Behaviour of Mechanical Properties of Aluminium Metal Matrix Composites on addition of Iron and Bronze by sand Casting Method

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Abstract— Composites are widely used in a variety of industries, including marine, aerospace, and automotive. The primary goal of this research is to look into the mechanical qualities of aluminum, iron, and bronze metal matrix composites made by sand casting since they are lightweight and have better mechanical properties like hardness and toughness. This paper discusses an aluminum composite experiment in which different proportions of iron and bronze were mixed in varying proportions to make samples. Three specimens were prepared, each comprised of Al + Fe and Al +Fe + Bronze, with Fe and bronze compositions varying and combined at 20%, 30%, and 40%, respectively. The results demonstrate that hardness and toughness rises as the percentage of iron in aluminum increases, and that in the case of iron and bronze, hardness increases as the percentage of composition increases from 20% to 40%, but toughness decreases till 40%.

Keywords: Aluminium Matrix, Manufacturing, Sand Casting, Hardness, Toughness

I. Introduction

It is vital to find a means to produce advanced engineering materials for different engineering applications in the contemporary developing globe with rising urban growth. One of the most significant approaches to fulfill this need is through metal matrix composites (MMC) [1]. Composites are materials formed out of two or more distinct materials that have enhanced their qualities such as hardness, toughness, light weight, specific strength, specific modulus, damping capabilities and higher wear resistance than alloys that are non-reinforced. It combines the most advantageous features of each component while removing the less favorable features. Due to their better characteristics, in the aerospace, nuclear and marine industries aluminum alloys are progressively substituted with aluminum matrix composites (AMC). Several scientists investigate the compositions, characteristics and usage of various composites worldwide. Composite technology is widely utilized in the aerospace, automotive, and other technological applications, including environmental and economic benefits. Due to its mechanistic qualities, such as strong corrosion resistance, low density and great thermal conductivity, aluminum is the most widely used metal in industry. The module is highly youthful and has a high hardness and a melting point of 600oC. If the temperature increases, aluminum strength drops but mixes aluminum with strengthening materials such as zircon sand, carbide tungsten (TC), carbide silicone, alumina oxide (Al2O3) etc. It is tougher, fortified and has a nice feature as strengthened by TiB2 particles.The composite material combines the best desired qualities of its elements since it has unique mechanical and physical characteristics. It eliminates the unwanted material characteristics [2]. Aluminum alloys have been largely replaced by the aluminum matrix composite, due to the improved characteristics provided by composite material (AMCs). The mechanical behavior of metal composites is investigated by researchers all around the world. Its broad applicability in the car, aviation, nuclear and marine industries is the major reason for this [3].The impact on the metals of metal aluminum composite and powder metallurgy method of adding manganese and boron carbide. It introduces a novel technique of hybrid composite production. Rockwell hardness test and microstructural analysis have revealed that Al-B4C composite hardness has increased from 2% to 4% and then further reduced when the proportion of B4C has grown from 4% to 6%. The SEM results indicated that the B4C particles in the aluminum composite are uniformly distributed [4]. Various techniques for the manufacture of composites with metal matrix are utilized depending on the enhanced particles, such as sand casting, casting and coating [5].Aluminum metal matrix composites were produced with various percentages of particulate matter of carbide (WC) including 2 percent, 4 percent, 8 and 10 percent, by weight, reporting reduced impact strength and length with addition of tungsten carbide (WC) reinforcement, and investigated that composite mechanical properties [6]. Multiple routes in MMC production include sand casting, stir casting, powder metallurgy and techniques of infiltration. Aluminum alloys were formerly used but are rapidly replaced by AMCs in the nuclear, car, marine, and aero spatial sectors because of their improved characteristics [7, 8].Several researchers worldwide are investigating the manufacturing, properties and usage of various composites [9]. AMC was used in permanent mould casting, especially where no further treatment is required [10-15], and in the manufacture of non-stressed thin sections [16-20].Mechanical characteristics for composites with aluminum matrix affect by casting process, matrix, and reinforcement. The casting process is the most important characteristic affecting the distribution of the boosting material between the matrix and its strengthenings [21, 22].Aluminum matrix composites were developed in both liquid and solid forms. The sand casting technique that has attracted attention due to its low cost and its capability to spread a variety of composites is easy to produce composites for particles-reinforced aluminum material. The casting of sand is one of the oldest and most diversified processes of casting that can produce complex castings from different aluminum alloys. The adoption of this technology for moulding alloys enhanced the interest in light-weighted material and developments in sand casting processes.Any aluminum alloy may be casting in sand, even AMCs with hot shortages in methods for metal molding. The most cost-effective method of all manufacturing processes is predicted to be sand casting [23-25]. The technique provided the simplest possible use of benefits, cost savings, flexibility and mass production capabilities.This is the economic method to the production of heavy casting components in sectional metals [26, 27]. The cost of casting these composites amounts to about one-third or half of the standard methods, which in mass production is down to one tenth.

