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Characterization of Mechanical Properties of Aluminium Alloy Metal Matrix Composites

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***Abstract*— The present research work is on aluminium (Al 6061) alloy metal matrix composite reinforced with alumina i.e. Al_2O_3 particulate in weight percentage of 3%, 6% and 9%. The specimens can be produced by Liquid metallurgy technique (Stir casting method) will be used to produce metal matrix composites using Aluminum Copper alloys as matrix material. The produced composites will be characterized with respect to mechanical properties and wear properties. Results obtained from the above investigation, it can be seen that the rate of wear is decreased with increasing Alumina and will be helpful for the end of users in the foundry of automobile and aerospace industries.**

Keywords*— Metal Matrix Composite, Mechanical Properties, Alumina,Liquid Metallurgy Technique.

I. INTRODUCTION

1.1 Composites

Composite materials are light weight engineering materials which are gaining popularity. The metal matrix composites are advanced engineering materials produced from two or more materials in which one is a metal and other is a non metal. When at least three materials are present, it is called a hybrid composite. With continuing quest for new generation of materials which have enhanced properties over conventionally available materials, research activities were pursued vigorously in this desired direction to develop a new generation of materials, which are light in weight, possess higher strength and are of lower costs.

II. OBJECTIVES & METHODOLOGY

- Low Temperature Toughness: Toughness, at low temperatures especially in the presence of notches, flaws or cracks, is an important factor in metal selection for cryogenic services. Catastrophic failures have resulted from embrittlement of some construction materials. Storage tanks for cryogenic fluids illustrate the potential problems and show why aluminum alloys are chosen to ensure maximum safety, that are large welded structures, these storage tanks contain residual stresses, stress concentrations at. Undetected flaws and cracks, and are subjected to vibration stresses from vehicles or tremors. With these structures made of appropriate aluminum ductility remain high or even increases as the temperature drops. This permits the metal to yield at the point of stress concentration, thus redistributing localized stresses in the structure to a tolerable level without fracture. Metals without low temperature ductility should fracture or shatter.
- Strain Rate & Impact: Contrary to popular belief, Impact tests provide no information on the effects of rates of loading, simply because they do not provide data at normal or low loading rtes to permit the assessment of the influence of the application of very high rates. Tensile tests at various controlled rates, at higher strain rates, the total energy to fracture is at least equal to that at conventional rates. The tests are also useful in examining the effect that welding has on the integrity of the plate. The data show alloy 5083 retains its ductility at cryogenic temperatures in both plain and in welded panels.
- Notch Yield Ratio: To provide meaningful measure of toughness at low temperatures, test data should indicate the relative ability of the metal to resist the crack initiation and propagation. Specifically, these data should give a measure of metals ability to deform plastically in the presence of cracks, notches or weld defects and to absorb energy by deforming rather than rupturing so that catastrophic fracture is not triggered by such discontinuities. One of the most useful relative measures of low temperature toughness is a metal’s notch yield ratio. As the name indicates the notch yield ratio relates the tensile-yield strength of the un-coated specimen.
- Tear Resistance: Another measure of toughens is tear resistance, which is measured by the amount of energy, required to propagate a crack. The test determining tear resistance represents among materials that begin to tear at the same force level, aluminum differ widely in its ability to absorb energy during tearing. Aluminum alloys shows that at subzero temperatures.
- Corrosion resistance: Data on the resistance of aluminum to specific chemicals and environments can be obtained from standard alloys. Like the alloys of other metals, there are aluminum alloys that under certain conditions may be susceptible to stress corrosion as well as chemical or electrolytic attack.
- Tensile Strength: Commercial pure aluminum has a tensile strength of approximately 90 MPa and can be improved to around 180 MPa by cold working. The heat treatable grades can develop a tensile strength of around 570 MPa. This value is comparable to that of mild steels Reference to Australian Standards AS2848 and AS 1874

shows the various mechanical properties can be obtained from the cast and wrought grades. It is interesting to note that aluminum alloys increase in strength without loss of ductility or brittle failures. It is interesting to note that the strength of aluminum alloys (either after heat-treatment or subjecting to cold working) yields high strengths without appreciable loss of ductility.

III. RESEARCH METHODOLOGY

The present work will be carried out in the following phases:

- Metal matrix composites will be produced using Alumina as reinforcement material and aluminum copper alloy as the matrix material.
- Liquid metallurgy route namely stir casting technique will be used to produce the composite.
- The composites so produced will be characterized for the mechanical properties; viz, ultimate tensile strength, percentage elongation, hardness test, etc., microstructure examination for varying percentages of reinforcements.
- Wear studies will be carried out in detail by varying the various test parameters.
- The different wear tests and the procedures for the same have been highlighted hereunder.

