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Evaluation of Micro Structural Change and Mechanical Properties Response of Aluminium (6061) Reinforced with Tungsten carbide Particulate and Fly ash Metal Matrix Composites

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ABSTRACT: Metal matrix composites are moulded by Combination of two or more materials (at least one of the materials is metallic) having dissimilar features generating wide interest in many of the applications. In this present research aluminium (Al 6061) as base matrix metal and tungsten carbide (WC) particulate, fly ash as reinforcements. Aluminium MMCs are prepared by stir-casting process. The Tungsten Carbide particulate was added in quantities of 1.5%, 3% and 4.5% and Fly ash was added in quantity of 2% (constant) on weight fraction basis to the liquefied metal. The different combination sets of composites were prepared to study Mechanical properties like microstructure; hardness and tensile strength as cast Al6061 as well as reinforced Al6061 models before heat treatment and same properties studied after heat treatment. Microstructure examination was carried by using optical Microscope to get the dissemination of tungsten carbide particulate and fly ash in base matrix metal. From the outcomes, it was found that the tensile strength and the hardness of the prepared metal matrix composites increased with increase in tungsten carbide, (3.5%) and fly ash(2%) content in both untreated and treated Micrographs of the samples indicated uniform distribution of tungsten carbide and fly ash particles in the base matrix without voids.

KEYWORDS: MMC's, Tungsten Carbide (WC), Fly-ash, Composites, Stir cast, Heat treatment.

I. INTRODUCTION

Automotive, aerospace and marine are few of the fast growing industries from past few decades. These industries are attracted to light metal matrix composites (MMC's) due to their enriched properties like light weight, high strength, and stability [1]. Al 6061 is precipitation cementing aluminium, containing magnesium and silicon as its major alloying parts. It has extraordinary mechanical properties and showcases incredible weldability. Fly ash remains as particles (as a rule of size 0.5-100 micron) which are removed from developments delivered in the consuming of coal. Fly-Ash powder has low thickness having extraordinary wettability property. On the other hand chemical compound of tungsten and carbon atoms is known as tungsten carbide. WC is commonly available in the form of fine grain powder, but it is flexible and it can be formed into any different shapes and used in different applications, Like In cutting tools, Industrial machineries, as abrasives, Armour-piercing rounds etc.

Hence effort is made to build a metal matrix composite with high strength to weight ratio. Also micro structural changes were observed due to addition of reinforcement material as a function of heat treatment. Two set of specimens with different compositions i.e. Fly ash 2% fix and varying Tungsten carbide (1.5%, 3 % & 4.5%) reinforcements in the Aluminium matrix are prepared by stir casting method. From that one set of specimens were heat treated (Normalizing) [9]. By using optical microscope microstructures were observed for all the specimens at 500x magnification. Tensile test and Brinell hardness test is conducted to observe the changes in strength as well as hardness

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of both heat treated and un-treated specimens with varying compositions of Fly-ash and WC in comparison with as-cast Al(6061). Changes in microstructure were observed and it is seen that the tensile strength and hardness increased as the wt.% of WC increased up to 3% further increase of WC i.e. 4.5 wt% decreases the strength and hardness.

II. EXPERIMENTAL DETAILS

The Al (6061) alloy is melted in electrical induction furnace at 800°C for 3 hours in a graphite crucible. Degassing is used in order to remove entrapped air from molten metal and to get specimens free from porosity and other casting defects. Then the molten metal is poured in to the moulds of required dimension. Then the specimens are machined to specific dimensions to carry out tests.

To conduct microstructural test, the specimens are prepared by polishing using emery paper of size 200,400,600,800 and 1000 grit size respectively. Then fine surface of the specimen is worked on Disk Polishing Machine for 20 to 25 minutes. During polishing water and Al₂O₃ is sprinkled on polishing cloth to carry out polishing operation smoothly, without generating heat and friction at about 800rpm. Once the mirror surface is obtained final finishing is done by etching process i.e. dipping specimen surface in 95% of water and 5% of HNO₃. The polished specimen is then observed in the optical microscope and the images of microstructures are taken.

