FORMATION AND EVALUATION OF TENSILE STRENGTH AND HARDNESS PROPERTIES OF AL2024 ALLOY REINFORCED WITH BORON CARBIDE PARTICULATES.

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Abstract: In the research paper, formation of Al-Cu alloy based MMCs reinforced with boron carbide particulates with different mesh size through stir casting technique was done. Aluminum 2024 alloy was reinforced with 1 wt%, 3 wt% and 5 wt% of B_4C particulates having 100, 200 and 300 mesh size. Machining was done as per ASTM standards for the formed metal matrix composites. Artificial Age hardening was done for the test specimens by 1 hr, 3 hrs and 5 hrs. Further, evaluation was done to determine the tensile strength and hardness properties of heat treated metal matrix composites. The test results were compared with the as cast test specimens and exhibits better properties when reinforced with boron carbide particulates.

Keywords: Al2024 Alloy, Artificial Age hardening, Mesh size, MMCs.

1. INTRODUCTION

Manufacturing of a component is normally influenced by the mechanical properties of the work material. The knowledge of mechanical properties of engineering materials is important to a manufacturing engineer [11]. Casting mainly involves pouring molten metal into a refractory mould with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the refractory mould either by breaking the mould or taking the mould a part [11].

The aluminum metal matrix composites are created by the combination of two or more materials usually composed of reinforcing material and a compatible binder (matrix), to obtain specific characteristics and properties [12]. Boron carbide is the third hardest substance known, after diamond and cubic boron nitride. Boron carbide is known as a robust material having high hardness, good shielding properties against neutrons, stability to ionizing radiation [13].

It is reported that hardness of composite material LM25 B_4C is Increases when compared to pure aluminium LM25. It is reported that density of Composite material LM25 B_4C decreases when compared to pure aluminium LM25 [1]. The tensile strength improves with increase in weight (%) of the reinforcement of B_4C. It has been exposed that hardness of composite material decreased when weight (%) of B_4C added, stirring speed and stirring time is increased. It is reported that the distribution of ceramic particles inside the matrix of aluminium is uniform over the matrix however the distribution of aluminium particles is more even. The average size of the aluminium particles visualized is 100 μm [2]. It is reported that tensile strength with varying B_4C content are found to be 131.4, 137.5, 139.4 MPa for 4, 6 and 8 wt. % of reinforcement and hence tensile strength increases with increasing amount of B_4C. It is evaluated that there was uniform distribution of the

HBN in Al6061 matrix [3]. It is found that with the increase in % of reinforcement (boron carbide) the tensile strength of the composite increased from 170 MPa for pure alloy to 259 MPa for 15% reinforced composite. The % of compression varies from 28.75% for pure LM6-Al alloy to 15% for 15% reinforced LM6-Al-B_4C composite. It is reported that the density of the composite decrease from 2.65gm/cc for pure LM6Al-alloy to 2.6305 gm /cc for LM6 Al-B_4C 15% composite[4]. The investigation shows the increase in weight percentage of Boron Carbide (B_4C) with Aluminium (LM25) tensile strength is increased gradually. It is determined that the wear resistance increases with increase in content of reinforcement. It is determined that hardness increases with the addition of B_4C particles in the as-cast condition. For Aluminium (LM25) hardness can be increased with increase in content of reinforcement B_4C. The microstructure study of Aluminium reinforced with Boron Carbide & Tungsten Carbide was discussed. It was concluded that the use of Hybrid aluminium metal matrix composites instead of monolithic or metal matrix composites results in reduction of weight [5].

The maximum tensile strength (189 MPa) is obtained for 9wt.% B_4C and 3wt.% CSFA composite that increased by 66% compared with the unreinforced aluminium7075. The ductility of the composites decreases with increasing the weight percentage of reinforcement particles. Hardness of composites increases with increasing reinforcement content in the matrix. The maximum hardness (169.5 BHN) of composites is observed for the 12wt.% B_4C and 3wt.% CSFA composite[6]. It is reported that ultimate tensile strength and fracture strength was increased by 20.81 % and 18.17 % for the reinforcement of 20 wt% Silicon Carbide to Al 6061 matrix [7]. It has been reported that the tensile strength of Aluminum alloy (LM25) is marginally higher than hybrid composite specimen because of its aluminum content. It is reported that the brinell hardness for LM25- Aluminum alloy reinforced with Alumina -1% Boron carbide - 4% shows higher value (63.73 BHN) [8]. It was reported that the highest value we get with hybrid composition.

Weight percent of both the reinforcement were 5%.The highest value occurred with 5% of RHA and 5% of ceramic B4C.Obtained value is 115 HV [9]. It was investigated that Ultimate tensile strength were found increasing with increase reinforcement boron carbide in aluminium Metal Matrix Composites. It was investigated that Hardness was found increasing with increase with reinforcement boron carbide in aluminium Metal Matrix Composites[10].