It was found from the literature examined, as well as contemporary study, that Bronze was not employed as a reinforced particle. It has a better strength to weight ratio as the main benefit of combining brass with Al-Fe composite. Because of its various benefits, bronze, an alloy consisting of copper and tin, has been more durable than copper and tin. This is why the mechanical behaviour of hybrid composite resulting in the addition of bronze in Al-Fe material composite (such as hardness and strength) has to be studied realistically

II. Material and Method

A. *Matrix Materials*

The most common materials utilized as matrix composite material are the metals such as titanium, magnesium, aluminum and their alloys. Due to its desirable characteristics, such as corrosion resistance, strength, good strength and light weight, aluminum may be used as the material matrix in this study. However, due to weak mechanical characteristics, the widespread usage of aluminum is limited [28].

B. *Reinforcement Material*

The selection of the reinforcing material requires important criteria for properties including physical characteristics, mechanical characteristics and their cost-efficiency. Recent study has focused primarily on the particulate-reinforced MMCs. It is apparent why superior workmanship, increased physical and chemical characteristics, decreased weight and good working properties are advantageous. In particulate-reinforced MMCs, both the metal matrix and the reinforcing particle share load.

C. *Fabrication process*

Melt stir casting is a very good way to make MMCs because of the advantages of simplicity, volumetric application, flexibility, material selection, and a wide range of processing conditions [29]. Furthermore, large Particles may be easily produced using this casting method. Another reason for adopting sand casting in this study is its capacity to disperse reinforced particulates throughout the MMCs system at a low cost [30]. In comparison to other manufacturing methods, stir casting has a half or third of the cost of other methods [31]. In the stir casting method, matrix material is melted in a crucible, and then the molten material is stirred to create a vortex. The reinforcing particulates are then combined in the vortex. It is critical to ensure that the matrix reinforcement is consistent during the stir casting process; otherwise the specimen produced will have severe flaws [32]. The problem associated with

1) Agglomeration and sedimentation of reinforcing material in matrix material
2) Impurities interacting with the melt
3) Melt solidification
4) Air trapped in the melt

All of these issues eventually degrade the quality of the final specimen produced. Figure 1 depicts the technique or process/step used in this investigation.

First, in our investigation of the stir casting method, aluminum was heated and melted in a graphite crucible to a temperature of about 700 ^{O}C. The iron powder was then put into the same crucible that held the molten aluminum, and the temperature was raised to 1000 ^{O}C. Figure 1 depicts the sand casting method used to create the composite. To produce three samples of Al-Fe and Al-Fe-Bronze, the optimal weight percentages of Fe and Bronze were added one by one in percentages of 20%, 30%, and 40% to make rectangular shape specimens. The total weight of the composite was 14g, with the addition of Fe and Bronze varying across samples. The Fe content of the three Al-Fe composite samples varies as follows: 2.8gm for sample 1, 4.2gm for sample 2, and 5.6gm for sample 3. Similarly, three further samples were produced, using the composition chosen for the hybrid composite of Al-Fe and Bronze, total weight of sample 14gm. The quantity of Bronze changed in the same composition as the amount of Fe in the Al-Fe composite. Both the Al-Fe and AL-Fe-Bronze mixtures were stirred continuously for some time at about 200-1000 rpm, followed by sand casting for final specimen preparation. Figure 3 depicts the sample produced.