1) Dry sliding wear tests: Standard instrumented type pin on disc machine will be used to assess the wear of the specimens (cylindrical) under dry sliding condition. The test will be conducted by varying the parameters viz. speed, load, and the track radius.

2) Wet abrasive wear tests: Wear abrasive test would be conducted using a wet abrasive type of wear testing machine; finger type bolt headed specimens machined from the castings will be used for the purpose.

3) Erosive wear tests: Wear tests will be conducted using a erosive wear testing machine, here finger type bolt headed specimens (machine from the castings) will be used for the assess of wear. The tests are planned for different speed; different loads of the abrasives, etc.

4) Tensile Tests: Standard Test Method for Tensile Properties of Metal Matrix Composites. Determination of the tensile properties of metal-matrix composites reinforced by alumina particulate.

5) Corrosion Tests: This Procedure is used to assist in the selection of test methods that can be used in the identification and examination of pits and in the evaluation of pitting corrosion to determine the extent of its effect.

IV. WORK CARRIED OUT

Preparation of the Composites

The following composites with different compositions were prepared in a furnace at a reaction temperature of 1000º C and reaction time of 30 min. Table 1. Shows the Different compositions of composites

Sl. No	Casted Specimen dia, mm	Composition
1	30,20 & 10	Al-4.5%Cu
2		Al-4.5%Cu 3% Al_2O_3
3		Al-4.5%Cu-6% Al_2O_3
4		Al-4.5%Cu-9% Al_2O_3

Table.1. compositions of composites

From these different compositions the following tests are done.

- Micro structural studies
- Tensile strength
- Hardness test
- Corrosion test
- Wear strength

Micro Structural Studies

Figure shows microstructure of as Al+4.5%Cu (Dia 30mm) alloy using Image Analyzer (figure (1) and (1.1) Microstructure consists of very fine particles of $CuAl_2$ segregation (Dark Area) and large particles of the precipitation at the grain boundary in aluminium matrix. By Etchant 0.5% H.F. The composites were prepared at a reaction temperature of 1000ºC and a reaction time of 30 minutes. Since the reactions involved clearly shows the formation of Al-Cu, it is quite clearly established that the reaction temperature of 1000º C and a reaction time of 30 minutes is required for the exothermal reaction to be completed. The figure clearly shows the presence of large Al-Cu phases along with Cu in the interdendritic region.

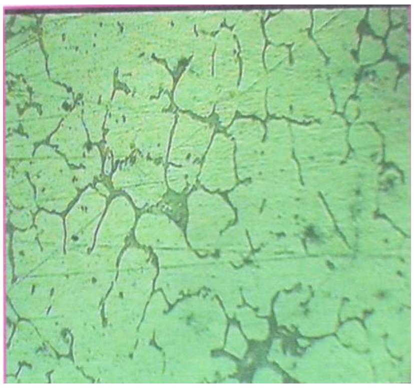

Figure.1. Shows Image Analyzer Micro Photograph of 2-1 composite at 500X Magnification

Figure.1.1. Shows Image Analyzer Micro Photograph of 2-1 composite at 500X Magnification

Micro Structural Studies

Figure shows microstructure of as Al+4.5%Cu+3%Al_2O_3 (Dia 30mm) composite using Image Analyzer (figure (1.2) and (1.3). The composites were prepared at a reaction temperature of 1000ºC and a reaction time of 30 minutes. Microstructure consists of inter dendritic network of undissolved $CuAl_2$ with grain boundary precipitation in aluminium matrix. By Etchant 0.5% H.F. Since the reactions involved clearly shows the formation of Al+4.5%Cu +3% Al_2O_3 composite, it is quite clearly established that the reaction temperature of 1000º C and a reaction time of 30 minutes is required for the exothermal reaction to be completed.