2. MATERIALS AND COMPOSITE FORMATION

Figure 2.1 Ingot of Al2024 alloy

Figure 2.1 Shows the Al2024 alloy was chosen has matrix material. The mass of single ingot specimen approximately 0.615 kg. The following table 2.1 shows the chemical composition of Al2024 alloy.

Table 2.1 Chemical Composition of Al2024 alloy

Elements	Weightage (%)
Silicon	0.16
Iron	0.42
Copper	4.48
Magnesium	0.81
Vanadium	Traces
Zinc	0.15
Aluminium	92.82

Figure 2.2 (a) 100 B_4C (b) 200 B_4C (c) 300 B_4C

Figure 2.2 (a), (b) and (c) shows the different boron carbide Particulates chosen as reinforcement material having 100, 200 and 300 mesh size respectively.

Figure 2.3: Pouring of metal matrix composite.

The figure 2.3 shows the pouring of metal matrix composite. The calculated amount of matrix and preheated reinforcement materials are melted in an electric pit furnace to a temperature of 700 ºC. The degassing tablet was added during melting to release all the absorbed gases from the molten metal to prevent blow holes, porosity etc. The crucible is taken out from the furnace by using ladle and poured on to the pre-heated die manually. The molten metal flows inside the die cavity and fills the die completely then allowed to cool for 20 min. The clamps are removed manually by using chisel and hammer the split die is separated. The cast components are removed from the die cavity by using dot punch and hammer.

Figure 2.4: MMCs after casting.

The figure 2.4 shows the Al-Cu based metal matrix composite after removing from the split die cavity. The cast components have dimension 25 mm diameter and 220 mm in length, which are cut and machined to ASTM standard size by machine tool to evaluate the properties of MMCs.

3. TEST SPECIMENS AND HEAT TREATMENT

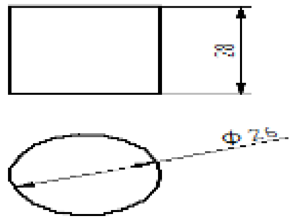
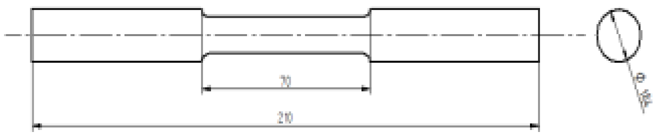


Figure 3.1 (a) Hardness Test Specimen



(b) Tensile Test Specimen.

Figure 3.1 (a) and (b) Shows the ASTM standard size of hardness and tensile test specimens. Hardness test specimens have 26 mm diameter and 28 mm length (IS: 1500). Tensile test specimen having overall length of 210 mm and gauge length of 70 mm. The end diameter of 18.4 mm and gauge diameter of 12.5 mm (E8-16A).

3.1 Artificial Ageing

Figure 3.2 (a) Heat Treatment. b) Water Quenching.

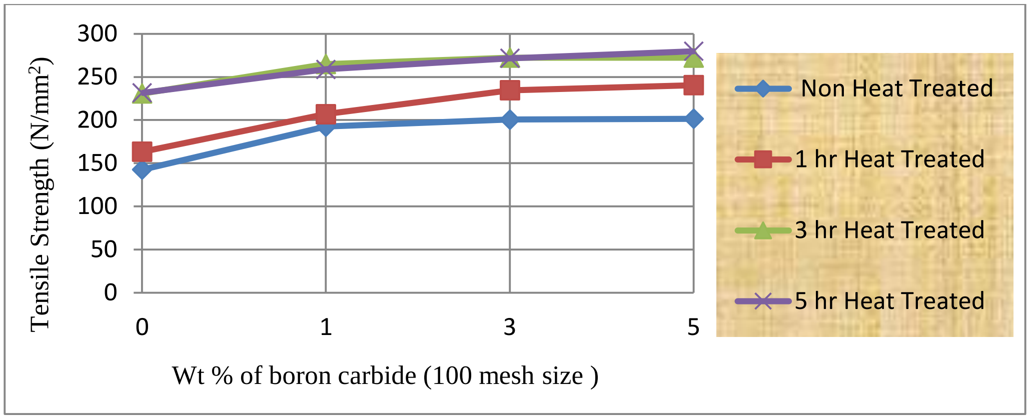
Figure 3.2 (a) and (b) Shows the artificial age hardening process and water quenched.. The machined specimens are heated to a temperature of 520 ºC to carryout solution treatment for 24 hr. The specimens are water quenched and then raised to a temperature of 175 ºC for 1 hr, 3 hr and 5 hr for the respective specimens for ageing of specimens.

Figure 3.3 (a) Hardness Test Specimen (b) Tensile Test Specimen.