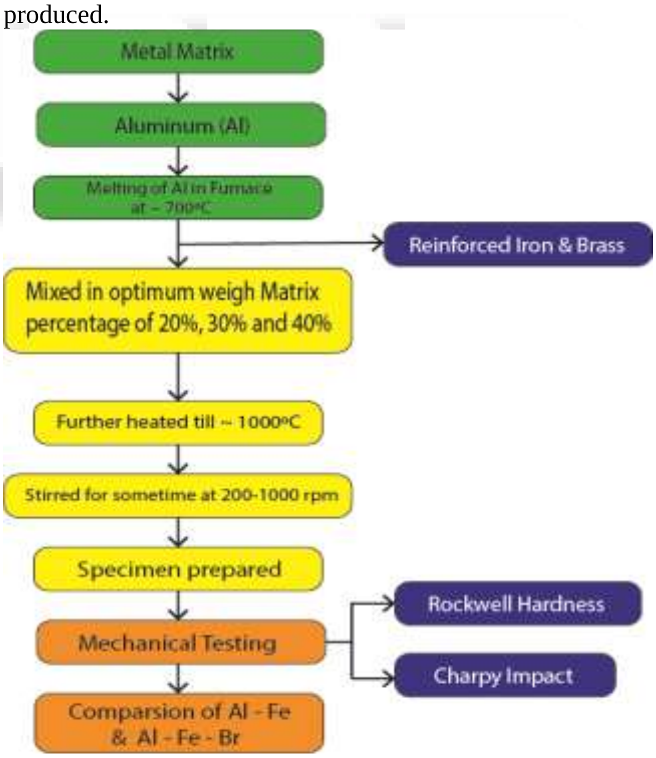

Fig. 1: shows the steps involve in making the samples

Fig. 2: To produce the final specimen, sand-casting is being done.

Fig. 3: show the samples of Al+Fe and Al+Fe+Bronze after testing produced by sand casting method

III. TESTS PERFORMED ON SPECIMEN

The current investigation primarily employed two tests, namely the hardness and toughness tests. The testing technique and equipment used for this purpose include the Rockwell hardness test for evaluating hardness and the Charpy impact test for determining composite toughness.

A. Rockwell Hardness test

Hardness is a measure of a material's resistance to localized deformation. The term refers to deformation produced by bending, indentation, scraping, or cutting. Because hardness measurements are quick and non-destructive when the marks or indentations produced by the experiment are in low-stress locations, they are commonly used to evaluate the material's quality. A material's hardness can be determined in a variety of ways. Some of the most common procedures include Vicker's hardness test, Rockwell hardness test, and Brinell hardness test [33]. The Rockwell hardness test is the most cost-effective and straightforward to perform of these. The hardness of the prepared compacts was determined using the B scale rockwell hardness test. A steel ball indenter with a diameter of 1/16 inch was used in the hardness test. To begin, a small force of 10kgf was used to generate a zero position in order to account for the effects of surface quality. The hardness value was determined from the dial indicator's final condition after a substantial stress of 60kgf was applied with a dwell time of 10 seconds before being released. The Rockwell Hardness test results for Al+Fe and Al+Fe+Bronze composite are given below in table 1 and table 2. A graph for the hardness of Al+Fe and Al+Fe+Bronze is given below see in figure 6 and the Rockwell hardness testing machine shows in figure 4 below