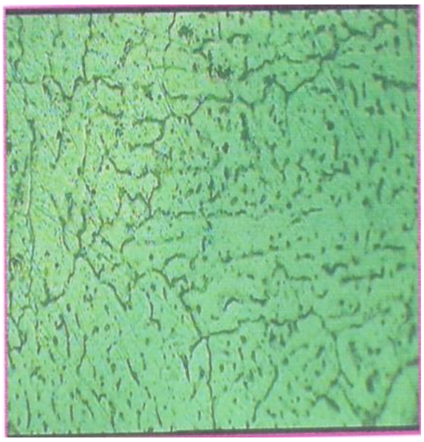

Figure.1.2. Shows Image Analyzer Micro Photograph of 1-1 composite at 200X Magnification

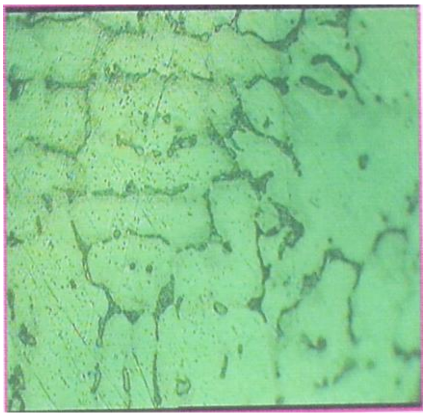

Figure.1.3. Shows Image Analyzer Micro Photograph of 2-1 composite at 500X Magnification

Micro Structural Studies

Figure shows microstructure of as Al+4.5%Cu+6%Al_2O_3 (Dia 30mm) composite using Image Analyzer (figure (1.4) and (1.5). The composites were prepared at a reaction temperature of 1000ºC and a reaction time of 30 minutes. Microstructure consists of very fine particles of $CuAl_2$ segregation (Dark Area) and large undissolved particles of the precipitation in the form of stringers in aluminium matrix. By Etchant 0.5% H.F. The composites were prepared at a reaction temperature of 1000ºC and a reaction time of 30 minutes. Since the reactions involved clearly shows the formation of Al+4.5%Cu +6%Al_2O_3 composite, it is quite clearly established that the reaction temperature of 1000º C and a reaction time of 30 minutes is required for the exothermal reaction to be completed.

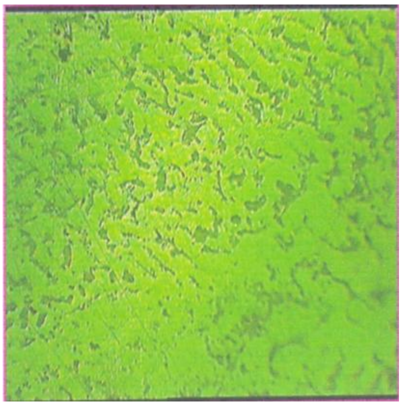

Figure.1.4. Shows Image Analyzer Micro Photograph of 1-1 composite at 200X Magnification

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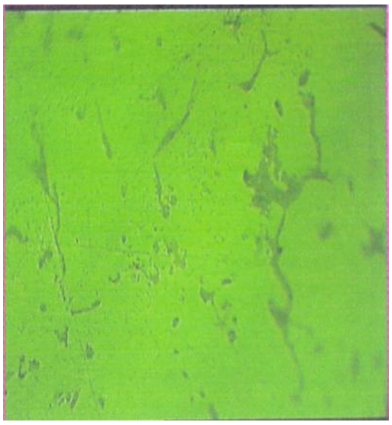

Figure.1.5. Shows Image Analyzer Micro Photograph of 2-1 composite at 500X Magnification

Figure shows microstructure of as Al+4.5%Cu+9%Al_2O_3 (Dia 30mm) composite using Image Analyzer (figure (1.6) and (1.7). The composites were prepared at a reaction temperature of 1000ºC and a reaction time of 30 minutes. Microstructure consists of very fine particles of $CuAl_2$ precipitation in the aluminium grains and undissolved particles precipitation at grain boundary in aluminium matrix. By Etchant 0.5% H.F. The composites were prepared at a reaction temperature of 1000ºC and a reaction time of 30 minutes. Since the reactions involved clearly shows the formation of Al+4.5%Cu +9%Al_2O_3 composite, it is quite clearly established that the reaction temperature of 1000º C and a reaction time of 30 minutes is required for the exothermal reaction to be completed.

