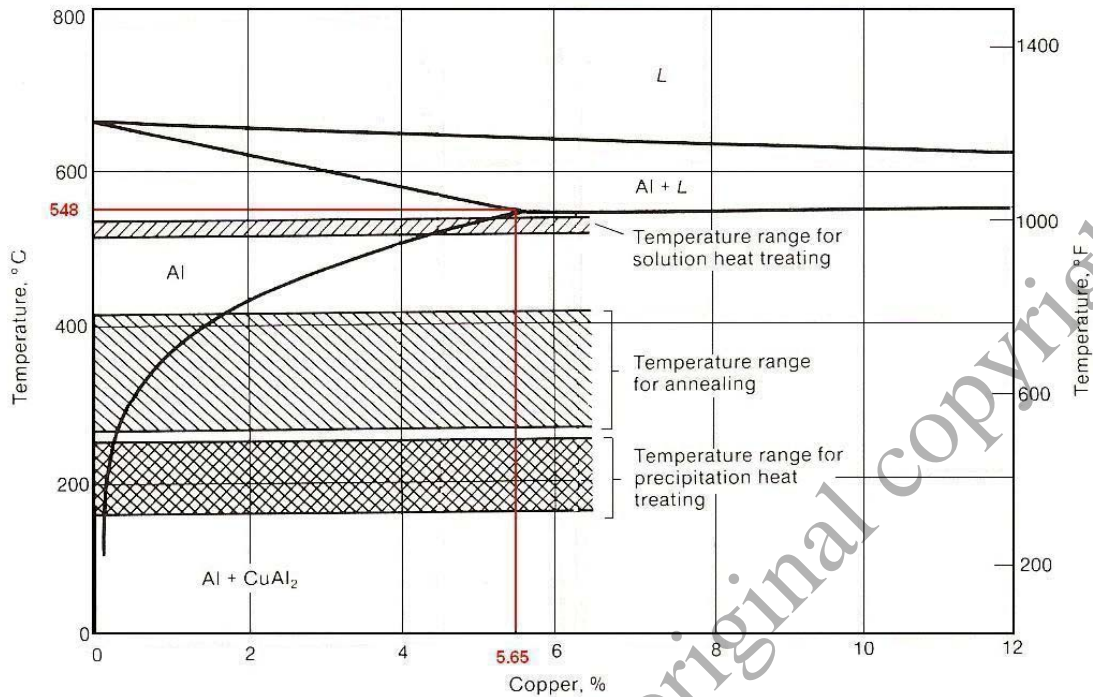


Figure 1.1. Phase diagram Al-Cu Alloy (ASM Handbook, 1991).

Discontinuously (particles) reinforced aluminium matrix composites have received significant attention in recent years. The high specific strength is like hardness make discontinuous reinforced aluminium composites attractive as candidate materials for many applications in industry (KK. Chawla et, al., 1972). The great number of glasses available from recycling activity of industrial wastes leads to the need for new applications, with the development of new materials such as low cost composite materials from a powder technology route (E. Bernardo, et. al, 2004).

1.2. Problem statement

In this research, aluminium-copper alloys as prime importance as materials engineering is treated as composite and it is added with glass as reinforcement. Commercially source of glass is abundance and glass disposal can be recycled as particulate reinforcement in metal matrix composite.

Glass is chosen because it is popular as reinforcement materials because it is easily drawn into high-strength fibre from the molten state (Calijster, 2003). The fact of the glass is relatively weak in tension but relatively strong in compression (Shackelford, 2005). In some general statements it is made concerning to the properties of glass is harder than many metals (400 to 600 kg/mm²) and glasses have a compressive strength of about 945 MPa (Horrat, 2001).

1.3. Objectives of the research

The objectives of this research are:

1. To fabricate aluminium-copper both of reinforced and unreinforced with recycled window glass by powder metallurgy technique.
2. To carry out heat treatment ageing to the composite to improve the hardness property.
3. To investigate its microstructure and to study the effect of glass addition on ageing characteristic.

1.4. Scope of the research

Fabrication of aluminium matrix composite is carried out by powder metallurgy technique. Powder metallurgy is well established for the production of discontinuous fibre, whiskers or particulate reinforced metals. The components are mixed and then pressed, followed by sintering at high temperature (Matthews and Rawling. 2002). Flow chart of the research methodology is given in Figure 1.2.

