Effect of Heat treatment on Fatigue Behavior of B₄C and Copper Coated short Basalt fiber Reinforced Al 2014 Based Hybrid Composite

Ranganatha S R, Shantharaja M, Manjunatha M V

Abstract- Boron carbide (B₄C) particulate and Copper coated Basalt fiber reinforced Al2014 composites were fabricated by stir casting technique. Boron carbide particles and short copper coated basalt fiber were varied from 2 wt. % to 8 wt. % in steps of 2 %. To improve the interfacial bonding between basalt fiber and matrix Al2014 alloy, the fibers are coated with copper by electroless deposition method. The Scanning Electron Microscope (SEM) clearly shows the uniform coating of copper on the surface of fiber and also observed that, increased wt % of reinforcement in ascas composites results in momentous progress in fatigue strength. The addition of boron carbide shows better fatigue strength compared to the addition of copper coated basalt fiber in Al2014. The Heat treated hybrid composites for all weight % of reinforcement’s shows 1.2 to 2 % better fatigue life as compared to ascas composites. This may be due to the refinement of grains and development of strong intermolecular bonding between the particles of composites. The fracture analysis done by SEM, clearly revealed that the crack initiated from the region of voids or porosity in the matrix and not in the region of boron carbide and copper coated basalt fiber interface.

Keywords : Al2014, HAMCs, Boron carbide, Basalt fiber, electroless, Coatings, Stir casting, fatigue life and fatigue strength.

I. INTRODUCTION

Aluminium Metal Matrix composites (AMC) are promising light weight materials with better mechanical properties, light weight, low cost and high strength which are used in various industries [1]. It can be used in automobile and aircraft structural applications by reinforcing with carbide and ceramic particles which will reduce the weight, cost and thereby increasing the efficiency of the engine by reducing the fuel consumption [2]. Several investigations revealed that the fiber reinforced composites are more proficient than other types of composites at present. The typical ceramic fibers are reinforced with metal matrix have wide applications in structural components of aircraft, automobile and marine industries [3-5]. This research is to contribute the development of Aluminium Matrix Hybrid Composites (AMHCs) with high strength at low cost. Ceramic particles coated with alloys are used as a reinforcing particle in Metal matrix composites exhibits superior mechanical and tribological properties when compared with uncoated particles [6-7]. Many researchers reported that, the fatigue behavior of metal matrix composites mainly depends on the nature of interface bonding between matrix and reinforcement, reinforcement shape, size, volume fraction and processing technique etc [8]. The fatigue strength of Ni-P coated Si₃N₄ reinforced Al6061 composites for both as cast and hot forged conditions has significant improvement with increase in the content of reinforcements [9].

II. MATERIALS USED

2.1 Matrix Materials: Al2014 is used as the matrix material. The main alloying element is Copper and it is the 2nd most accepted materials in 2000 series of the aluminium alloys, next to 2024 Al alloy. This alloy also used in aircraft and automobile industry for structural components. The machinability and Hardness properties of this alloy are better compared to other aluminium alloy.

2.2 Reinforcement Materials

2.2.1 Boron carbide (B₄C) is used as one of the reinforcement materials with particulate size of 50 to 60 Microns. Boron carbide has good mechanical properties and low specific gravity.

2.2.2 Basalt fiber with main compositions of SiO₂ and Al₂O₃ is selected as second reinforcement material. The short Basalt fiber of 60 microns diameter and length of 2-3 mm were used in this composite. These have better strength and high tensile modulus compared to natural and synthetic fibers.

III. EXPERIMENTAL WORK

3.1 Electroless deposition of copper on short Basalt fiber- The electroless technique is used to deposit the copper on the surface of short basalt fiber. The electrolysis technique has sequences of operation like 1) Preheating 2) SENSITIZATION 3) Activation 4) Metallization along with cleaning and drying [10].

3.2 Fabrication of hybrid composites: The hybrid metal matrix composite used in this investigation is fabricated by stir casting method. The Al 2014 alloy was heated in a muffle furnace up to 800°C. The measured quantity of preheated boron carbide and coated short basalt fiber were added at a rate of 10-30 g/min into the melt and mixed with the help of a stirrer rotating with speed in the range of 350-450 rpm for about 8 to 10 minutes for uniform mixing of reinforcement in the vortex formed. The Molten composite is poured into the preheated metallic mold and is allowed to solidify at room temperature.
The 16 compositions of composites were casted by varying reinforcements from 2 wt. % to 8 wt. % in steps of 2 % and designated by A2BC2BF (2% Born carbide, 2% Basalt fiber in Al2014 matrix) to A8BC8BF (8% Born carbide, 8% Basalt fiber in Al2014 matrix).

3.3 Heat treatment

One set of cast specimens were heat treated using muffle furnace of maximum temperature range up to 1400°C for T6 conditions. The heat treatment (T6) cycle is shown in the Figure 3.2.