The tensile test specimens are prepared on lathe machine with dimensions as shown in figure 2.



Figure 1: Specimens for Optical microscopic test.



Figure 2: Specimens for Brinell Hardness Test.

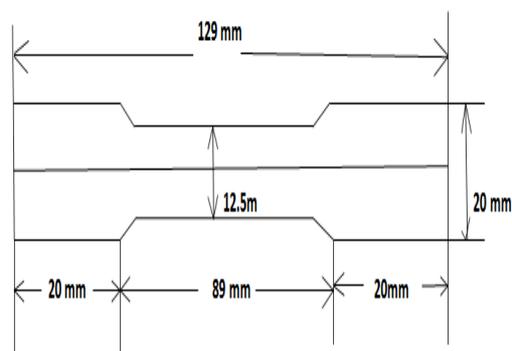


Figure 3: Showing specimen dimensions for testing UTS (Ultimate Tensile Strength) on UTM.

The specimens for hardness test are prepared as per ASTM E10 shown in Figure 3 of dimensions 20mm height, and 20 mm diameter. The test was carried out on MRB 250 Brinell hardness tester.

All the prepared specimens are heat treated in muffle furnace at 350°C for 6 hours then air cooled.

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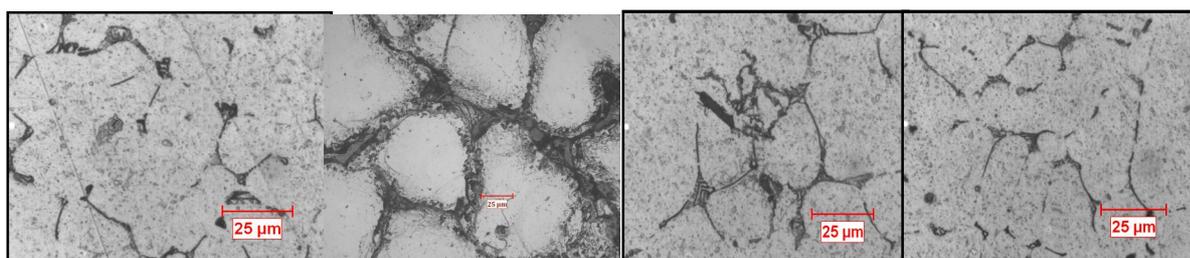
Table 1: shows the designation of reinforcement with tungsten carbide and Fly ash.

Sl. No	Material compositions	Alloy Designation	Wt.% Of Tungsten Carbide	Wt.% Of Fly Ash
1	Al6061 as cast	A1	0	0
2	Al6061+1.5% WC +2% Fly Ash	A2	1.5	2
3	Al6061+3% WC +2% Fly Ash	A3	3.0	2
4	Al6061+4.5% WC +2% Fly Ash	A4	4.5	2
5	Al6061 as cast	A1H	0	0
6	Al6061+1.5% WC +2% Fly Ash heat treated	A3H	1.5	2
7	Al6061+3% WC +2% Fly Ash heat treated	A3H	3.0	2
8	Al6061+4.5% WC +2% Fly Ash heat treated	A4H	4.5	2

