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Investigation of Mechanical Properties of AlFe Intermetallic Composite

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***Abstract*— Iron powder of particle size 44μm is dispersed into aluminum matrix to produce composites by liquid metallurgy route. Aluminium iron intermetallic is developed by varying iron particulate content based on weight percentage. The specimens are prepared with three different wt% of iron, viz 2%, 4% and 8%. By conduction of various mechanical tests as per ASTM B308 standard, the divergence of tensile, shear, hardness and wear properties is being studied. From the study it is observed that maximum tensile strength of 155.06 MPa for 8wt% addition of iron. The results also revealed that the mechanical properties enhanced with the increase in wt % of iron.**

Keywords*— Intermetallic, Iron, Aluminum, Composite, Stir Casting

I. INTRODUCTION

The global energy crisis and depleting energy resources as well as stringent requirements of the quality of a product necessitated the development of lightweight energy efficient materials to be used in automotive industries. The development of metal matrix composite with the dispersion of second phase particle had been catalyzed by the need for structural materials with high strength and stiffness to enhance the wear resistance [1]. Pure aluminum is weak having a tensile strength between 90 to 140N/mm^2. Aluminum alloys are used extensively in making mechanical parts due to its high specific strength (strength/density). The main usage of aluminum alloys are in applications requiring lightweight materials as in aerospace industries and in automotive industries. The second important property of aluminum is its resistance to corrosion. Aluminum has a strong protective oxide layer which prevents continues corrosion of the base material. Therefore, a lot of work is done to achieve better properties of aluminum by alloying, heat treatment and other processes. On the other hand aluminum has a big disadvantage of having a low melting temperature which put limits on the temperature range of application [2]. Intermetallic phases based on the high activity of aluminum have very attractive properties as low density, high melting point, high thermal conductivity, excellent oxidation, hot corrosion resistance and good mechanical properties [5]. Intermetallic compounds have potential use in systems requiring excellent behavior of materials in aggressive environments such as steam generators and coal-fired gas turbine because of its high resistance to high temperature oxidation and lower density compared to conventional Fe and Ni based alloys [6]. High-temperature strength and superior oxidation resistance make intermetallic materials exceptional candidates for use in high temperature component design providing not only longer equipment service-life but the potential to operate at above normal temperatures. Promising applications include heat-treating fixtures, transfer rolls for hot metal processing, forging dies, radiant burner tubes, or pyrolyzer parts [7]. Iron is the most common impurity found in aluminum. It has a high solubility in molten aluminum and is therefore easily dissolved in the liquid state of aluminum, however its solubility in the solid state is very low (~0.04%). The low solubility of iron in the solid state is accompanied by decreased ductility as a result of the formation of intermetallic phases like FeAl and/or Fe_3Al. These intermetallic phases increases the strength of the aluminum alloy they also enhances corrosion resistance [2,3,4]. Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted and currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large scale production and because in principle it allows a conventional metal processing route to be used and its low cost [8]

II. EXPERIMENT DETAILS

A. Materials

The base material used in the experimental investigation is commercially available pure aluminium. The iron powder used is collected from M/s Sri Durga Laboratory Equipment Supplies, Mangaluru, India. The particle size of iron powder is 44μm.

B. Sample preparation

A calculated amount of commercially pure aluminium is charged into the crucible and melted in the electric furnace as shown in fig.1. A mechanical stirrer is inserted into the melt furnace and stirred at a speed of 200 rpm at 700˚C. The melt temperature is maintained between 660˚C to 780˚C during addition of iron powder particles. The dispersion of iron particles is achieved by vortex method. The melt with reinforced particles is poured into the preheated permanent metallic mould. The pouring temperature is maintained at 700˚C. The melt was then allowed to solidify in the mould. The composites were made with a different amount of iron powder (i.e., 2, 4 and 8 wt %). Specimens are machined according to ASTM B308 standard.

Fig.1. Stir casting setup

C. Determination of Tensile and Shear strength properties

The tensile testing of the composite is done on universal testing machine (UTM) Standard specimens with 50mm gauge length is used to evaluate the ultimate tensile strength. The comparison of properties of composite material is done with the commercially available pure aluminium. The double shear test of the composite is also done on UTM. Standard specimen with 20mm diameter and 100mm length were used to evaluate the shear strength.

D. Investigation of wear and Hardness properties

Hardness test of the specimen were done on Rockwell hardness testing machine. The Rockwell test determines the hardness by measuring the depth of penetration of an indenter under a large load compared to the penetration made by preload. Wear test is a simple test for evaluating the abrasion or wear resistance of the test specimen. A pin on disc wear testing machine was used for this purpose.

III. RESULTS AND DISCUSSIONS

A. Tensile

Test From the tensile test results the variation of UTS with the increase in iron percentage is as shown in fig. 2. As the weight percentage of iron increases, the tensile strength increases gradually. The tensile strength increases 88.85MPa, 116.75 MPa and 155.06 MPa for 2, 4 and 8wt% of addition of Fe. This indicates that as the addition of Fe increased the composite turns to become brittle and percentage of elongation decreases.

