RESEARCH ARTICLE OPEN ACCESS

Mechanical Behaviour ofAl2014 Reinforced with Boron Carbide and Short Basalt Fiber Based Hybrid Composites

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ABSTRACT

The present study was aimed at evaluating the effect of short Basalt Fiber and B_4Con hardness and impact strength of Al 2014 Composites. These AMCs with individual and multiple reinforcement (hybrid MMCs) are finding increased applications in aerospace, automobile, space, underwater and transportation applications. An effort is made to enhance the Hardness and Impact properties of AMCs by reinforcing Al2014 matrix with Varying Proportion of Short basalt fiber and Boron carbide by stir casting method. Aluminum alloy matrix varying proportions of boron carbide particulates and Short Basalt fibers were fabricated. The microstructure, hardness and impact strength properties of the fabricated AMCs were analyzed. The optical microstructure study revealed the homogeneous dispersion of B_4C particles and Short Basalt fiber in the matrix. Based on the results obtained from the Hardness and Impact of the metal matrix composites it is observed that, the hardness and impact strength increases with increase in the amount of reinforcement's.

Keywords: Al2014, boron carbide, basalt fiber, Impact strength, Micro Structure, Hardness.

I. INTRODUCTION

Composites are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties that remain separate and distinct within the finished structure. Aluminum matrix composites (AMCs) are the competent material in the industrial world. Due to its excellent mechanical properties, it is widely used in aerospace, automobiles, marine etc [1].

The aluminum matrix is getting strengthened when it is reinforced with the hard ceramic particles like SiC, Al_2O_3andB_4C etc. Aluminum alloys are still the subjects of intense studies, as their low density gives additional advantages in several applications. These alloys have started to replace cast iron and bronze to manufacture wear resistance parts. MMCs reinforced with particles tend to offer enhancement of properties processed by conventional routes. The Al2014 Reinforced with 0%, 2%, 4%, 6% & 8% of each short basalt fiber and B_4C was produced through stir casting method.

A limited research work has been reported on AMCs reinforced with B_4C and Basalt fiber due to higher raw material cost and poor wetting. B_4C and Basalt fiber is a robust material having excellent chemical and thermal stability, high hardness and low density and it is used for manufacturing bullet proof vests, armor tank etc. Hence, B_4C reinforced aluminum matrix composite has gained more attraction with low cost casting route [2]. B_4C and Basalt fiber is lower in density and has higher hardness than SiC and Al_2O_3, thus a better reinforcement type for high performance MMCs (Zhang, 2004).[3] The volume fraction of reinforcement in the microstructure as low as 5% and as high as 20% plays a Major role in the powder consolidated Al- B_4C MMCs. The density of the every sample reduces in a small variation with respect to the increment percentage of reinforcement due to the low density value of reinforcement. The hardness values were gradually increasing according to the percentage of increment in the reinforcement. The hardness value is very high for the 20% reinforced B_4C sample [4].

Discontinuous fiber reinforced composite forms an important category of materials used in engineering applications. The metal-matrix composites offer a spectrum of advantages that are important for their selection and use as structural materials. A few such advantages include the combination of high strength, high elastic modulus, high toughness and impact resistance, low sensitivity—to changes in temperature or thermal shock, high surface durability, low sensitivity to surface flaws, high electrical and thermal conductivity, minimum exposure to the potential problem of moisture absorption resulting in environmental degradation, and improved fabric ability with conventional metal working equipment [5].

In the literature, the effect of fiber length and fiber orientation on mechanical properties of discontinuous fiber composites has mainly been investigated for short fiber composites (characterized by an average fiber length less than 1 mm) [6-8]

II. FABRICATION OF COMPOSITES

The simplest and the most cost effective method of liquid state fabrication is stir casting [9]. In this work stir casting technique is employed to fabricate, which is a liquid state method of composite materials fabrication, in which a dispersed phase (reinforcement particulates) is mixed with a molten metal by means of stirring. The fabrication of Al2014, B_4C and Basalt fiber composites were carried out by stir casting process. The line diagram of the experimental set up used for making of these composites was shown in figure-1. Boron carbide particles and short basalt fiber were preheated at around 800^0C for 1 hrs to make their surfaces oxidized. Al-2014 alloy ingots were taken into a graphite crucible and melted in an electrical furnace. Varying proportion of boron carbide and Short Basalt fiber (0%, 2%, 4%, 6%, and 8%)

Were added and mixed with mechanical stirring at 300rpm for 5 min. The final temperature was controlled to be around 750 ^{0}C. After through stirring the melt was poured into cast steel moulds of 20mm diameter dies and allowed to cool to obtain cast rods. The Specimen were prepared from these cast rods as per ASTM Standards.