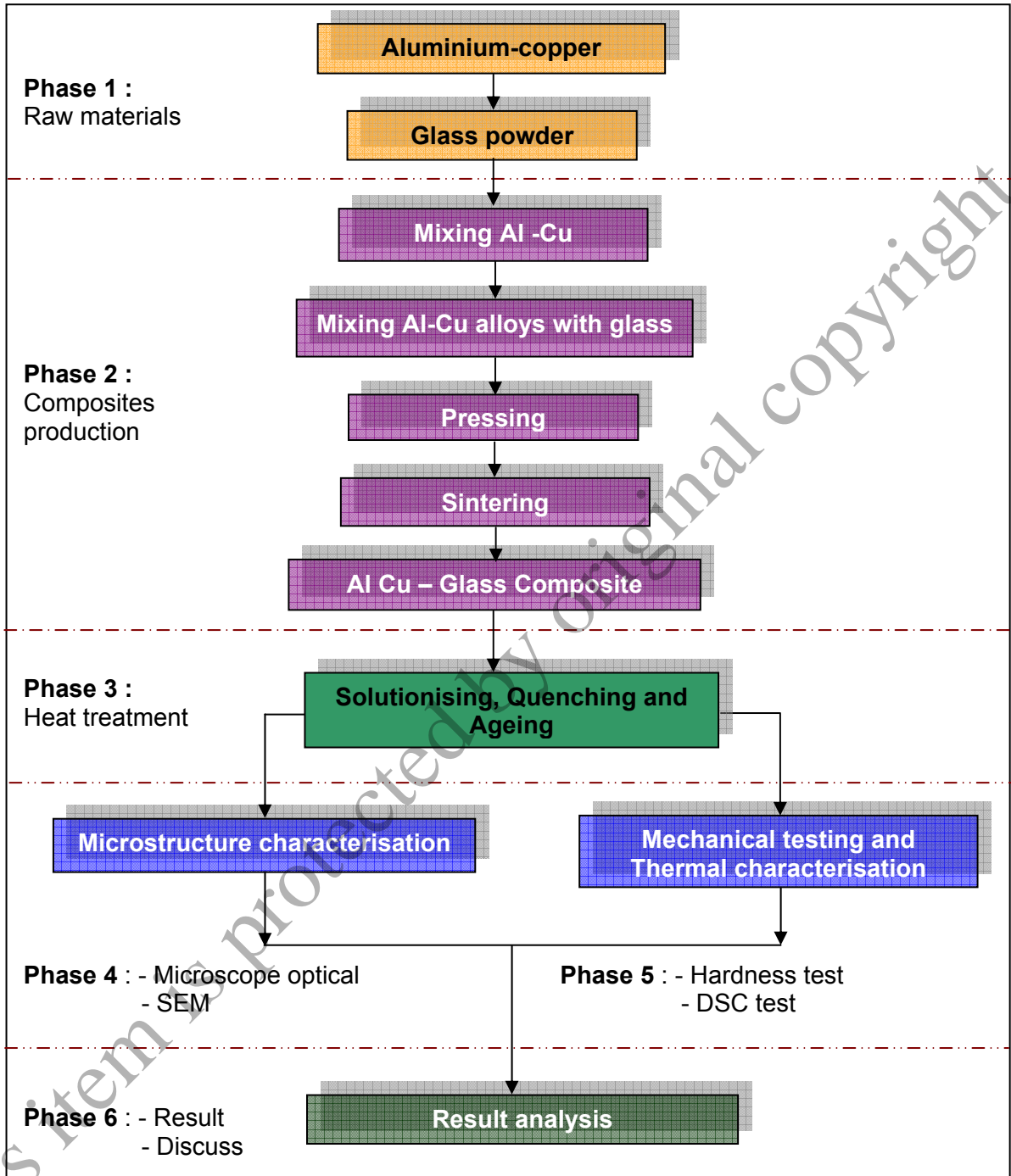


Figure 1.2. Flowchart of research of methodology.

In this methodology is used technical term of research flow by Phase 1, 2, 3, 4, 5 and 6 while each phase is representative of level work.

Phase 1 in Figure 1.2 shows that raw material should be provided especially for glass particulates. Glass particulates obtained from glass disposal and processed to be

particulate. The size glass particulates as reinforcement must be smaller than aluminium matrix so, that ease drawn into matrix.

In technical term of Phase 2 is process to fabricate the composites that shown which is mix the aluminium with copper and then Al-Cu mix with glass particulates. In powder metallurgy technique after mixed the materials powder will go to press then sinter to obtain product of composites. Phase 3 is treating of sample to prepare the data of the composites. In this research that the way to get the hardness property of aluminium-copper composites are solutionising, quenching and ageing.

Term of Phase 4 explained that Microscope optical and Scanning Electron Microscope (SEM) to carry out the composites microstructure characterisation.