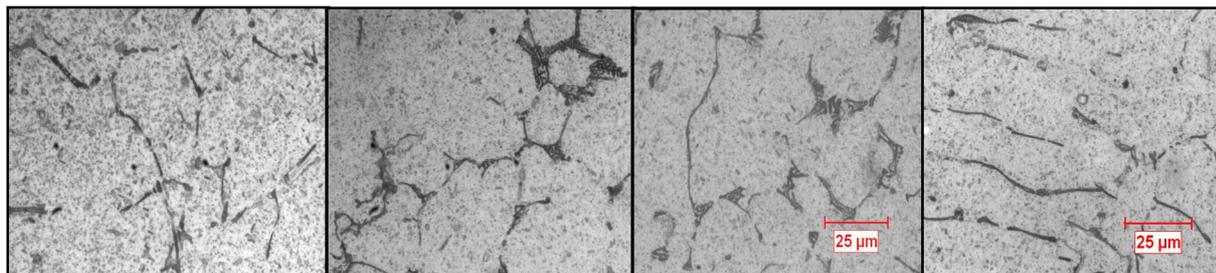
III.RESULTS AND DISCUSSION

1. MICROSTRUCTURE

Figure 5 shows micrographs of Al601/WC/Fly-ash MMCs. The constituents of composites are distinguished well. The suspension of WC particles at columnar grain boundaries of Al is clearly observed. And uniform dispersion of WC reinforcement was attained for 3wt% addition of WC. Also the addition of Fly-ash 2 wt% has not much affected the grain distribution. Heat treatment caused the regrowth of grains with low angle boundaries. And dispersion of WC became more intense.



i) As-cast Al6061 ii) 1.5 wt% WC/ 2 wt% FA iii) 3 wt% WC/ 2 wt% FA iv) 1.5 wt% WC/ 2 wt% FA
Figure 4. micrographs of Al/WC/Fly-ash MMC



i) As-cast Al6061 ii) 1.5 wt% WC/ 2 wt% FA iii) 3 wt% WC/ 2 wt% FA iv) 1.5 wt% WC/ 2 wt% FA
Figure 5. micrographs of Heat treated Al/WC/Fly-ash MMC

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2. TENSILE TEST

Table 2: UTS of Al6061 alloy and its composites

SI No.	Alloy/Composites	UTS (MPa)
1	A1 (Al6061 as cast)	150.116
2	A2	160.085
3	A3	170.187
4	A4	139.792

Table 3: UTS of untreated as-cast Al6061 alloy and its composites.

SI No	Composites	UTS(MPa)
1	A1H (Al6061 as cast)	121.726
2	A2H	123.462
3	A3H	127.693
4	A4H	114.448

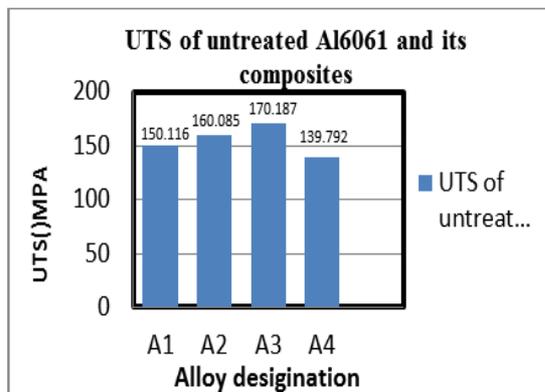


Figure 6: UTS of Al6061 and its composites

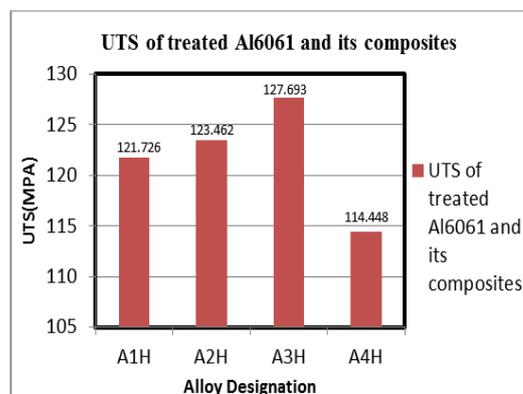


Figure 7: UTS of Al6061 and its composites

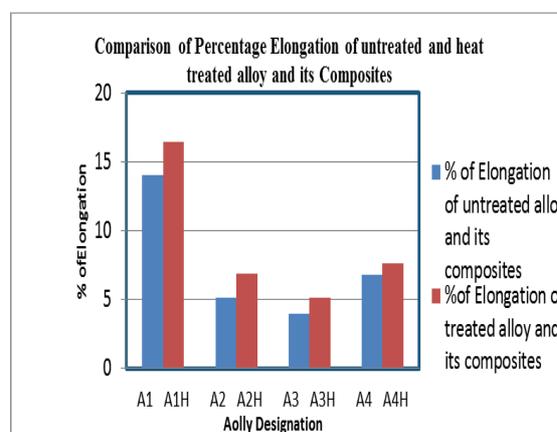


Figure 8: Comparison of UTS of Al6061 and its composites

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The Ultimate Tensile Strength of Al6061 increased as the reinforcement of WC increased up to 3 wt% with 2 wt% of fly ash as constant. But it is observed that further addition of WC decreases the tensile strength. Initially for the Al6061 the tensile strength was 150MPa but the addition of WC enhanced the strength to 170MPa further addition of WC brought back the enhanced strength to 139Mpa which is less than the as-cast specimen strength.