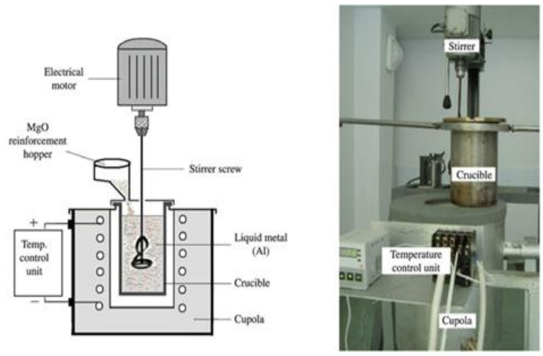

Figure 1. Melt stirring test apparatus (For the production of composite specimens).

Figure1: Stir casting process

III. EXPERIMENTAL PROCEDURE:

3.1 Brinell Hardness Test:

Brinell hardness test measure the resistance to permanent indentation on the layer of surface of the specimen. According to ASTM E10. In the process of hardness determination when the metal is indented by a indentor made from carbide, The indenter is pressed into the sample by an accurately controlled test force. Then the force is maintained for a specific dwell time, normally 15 seconds. After the dwell time is complete, the indenter is removed leaving a round indent in the sample. The size of the indent is determined optically by measuring two diagonals of the round indent using either a portable microscope or one that is integrated with the load application device. The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness.

$$\text{BHN}= \frac{2F}{\pi D(D-\sqrt{(D^2-d^2})}$$

Where,
F= Applied load in N
D= diameter of steel ball indenter.
d= diameter of impression left by the steel ball Indenter

3.2 Impact Test:

Impact testing involves the sudden and dynamic application of the load on the materials. This test measures the amount of energy absorbed by a material during fracture in joules. Charpy impact test is carried out in this work. The specimen is prepared as per ASTM E23 standard.

The impact test is carried out on a pendulum type testing machine (Charpy) which consisted of a moving mass is carried out on a pendulum type testing machine which consists of a moving mass whose kinetic energy is great enough to cause rupture of the test specimen. It also has a means for measuring the fracture energy of the specimen after it has been broken. [8] Angle of rise K can be calculating using formula.

$U = W\ L\ p\ (\cos\beta - \cos\alpha)$.
Where,
U = fracture energy (N-m)
W = weight of pendulum *9.81(N)
Lp= length of pendulum (m).
The impact strength ‘K” can be calculated
$K=U/A\ L_s$ N-m/mm^3
Where,
A= cross sectional area of the Specimen at the notch
(mm2)
K= impact strength N-m/mm3
L_s= length of specimen (m)

IV. RESULTS & DISCUSSIONS

4.1 Hardness Result:

The hardness test results of the unreinforced matrix alloy and Short Basalt fiber, boron carbide reinforced Al 2014 based hybrid composites are shown in the Fig.2. The surface hardness of hybrid composites increases with increase in the proportions of reinforcement's .At a maximum proportion of 8% boron carbide and basalt fiber shows maximum hardness of 104BHN. The increase in hardness is probably attributed to the fact that the hard basalt fiber and boron carbide act as barriers to the movement of the dislocations within the matrix Al2014 and exhibits greater resistance to indentation of the hardness tester. The specimen having highest BHN exhibits better hardness. This test method was based on penetration of specified indenter forced into the material under specified Conditions.

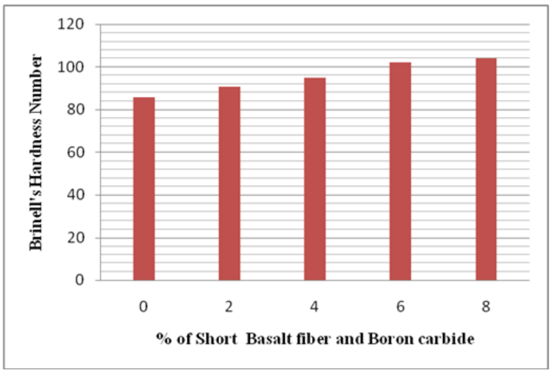

Figure 2: Brinell's hardness v/s percentages of boron carbide and basalt fiber

4.2 Impact Test Results:

Impact Energy:

The impact test results of the unreinforced matrix alloy and Short Basalt fiber, boron carbide reinforced Al2014 based hybrid composites are shown in the Fig.3. The impact energy of hybrid composites increases with increase in the proportions of reinforcement's .At a maximum proportion of 8% boron carbide and basalt fiber shows maximum impact energy of 14 joule. Due to proper bonding between the matrix and reinforcement materials. This test method was based on shock load under specified condition.