In this research, the thermal characterisation is used Differential Scanning Calorimetric (DSC) aiming to explore if the copper is present in solid solution and the glass presence to influence the process solutionising. It is related to the ageing and the hardness property of composites (term of Phase 5). Phase 6 shows discussion can be done if all results of data have been completed.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

The concept of composites was not invented by human being, it is found in nature. For an example, wood which is a natural composite material consisting of one species of polymer called cellulose fibres with good strength and stiffness in resinous matrix of another polymer called the polysaccharide lignin. In addition, celery, bamboo, corn, bone, teeth and mollusk are all examples of nature's composite. Other common variety of composites made by human being, an example in India, Greece and other countries, husks, sawdust or straw mixed with clay have been used to build houses for several hundred years. Mixing husk or sawdust in clay is an example of particulate composite and mixing straws in clay is an example of short fibre composite (Harris, 1999, Horat, 2001, Mazumdar, 2002).

The main concept of composite is that it contains matrix material. Typically, composite material is formed by reinforcing fibre in matrix resin as shown in Figure 2.1. The reinforcements can be fibres, particulates, or whiskers, and matrix materials can be metals, polymers or ceramics (Mazumdar, 2002).

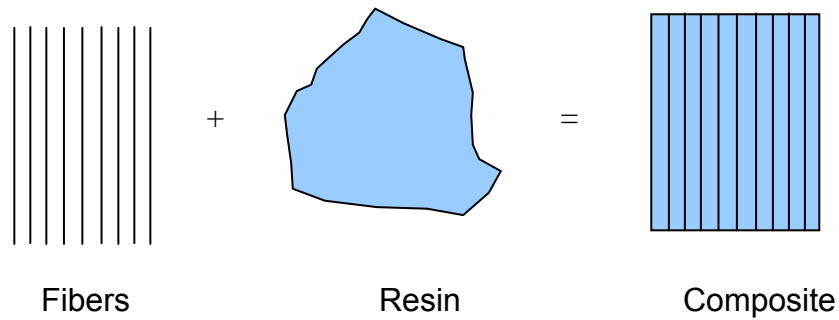


Figure 2.1. Formation of composite material using fibres and resin (Mazumdar, 2002).

According to Mazumdar (2002), reinforcement of composite has function to carry the load in structural composites, for the fibre carries 70 % to 90 % of the load. The reinforcement of composite also provides stiffness, strength, thermal stability, and other structural properties in the composites. Electrical conductivity or insulation has provided, depending on the type of reinforcement used.

A matrix of materials fulfils several functions in a composite structure, most of which are vital to the satisfactory performance of the satisfactory performance of the structure. The important function of matrix material binds the fibres together and transfers the load to the fibres. It provides rigidity and shape to the structure. The matrix isolates the fibers so that individual fibres can act separately. This stops or slows the propagation of a crack. The matrix provides a good surface finish quality and aids in the production of net-shape or near-net-shape parts. The matrix provides protection to reinforcing fibres against chemical attack and mechanical damage (wear). Depending in the matrix material selected, performance characteristics such as ductility, impact strength. are also influenced. A ductile matrix will increase the toughness of the structure. For higher toughness requirements, thermoplastic-based composites are selected. The failure mode is strongly affected by the type of matrix material used in the composite as well as its compatibility with the fibre.

Composite materials can be selected to give unusual combinations of stiffness, strength, weight, high-temperature performance, corrosion resistance, conductivity or hardness (Askeland and Phule, 2006).

In general a composite is a material made by combining two or more materials to give a unique combination of properties that exhibit improved properties over their individual components (Harris, 1999, Horat, 2001, Mazumdar, 2002, Calijster, 2003).

2.2. Strengthening mechanism in metals

Strengthening mechanisms is the relation between dislocation motion and mechanical behaviour of metals. Because macroscopic plastic deformation corresponds to the motion of large numbers of dislocation, the ability of a metal to plastically deform depends on the ability of dislocations to move. Since hardness and strength (both yield and tensile) are related to the ease with plastic deformation can be made to occur, by reducing the mobility of dislocations, the mechanical strength can be enhanced; that is, greater mechanical forces will be required to initiate plastic deformation. In contrast the more unconstrained the dislocation motion, the greater the facility with which a metal deform, and the softer and weaker it becomes. Virtually all strengthening techniques rely on this simple principle; restricting or hindering dislocation motion renders a material harder and stronger (Calijster, 2003).

Strengthening mechanisms are as following: solid solution strengthening, strain or work hardening, grain boundary strengthening, dispersion strengthening and precipitation hardening (Henkel & Pense, 2001, Calijster, 2003, Bowman, 2004).

2.2.1. Solid solution strengthening

Solid solution is a solid containing two or more elements atomically dispersed at random in single crystalline structure. In the substitutional type of solid solution, atoms of the solute element are substituted for solvent atoms at random points in its lattice. In