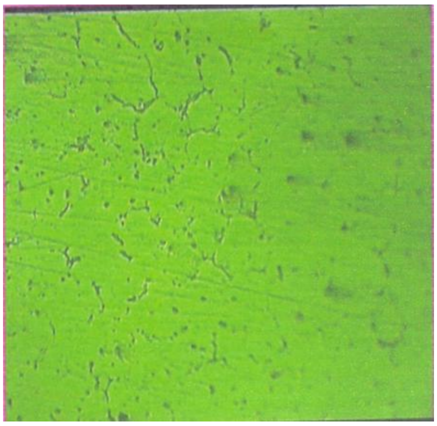

Figure.1.6.Shows Image Analyzer Micro Photograph of 1-1 composite at 200X Magnification

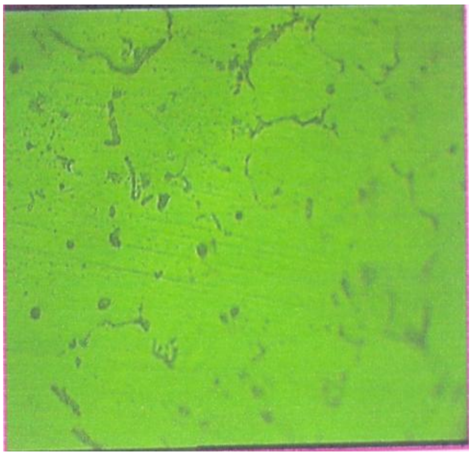

Figure.1.7. Shows Image Analyzer Micro Photograph of 2-1 composite at 500X Magnification

TENSILE STRENGTH

From the graph 2.1. We can observe that how the tensile strength of the Al base copper alloy is decreased with increasing the Alumina percentage.

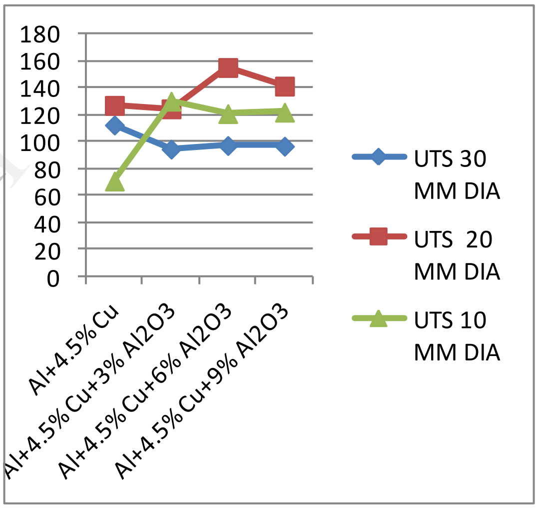

Figure.2.1. Tensile graph for 30, 20 and 10 mm diameter rod

HARDNESS TEST (BRINELL HARDNESS)

The hardness values of the composites are shown in below graph. It can be seen from the graph that the hardness of specimen is decreased with increasing in Alumina. This mainly due to the refinement of the size of Al- Alumina in the specimen.

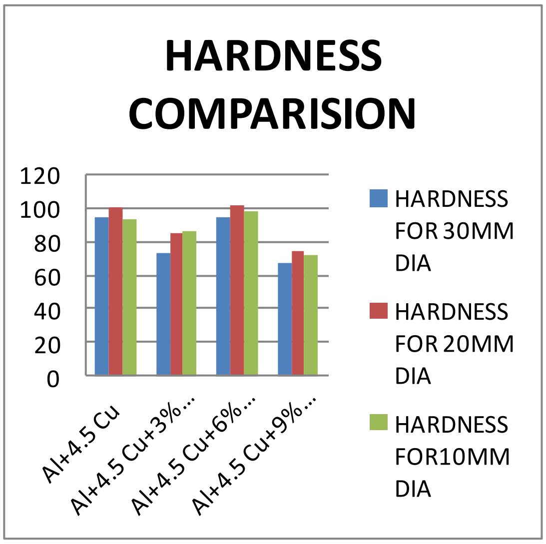

Figure.3.1. Hardness Number graph for 30, 20 and 10 mm diameter rod

CORROSION TEST

This Procedure is used to assist in the selection of test methods that can be used in the identification and examination of rust, pits and in the evaluation of rust and pitting corrosion to determine the extent of its effect.

Nature of Sample	Base:Aluminium Sample
Test Conducted	Neutral Salt Spray Test
Sample Description	Al+Cu Diameter 30mm Sample
Solution Used	5% A.R NaCl Solution
Temperature	35^{o}c $\pm 1^{o}$c
Volume of Salt Solution Collected	1.6ml per hour in $80cm^2$
pH of Collected Solution	6.75
Specified Duration	No white rust for 72hours
Test Result	
Observation	White Rust observation at 70^{th} hour.