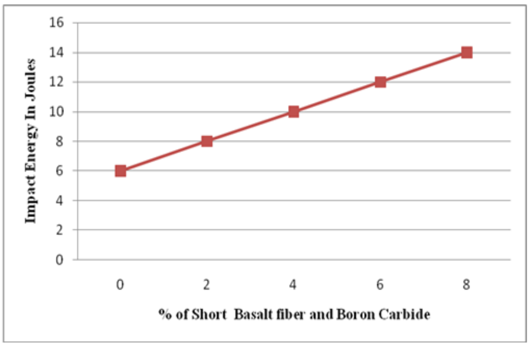

Figure 3 impact energy v/s % of short basalt fiber and boron carbide

Impact Strength:

The impact strength of the unreinforced matrix alloy and Short Basalt fiber , boron carbide reinforced Al2014 based hybrid composites are shown in the Fig.4. The impact strength of hybrid composites increases with increase in the proportions of reinforcement's .At a maximum proportion of 8% boron carbide and basalt fiber shows maximum impact strength of $3.182*10^{-3}$ J/mm^3. This may be due to inter phase bonding in the region of the reinforcement side wall promotes void nucleation and growth in the matrix between the side wall of the reinforcement because shear lag transfer of load will be indered by inter phase bonding.

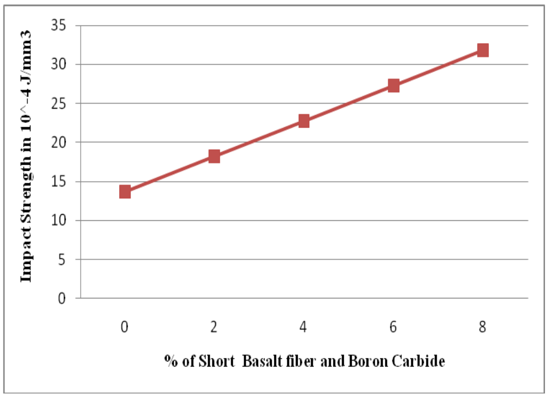

Figure 4 Impact strength v/s % of boron carbide and basalt fiber

The angle of rise of the arm shows steady decline with the increase in the percentages of boron carbide and short basalt fiber. as shown in fig.5. This means absorb energy(Toughness) by the hybrid composites increases with increasing the percentage of reinforcement's. Due to the inter phase bonding in the region of the reinforcement side wall promotes void nucleation and growth in the matrixAl2014.The Maximum angle of rise is for unreinforced matrix alloy Al2014 is $141.41^0$and least for 8% reinforcement it is 137.02^0

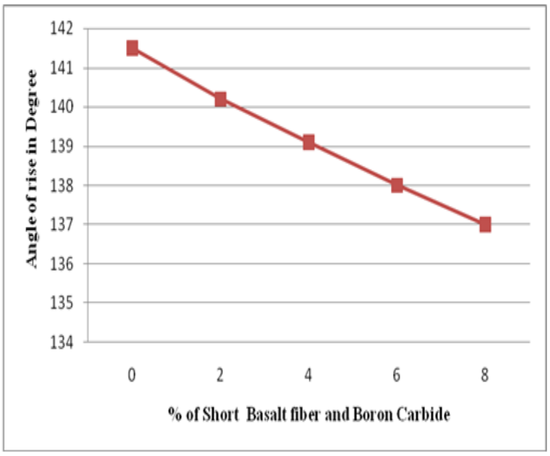

Figure 5 Angle of rise v/s percentage of boron carbide and basalt fiber

V. CONCLUSIONS

Based on the analysis of experimental results and findings, the following conclusions can be drawn. This work shows that successful fabrication of a multi component hybrid Metal matrix composite (using Al2014 as matrix, Boron carbide and Short basalt fiber as reinforcement) was possible by Stir Casting Method. The optical micro structural study revealed the homogeneous dispersion of B_4C particles and Short Basalt fiber in the matrix. Incorporation of this Reinforcement's modifies the hardness and impact strength properties of the composites. A steady increase in the percentage of Reinforcement Short Basalt fiber and boron carbide in the filled Al2014 shows marked improvement in the impact strength, hardness properties.

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