Fig. 4: Shows the Rockwell hardness testing machine

B. Charpy Impact test

The charpy test is the industry standard for evaluating impact energy. This gives information on the material's characteristics during fracture. A pendulum-like arm is swung down to make contact with the test material. The amount of energy required to fracture the sample is recorded. The Charpy device consists of the specimen, anvils on which the specimen is freely supported, and a pendulum with affixed mass attached to a spinning arm pinned to the instrument body. The pendulum descends in a circular route, striking the test specimen at the span's centre, conveying kinetic energy to it, and the amount of energy necessary to fracture the sample is recorded. The charpy impact testing equipment was utilized to investigate toughness (Figure). The hardness of the samples produced of Al+Fe and Al+Fe+Si was determined using the charpy test. Each composite was given three samples. The amount of energy absorbed in splitting the specimen is measured in joules, indicating the notch toughness of the test material. At room temperature, three Al+Fe and three Al+Fe+Bronze specimens are measured; the result are presented in table 1and 2 and the behaviour of hardness and toughness is displayed in figure 7 and the charpy impact testing machine shows in figure 5 below.

Fig. 5: Show the Charpy imapact testing Machine

IV. RESULT AND DISCUSSION

The material Al+Fe is combined by percentage by weight with a composite of 20%, 30%, and 40%, and the total weight of the sample is 14gm by weight. These composites were produced in three samples using sand casting procedures, and their hardness and toughness were evaluated on Rockwell hardness testing machines and charpy impact testing machines, respectively. . The composition and result shown in table 1 below

Three samples of Al+Fe composite were prepared using the sand casting method and tested on a Rockwell hardness testing machine for hardness and a Charpy impact testing machine for toughness, with the results shown in table 2 and the variation of hardness and toughness of samples with varying compositions of 20%, 30%, and 40%.

Material	Weight (gram)	Rockwell Hardness test	Charpyimpacttest
Al+Fe	2.8	B7	18
	4.2	B9	18.2
	5.6	B25	18.6

Table 1: Observation and composition of hardness and Toughness result in Al+Fe composite

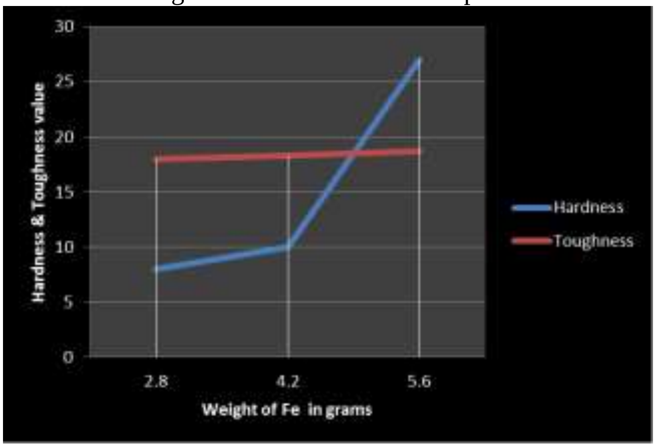

Fig. 6: Behaviour of Al+Fe metal matrix composite Hardness and Toughness with varying Fe composition

Figures 3 depict the mechanical behavior (hardness and toughness) of AMC (Al+Fe) with various proportions of iron, with a 20 percent HRB value of 18, a 30% HRB value of 18.2, and a 40% HRB value of 18.6. Figures 1 and 2 also demonstrate that as the amount of iron in the matrix grew, so did the hardness and toughness. The changing percentage composition is represented on the X-axis, while the hardness and toughness values are represented on the Y-axis.

The Al+Fe+Bronze hybrid composite was produced using the same sanding technique as the Al=Fe composite, but with various Bronze compositions in the sample at 20%, 30%, and 40% by weight in the Al+Fe composite. The overall weight of the hybrid composite was 14 grams. Table 2 and figures 4 illustrate the composition and outcome. Figure 5 also provides a comparison of the mechanical characteristics of Al+Fe and Al+Fe+Bronze composites, focusing on hardness and toughness.