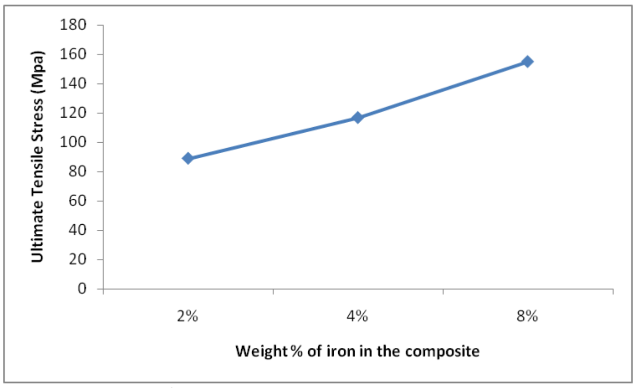

Fig.2. Variation of Tensile strength with respect to Iron weight content

B. Shear Test

The shear strength variation with respect to wt % of Fe is as shown in fig. 3. As the weight percentage of iron increases, the shear stress also increases gradually. The shear stress increases to 82.76 MPa, 92.3 MPa and 130.56 MPa for 2, 4 and 8wt% of addition of Fe.

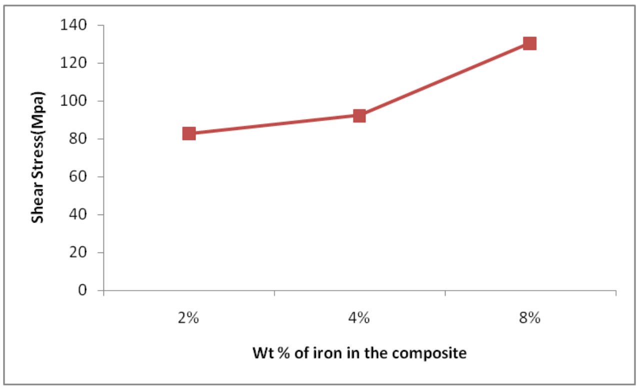

Fig.3. Variation of shear stress with respect to Iron weight content

C. Hardness Test

As the percentage of iron increases strength of the aluminum enhances. For pure Al 6061 hardness is 60 HRH, for 2%wt of iron in Al 6061 hardness increases to 66 HRH, similarly for 4%wt of iron in Al 6061 hardness is 91 HRH and for 8%wt of iron in Al 6061 hardness increases to 99 HRH. Fig. 4 shows the variation of hardness with increase in wt% of iron.

D. Wear test

From Fig.5 it is clear that the wear factor of AlFe intermetallic decreases as weight percent of iron powder increases. This is because as the weight percentage of iron increases, the hardness of the intermetallic composite enhances.

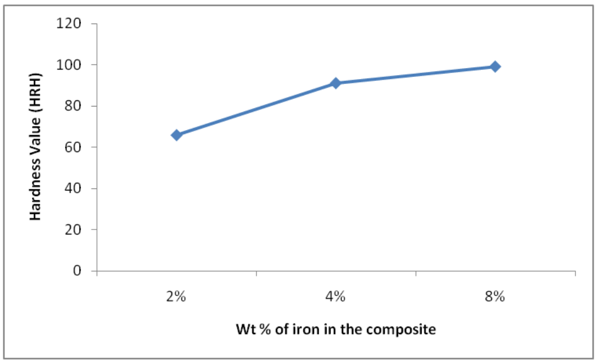

Fig.4. Variation of hardness value with respect to Iron weight content

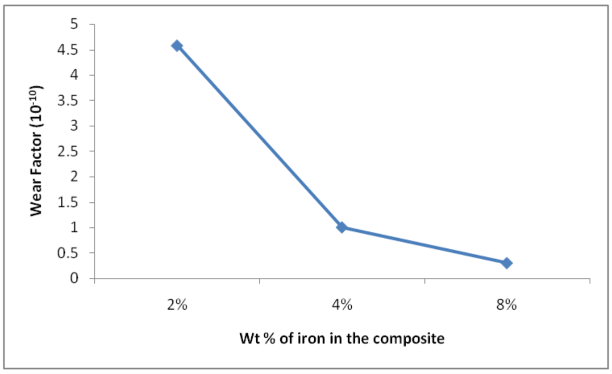

Fig.5. Variation of wear factor with respect to Iron weight content

1V. CONCLUSION

The Aluminium iron intermetallic composites were prepared by stir casting method and subjected to various tests. 2%, 4% & 8% Iron powder by weight is added to commercially pure aluminium by stir casting route to produce the composite. The hardness of Al 6061 increases with the increase in addition of iron powder. The ultimate tensile strength has increased with increase in iron content where as percentage of iron increases the material property of material changes from ductile to brittle. The shear stress is improved as the percentage by weight of iron content increases. The wear factor decreases as the percentage by weight of iron content increases due to improved hardness. The reason for improvement in mechanical properties is the formation of intermetallics of iron and aluminium, which needs further study. Hence this study reveals the potential of producing iron- aluminium intermetallics by a simple technique of stir casting.

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