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Influence of boron carbide, heat treatment on ductility and yield strength of Al2024 alloy.

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Abstract - The need of advance materials in aerospace industry is increasing day by day. Aluminium 2024 alloy posses light weigth and strong enough to fulfil the requriments of aeroscape industry. In this research article Al2024 alloy was choosen as matrix material and boron carbide was choosen as reinforcement material with different mesh size and also by varying wt.% of boron carbide particulates into the matrix materials. The stir casting technique was adopted to form the MMCs. The heat treatment was done for the machined test specimens in 2 stages that is solution treatment at 520ºC for 24 hours and continued with artificial aging process at 175ºC by holding time 1, 3 and 5 hours. From the research work, it was found that there was an increase in yield strength of the formed MMCs with the increasing of aging time and wt.% of boron carbide particles from 0 to 5 wt.%. Ductility of formed composite materials was found to be declined with increasing aging treatment and also when compared to aluminium 2024 alloy alone.

Index Terms - Al2024 alloy, artificial aging process, ductility, mesh size, MMCs, solution treatment, yield strength,.

1 INTRODUCTION

Al2024 alloy is often used in the aerospace industry. It is a high-strength alloy suitable for applications requiring a high strength-to-weight ratio and excellent fatigue resistance. Aluminum strength improvement can be done by heat treatment process in its fabrication process. One of heat treatment processes on aluminum and its alloys is artificial aging, especially in aluminum alloy with composition of Cu 2.5 – 5.0% [1]. 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 [6].

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 [7]. The low density, high strength, and high elastic modulus of boron carbide make it an attractive reinforcement. Boron Carbide (B4C) is one of the hardest materials known, ranking third behind diamond and cubic boron nitride [8]. It is reported that aging time could improve the hardness of aluminum alloy 2024 T3. The result of the micro photo showed the formed-particle was getting delicate with more aging time which caused the hardness of the material was increasing [1]. The yield strength increased with the increase in B4C content. The strength improvement of composites can be attributed to the good bonding between the matrix and reinforcement material. The percentage elongation decreased with increase in wt.% of B4C particulates in the Al2024 alloy matrix [2]. It is reported that microscopic examination shows the presence of reinforced particles in alloy and their uniform distribution of particles throughout the alloy [3]. It concluded that the Al2024 composites increases with increments in the B4C content up to 2.0 wt.%,reaching values of 110HV and 125 HV for samples milled for 1 and 2 h, respectively. It is reported that compressive strength of Al2024 increases with the addition of boron carbide reinforcement [4]. The observed microstructure consists of aluminium matrix with alloying element and these elements are distributed homogeneously. It is reported that MMCs corrosion behaviour may vary significantly due to the quality of their reinforcement and matrix alloy, the manufacturing technique, post thermo mechanical processing and other factors [5].

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

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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.

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 preheated 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

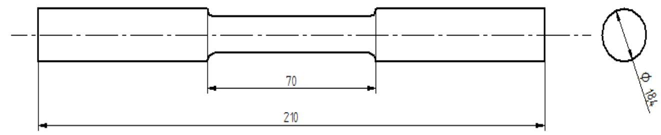


Fig 3.1 Tensile Test Specimen.

Figure 3.1Shows the ASTM standard size of tensile test specimens. 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 Heat treatment

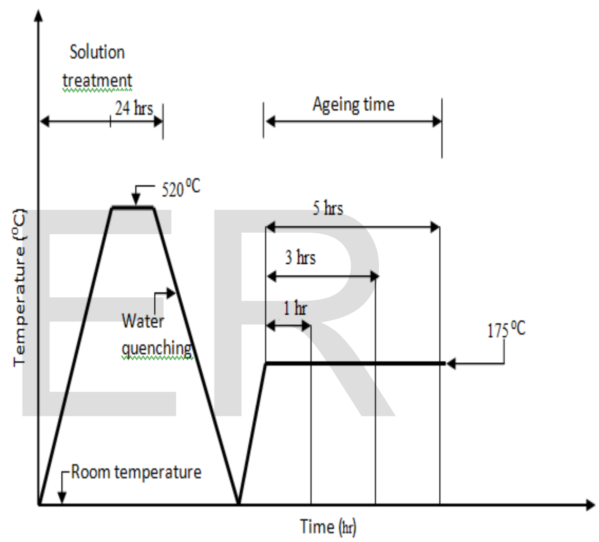


Figure 3.1 Schematic representations of solution treatment and ageing time on Al2024 alloy.

The machined test specimens are heat treated in 2 stages that is solution treatment at 520ºC for 24 hours and then water quenched to room temperature and further continued with artificial aging process at 175ºC by holding time for 1, 3 and 5 hours as shown in figure 3.1.