- Solution heat treatment for 4 hrs at a temperature of 540°C.
- Air cooled at room temperature.
- Aged for duration of 2 hours at 175°C.

![Figure 3.2: Heat treatment process](image)

3.4 Fatigue Test:

Fatigue tests were conducted using rotating-bending type low-cycle fatigue testing machine (R-R Moore test) according to ASTM E606 at atmospheric temperature. The tests were conducted at constant cyclic frequency 50 Hz (1440 rev/min), stress ratio(R) -1 and surface irregularities of the specimen reduced after machining and maintained 0.5 to 1μm on the gauge section of the test specimens by using finer grades of emery paper. The fatigue life (Nf) is the number of cycle for failure or fracture of the specimen. The maximum stresses applied during the tests was varied in the range of 110-230MPa. Averages of three test results were considered as fatigue life (Nf) of each sample.

![Figure 3.3.1: Dimensions of specimen according to ASTM E606.](image)

IV. RESULTS AND DISCUSSION:

Figure 4.1 (a) and (b) shows the uncoated basalt fibers surface characteristics and Figure 4.1 (c) and (d) shows copper coated on the surface of basalt fiber under metallization conditions, it can be clearly observed that there is uniform coating and morphology of the copper on basalt fiber.

![Figure 4.1: SEM images of fibers: (a) & (b) uncoated basalt fiber (c) & (d) copper coated basalt fiber at 45°C, pH 13 and 3 min.](image)

4.2 Fatigue strength:

![Figure 4.2: Stress-Number (S-N) of cycle diagram for 2% boron carbide with varying weight percentage basalt fiber in Al2014 at ascast condition.](image)

![Figure 4.3: Stress-Number (S-N) of cycle diagram for 4% boron carbide with varying weight percentage basalt fiber in Al2014 at ascast condition](image)

![Figure 4.4: Stress-Number (S-N) of cycle diagram for 6% boron carbide with varying weight percentage basalt fiber in Al2014 at ascast condition](image)
4.2.1 Effect of Boron carbide and short copper Basalt fiber on fatigue life:

Fatigue behavior of boron carbide/basalt fiber reinforced Al2014 based hybrid composites experimentally evaluated. It is observed from the figure 4.2 to figure 4.5 the number fatigue life cycle increases with increasing the Weight % of reinforcements and noted that, the highest fatigue life cycle of 1,39,032 obtained at maximum weight percentage of 8% copper coated Basalt fiber and 8% Boron carbide similar result was observed in other investigators this is might be due to strong intermolecular bonding between matrix and reinforcements and also observed from result that, the effect of boron carbide shows better fatigue behavior as compared to the effect of copper coated Basalt fiber.

4.2.2 Effect of heat treatment on fatigue life

Figures 4.5 to 4.8 show the effect of boron carbide and basalt fibers on the fatigue life of the heat treated hybrid composites for different loads with corresponding stresses of 118, 171, and 226 MPa. The fatigue life of the composites increases with the increase in wt % reinforcement content. As Percentage of Boron carbide increases from 2 to 8% with minimum 2% of basalt fibers composites there is an increase in fatigue life by 20.8 % at stress of 118 MPa, 22% at 171 MPa and 23.3% at 226 MPa and as the percentage of basalt fiber increases from 2 to 8% with minimum 2% Boron carbide there is increase in fatigue life by 8.4 % at stress of 118 MPa, 8.95% at 171 MPa and 8.56% at 226 MPa. The Short basalt fibers have less significant effect on fatigue life compared to Boron carbide particulates. It is observed that 8% Boron carbide and 8 % Basalt fibers reinforced composites shows better fatigue behavior. Heat treated hybrid composites for all weight % of reinforcement’s shows 1.2 to 2 % better fatigue life as compared to ascast composites. This may be due to the refinement of grains and development of strong intermolecular bonding between the particles of composites.

4.2.3 Fractured surface analysis:

Figure.4.6 (a-b) shows the fractured surfaces of ascast composites subjected to fatigue.
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V. CONCLUSION:

The following conclusions can be drawn from the Experimental investigation of fatigue behavior of Al2014 reinforced with boron carbide and copper coated short basalt fiber based hybrid composites.

- This work shows the uniform deposition of copper on surface of short basalt fibers by electroless deposition technique and this was observed using Scanning electron microscope and it has been clearly revealed the uniform deposition of copper on the surface of fiber.
- With the increases in the weight percentage of boron carbide (B,C) and copper coated short basalt fiber in Al2014 there is an increase in fatigue life. The effect of boron carbide shows good improvements in fatigue life as compared to addition of copper coated basalt fiber in the composites.
- Heat treated hybrid composites for all weight % of reinforcement’s shows 1.2 to 2 % better fatigue life as compared to ascast composites.
- Fracture analysis by using SEM it is clearly revealed that the cracks initiated from voids/porosity matrix material might be due to stress concentration and not in the region of boron carbide particle and copper coated basalt fiber interface with matrix.

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