Figure 3.3 (a) and (b) Shows the ASTM standard of hardness and tensile test specimens after artificial ageing process.

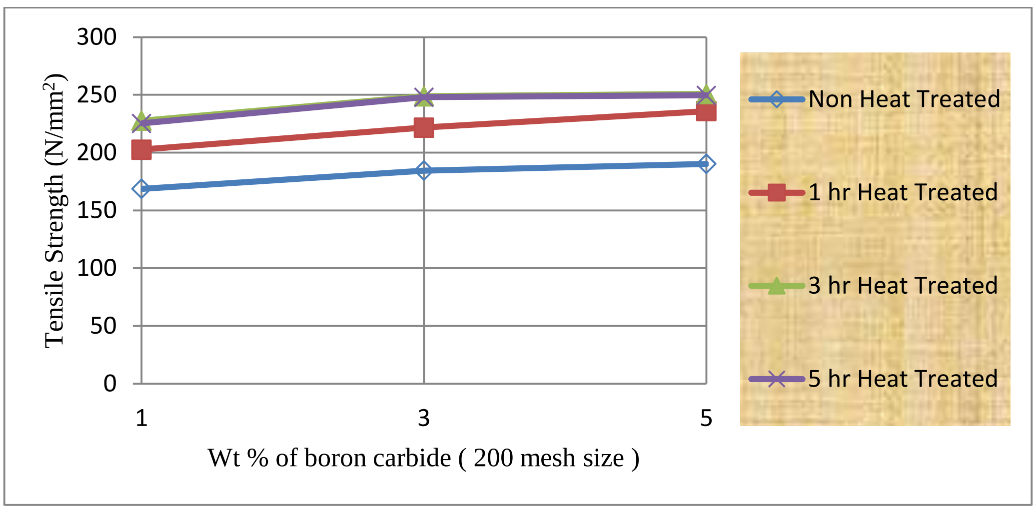
4. RESULTS AND DISCUSSION

4.1 TENSILE STRENGTH



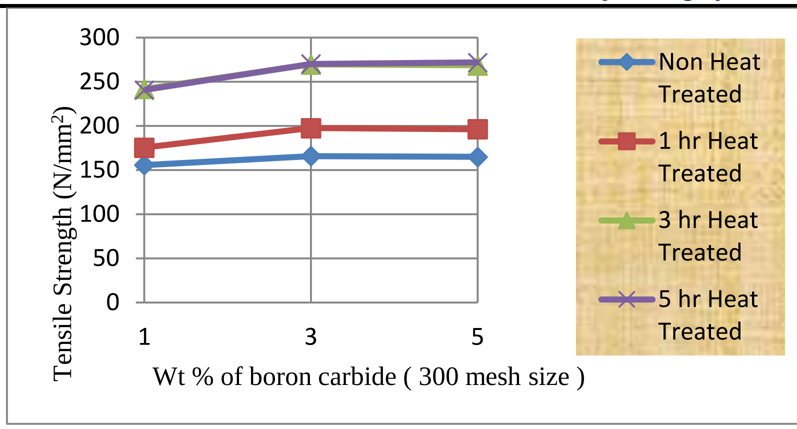
Graph 4.1 Variation of tensile strength due to increment of boron carbide particulate (100 mesh size).

The tensile strength of formed composites increases with increase in weight percentage of boron carbide particulates from 0 % to 3 %. From 3% to 5% tensile strength tends to attain a constant value. For as cast Al2024 alloy (0 % B_4C) tensile strength was found to be increased when subject to heat treatment duration. With increase in heat treatment duration from 1hr to 5hrs tensile strength value increased and it reveals that beyond 5hrs heat treatment tensile strength remains unchanged.



Graph 4.2 Variation of tensile strength due to increment of boron carbide particulate (200 mesh size).

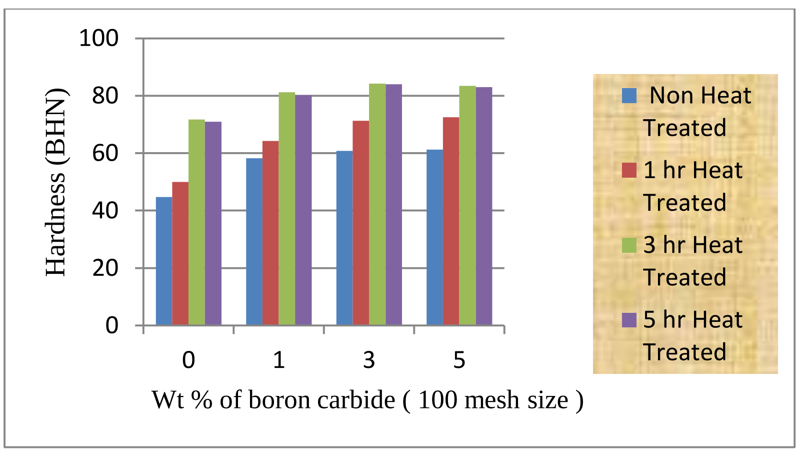
Formed composites exhibits increase in the tensile strength with increase in wt % of boron carbide particulates from 1 % to 5 %. For non-heat treated test specimens the tensile strength was found to be decreased as compared to heat treated test specimens. For 3hrs and 5hrs heat treated test specimens shows the tensile strength is almost converging to the same value.