Nature of Sample	Base: Aluminium Sample
Test Conducted	Neutral Salt Spray Test
Sample Description	Al+Cu+6%Al_2O_3 Diameter 30mm Sample
Solution Used	5% A.R NaCl Solution
Temperature	35^{o}c $\pm 1^{o}$c
Volume of Salt Solution Collected	1.6ml per hour in $80cm^2$
pH of Collected Solution	6.75
Specified Duration	No white rust for 72hours
Test Result	
Observation	White Rust observation at 50^{th} hour.

WEAR TEST

Composite specimen on contact with the disc surface is being rotate to the pre defined speed along the circumference. Initial weight and final weights are noted and tabulate the wear rate of the particular specimen. From the below graph it can be seen that the rate of wear is decreased with increasing in Alumina.

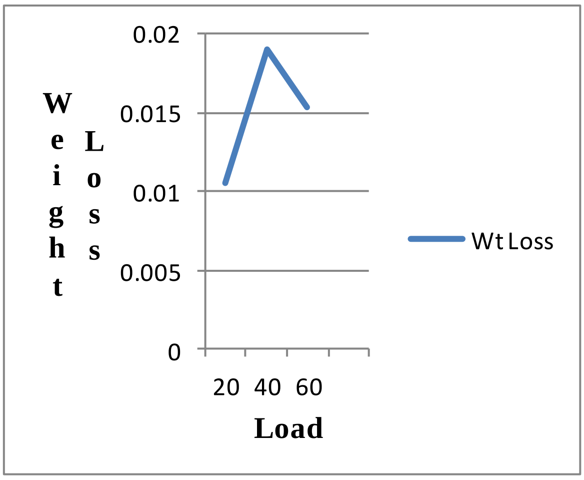

Figure.4.1. wear graph for Al + Cu

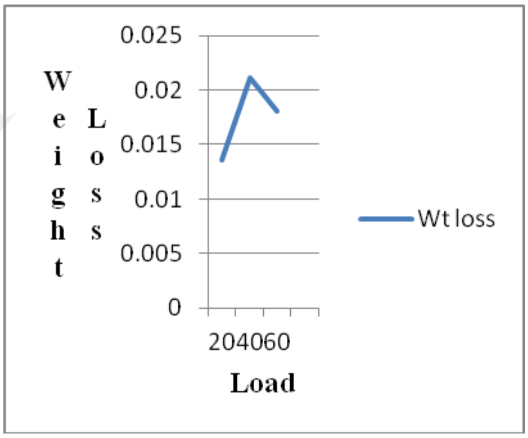

Figure.4.2. wear graph for Al + Cu + 3% Al_2O_3

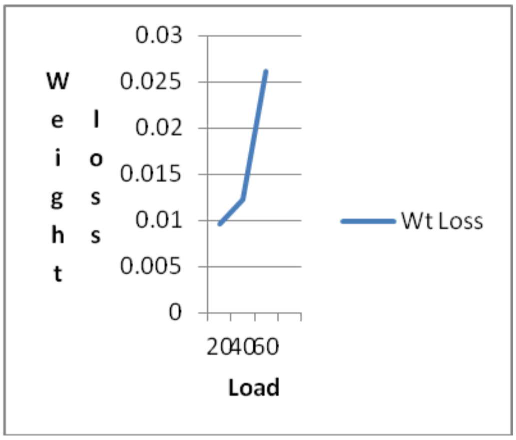

Figure.4.3. wear graph for Al + Cu + 6% Al_2O_3

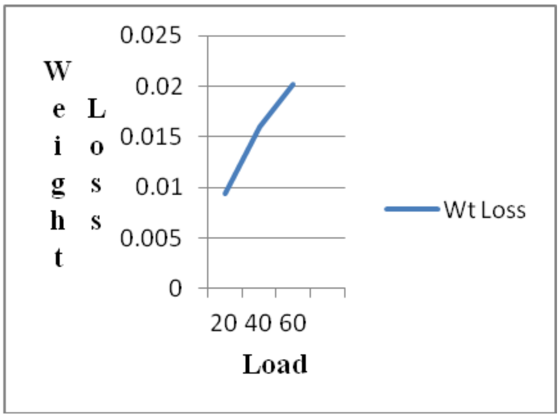

Figure.4.4. wear graph for Al + Cu + 9% Al_2O_3

VI. CONCLUSION

- Al Based metal matrix composites were successfully processed in Resistance Furnace at a reaction temperature of 1000º C and a reaction time of 30 minutes.
- The Micro Structural studies clearly show the formation of Al+4.5%Cu+ Al_2O_3 phases showing that the exothermal reaction was complete.
- The rate of wear is decreased with increasing in Alumina.

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