3.2 Artificial Ageing

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

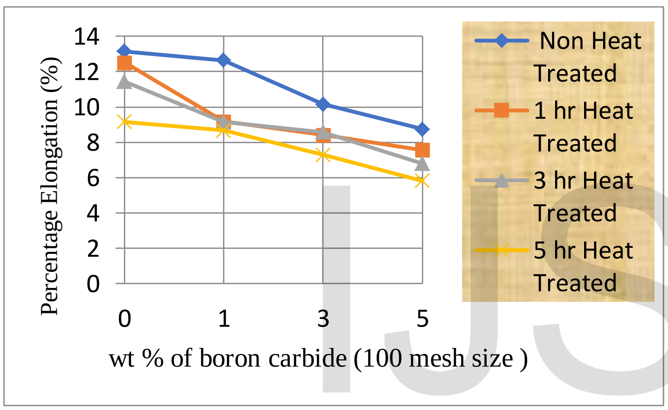
Figure 3.2 (a) and (b) Shows the artificial age hardening process and water quenched.. The machined specimens are heated to a temperature of 520 ºC to carryout solution treatment for 24 hr. The specimens are water quenched and then raised to a temperature of 175 ºC for 1 hr, 3 hr and 5 hr for the respective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

Figure 3.3 Tensile Test Specimen.

Figure 3.3 Shows the ASTM standard of tensile test specimens after artificial ageing process.

4. RESULTS AND DISCUSSION

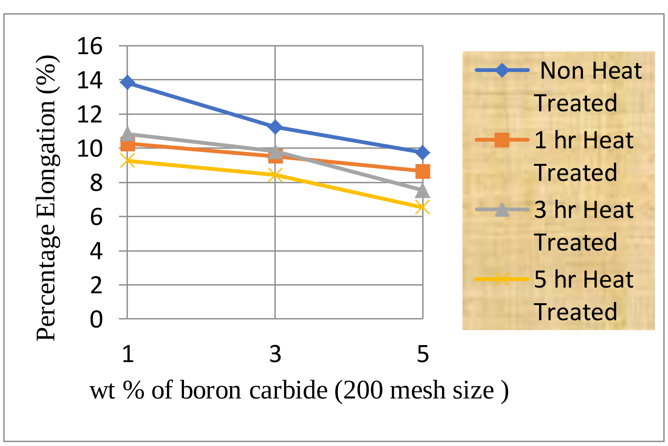
4.1 Percentage of Elongation



Graph 4.1 Effect of B4C and heat treatment duration on the percentage of elongation of the Al2024 alloy with B4C content having 100 mesh size.

Percentage of elongation of the composite material is decreased from 0 to 5 wt.% of boron carbide particulates in Al2024 alloy.

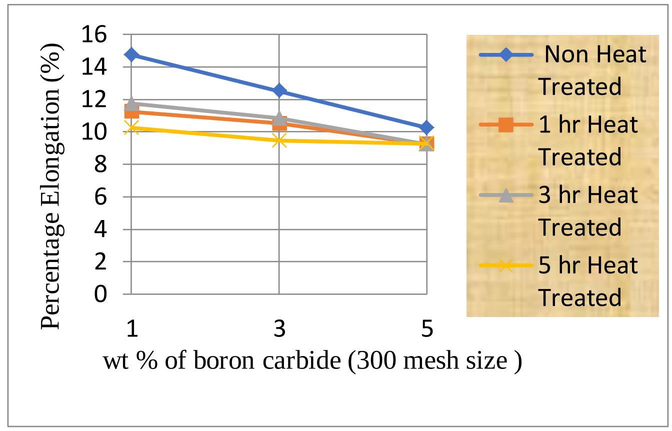
Heat treated test specimens shows the declined in percentage of elongation, when compare to non heat treated test specimens for the respective wt.% of boron carbide particles.



Graph 4.2 Effect of B4C and heat treatment duration on the percentage of elongation of the Al2024 alloy with B4C content having 200 mesh size.

Percentage of elongation of the composite material is decreased from 1 to 5 wt.% of boron carbide particulates in Al2024 alloy.

Heat treated test specimens shows the decrease in percentage of elongation of the formed composite materials as compared to non heat treated specimens.



Graph 4.3 Effect of B4C and heat treatment duration on the percentage of elongation of the Al2024 alloy with B4C content having 300 mesh size.

Increase in wt.% of boron carbide particle from 1 to 5 wt.% in Al2024 alloy, the percentage of elongation was found to be declined.

Percentage of elongation of the formed composite materials decreased with increase in heat treated duration. It was found that for 5 wt.% of born carbide particle in Al2024 alloy the percentage of elongation for heat treated test specimen was almost same.