Graph 4.3 Variation of tensile strength due to increment of boron carbide particulate (300 mesh size).

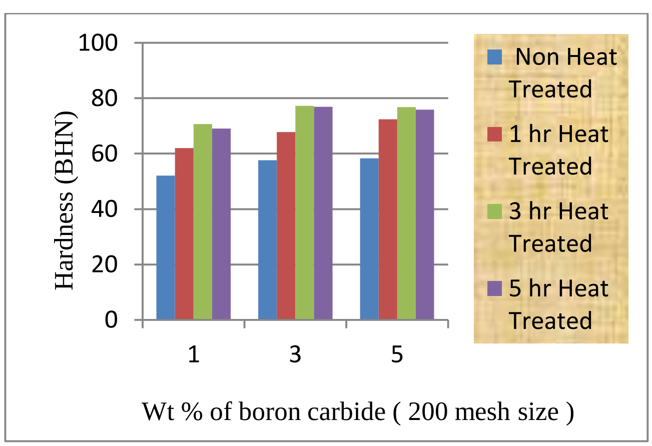
The tensile strength of formed composites increases with increase in weight percentage of boron carbide particulates from 1 % to 5 %. For 3hrs and 5hrs heat treated test specimens shows the tensile strength approximately same for the respective weight percentage of boron carbide particulates.

4.2 HARDNESS



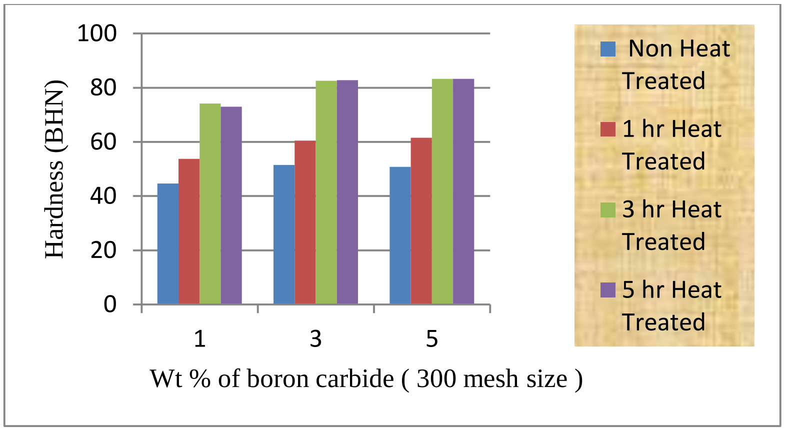
Graph 4.4 Variation of hardness due to increment of boron carbide particulate (100 mesh size).

For as cast Al2024 alloy (0 % B_4C) the hardness was found to be increased with increase in heat treatment duration.
Hardness for the formed composite materials was found to be increased with increase in weight percentage of boron carbide particulates.



Graph 4.5 Variation of hardness due to increment of boron carbide particulate (200 mesh size).

Increase in weight percentage of B_4C particulates in Al2024 alloy the hardness property increased and also increases when subject to the heat treatment duration.



Graph 4.6 Variation of hardness due to increment of boron carbide particulate (300 mesh size).

Hardness of the formed composites increased with increase in weight percentage of boron carbide particulates. For 3 hrs and 5 hrs heat treatment duration the hardness was found to be almost same.

5. CONCLUSION

The following conclusions have being drawn after carrying out the work on Al2024 alloy with varying wt % of boron carbide particulates and also varying artificial ageing heat treatment duration of metal matrix composite:

- The best method for formation of metal matrix composite is stir casting because proper mixing of reinforcement is possible in it. Due to proper mixing of reinforcement (B_4C) there is no loss of reinforcement and uniform distribution takes place.
- In this investigation, comparison study was done with heat treated and non-heat treated test specimens.
- The highest tensile strength and hardness occurred with 5 % of B_4C particles having 100 mesh size followed by 5 hrs heat treatment duration. Obtained value are 279.82 N / mm^2 an 84.97 BHN respectively.
- Tensile strength was found to be increased by 20.84 % compared with unreinforced Al2024 alloy.
- Tensile strength and hardness properties of formed composites increases when compared to Al2024 alloy alone.
- For the 100 mesh size of boron carbide particulates shows the better tensile strength and hardness value.
- Mesh size of reinforcement is lower (< 100 size) than better mechanical properties can be achieved.

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