Material	Weight (gram)	Rockwell Hardness Test	CharpyImpacttest
Al+Fe+Bronze	2.8	B34	19
	4.2	B79	18.6
	5.6	B80	18

Table 3: Observation for Hardness and Toughness result in Al-Fe-Bronze hybrid composite with varying Br composition

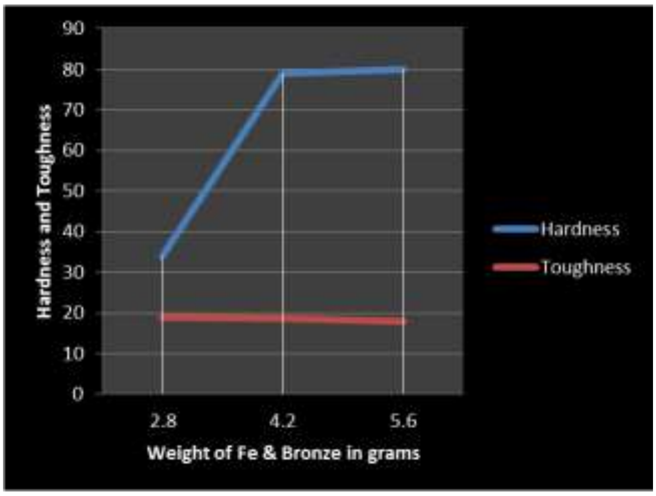

Fig. 7: Behaviour of Al+Fe+Bronze metal matrix composite Hardness and Toughness with varying Fe composition

The mechanical behaviour (hardness and toughness) of the AMC (Al+Fe+Bronze) with different proportions of Fe and Bronze is shown in Figures 4. Figure 4 shows that when the amount of Fe and Bronze in the matrix rises, the hardness of the matrix increases from 20% to 40% and demonstrates that when the ratio of iron and bronze increases, toughness falls until the composition reaches 40%.

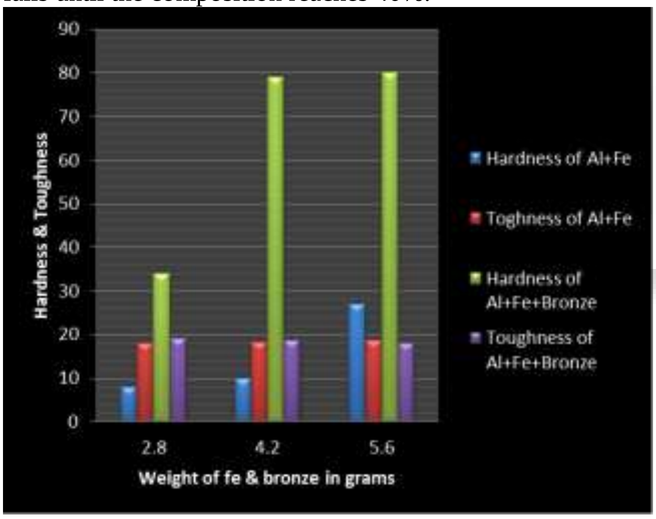

Fig. 8: Comparison of hardness and toughness of samples

V. Conclusion

This paper delves at the mechanical properties of two types of composites: Aluminum with Iron and Aluminum with Iron and Silicon Carbides. Adding reinforcing particles to aluminum powder can alter its properties, and changing the amount of additive can improve or worsen these properties. The type of casting used in the creation of either sand or metal casts was also identified in this study to have an impact on these characteristics. In this study on Aluminium, Bronze& Iron composites, the effect of adding Bronze and iron on the hardness and toughness of the composites was studied. The hardness of sand cast samples was determined using the Rockwell hardness test, and the impact strength was determined using the Charpy impact test. The following Conclusion has been made from the research:

- In an open environment, sand casting may be utilized to create Fe/Bronze/Al composites using a fabrication scheme derived from the literature study and detailed in the experimental.
- To address the issue of miss fitting, the particle size of reinforcement should be finer. The problem of centrifugal force, which promotes segregation in the melt and creates non-uniform features, can be mitigated by using small particle sizes.
- The Rockwell hardness of Al-Fe increases when the proportion of Fe in the sample increases from 20% to 30%, and then again as the percentages of additive increase from 20% to 40%.
- As the percentage of Bronze in Al-Bronze-Fe increases from 20% to 30%, the hardness decreases, and as the percentage of Bronze in Al-Bronze-Fe increases from 30% to 40%, the hardness increases.

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