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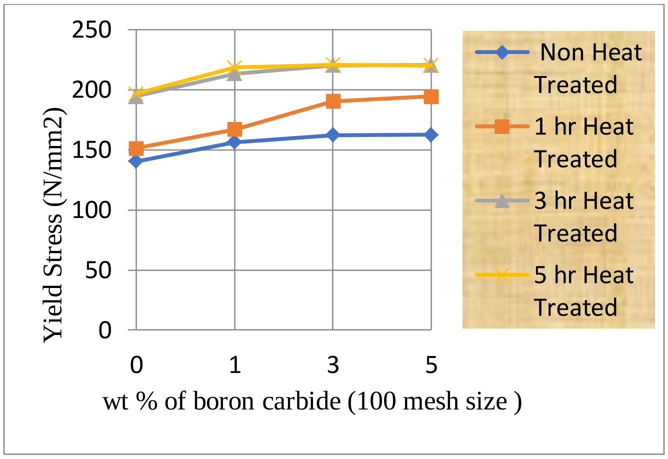
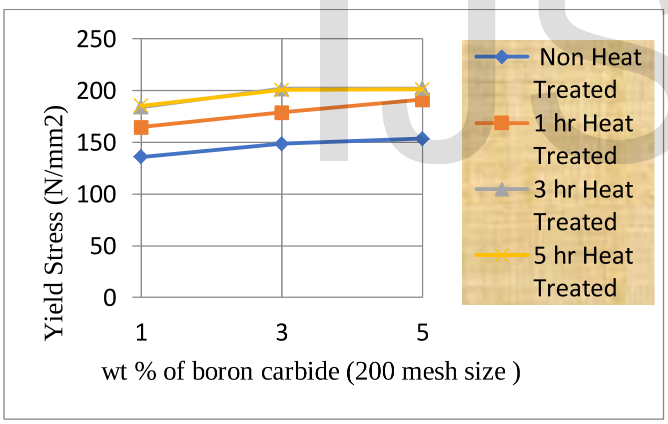
4.2 Yield Strength



Graph 4.4 Effect of B4C and heat treatment duration on the yield strength of the Al2024 alloy with B4C content having 100 mesh size.

Increase in boron carbide particle from 0 to 5 wt.% in Al2024 alloy, the yield strength was found to be increased.

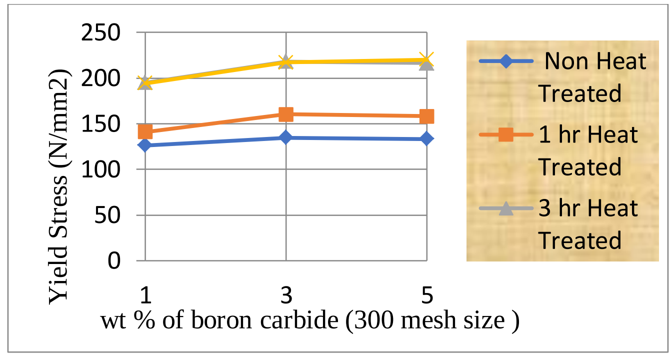
Heat treated test specimens shows the increase in yield strength from 1 hr to 5 hrs duration, beyound 5 hrs it may not vary much.



Graph 4.5 Effect of B4C and heat treatment duration on the yield strength of the Al2024 alloy with B4C content having 200 mesh size.

Yield strength was found to be increased with increase in boron carbide particle from 1 to 5 wt.%, for 3 and 5 wt.% yield strength was found to be almost same.

Heat treatment supported the yield strength of the composite materials from 1 to 5 hrs duration. It was found that for 3 hrs and 5 hrs heat treatment duration the yield strength value is found to be same value.



Graph 4.6 Effect of B4C and heat treatment duration on the yield strength of the Al2024 alloy with B4C content having 300 mesh size.

Increase in boron carbide particle from 1 to 5 wt.% in Al2024 alloy the yield strength was found to be increased.

Heat treatment duration supported the yield strength upto 5 hrs, beyond that yield strength may not give good result.

5. CONCLUSION

The following conclusions have being drawn after carrying out the research work on Al2024 alloy with varying wt % of boron carbide particulates and ageing time duration:

- The yield strength of Al2024 alloy was found to be increased with increase in wt.% of boron carbide particles, this is attributed to more percentage of boron carbide.
- From 3 to 5 wt.% of boron carbide particle in Al2024 alloy yield strength was found to be almost matching.
- Heat treatment for Al2024 alloy was supported upto 5 hrs aging time duration.
- Ductility was found to be decreased with increase in wt.% of boron carbide particle in Al2024 alloy, which is due to more bonding between Al2024 alloy and boron carbide particle.
- Heat treated test specimens shows the decline in ductility of Al2024 alloy with increase in ageing time duration from 1 hr to 5 hrs, which is attributed to more refine grain size and grain boundary.

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