The %elongation of the samples were examined, it is seen that the %elongation of test samples decreased as the reinforcement of WC increased. We can say that the addition of WC reinforcement decreased the ductility of the material samples. The same samples were heat treated in order to see the changes in elongation and it is seen that after heat treatment the ductility increased, comparison is given in the figure 8.

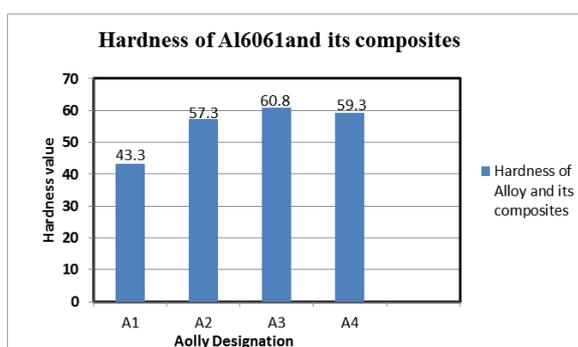
3. HARDNESS TEST

Table 4: Hardness of untreated Al6061 and its composite

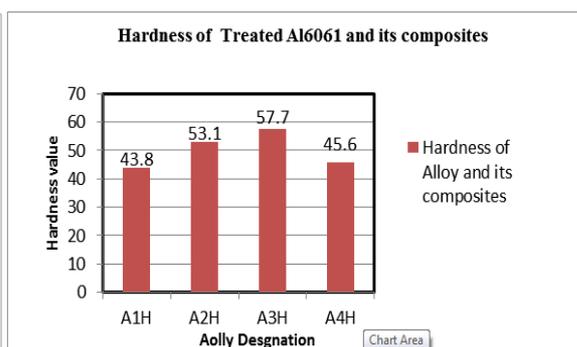
SI No	Alloy/Composites	Hardness value (avg)
1	Al6061 as cast A1	43.8
2	Al6061+ Fly ash2%+wc1.5% A2	57.3
3	Al6061+ Fly ash2%+wc3% A3	60.8
4	Al6061+ Fly ash2%+wc4.5% A4	59.3

Table 5: Hardness of Heat treated Al6061 and its composite

SI No	Alloy compositions	Hardness value
1	Al6061 as cast A1H	43.8
2	AL6061+Fly ash2%+Wc1.5% A2H	53.1
3	AL6061+Fly ash2%+Wc3% A3H	57.7
4	AL6061+Fly ash2%+Wc4.5% A4H	45.6



a) Without Heat treatment



b) With Heat treatment

Figure 9: Brinell Hardness Number(BHN) V/S Varying wt. % of WC at constant 2 wt. % of Fly ash in Al 6061.

The hardness of test material samples increased with the addition of WC reinforcement as shown in figure 6 (a). Initially for Al6061 the Brinell Hardness Value was 43.3 but the addition of WC with 1.5 wt. % increased HV drastically to 57.7. Further addition of WC was not affected the Hardness Value much, it remained almost same for 3 and 4 wt. % of WC.

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IV. CONCLUSION

The Al6061/Fly ash/WC composite is successfully fabricated with changed weight proportion of Tungsten carbide particulate and Fly ash(2%) reinforcement using conventional stir casting method.

Following conclusions are made

- The Microstructure study confirmed the uniform distribution of reinforcement particles in the matrix.
- The yield stress and tensile strength of the MMC increases when added the 3 % of tungsten carbide with 2% fly ash. Hardness of the material improved with increase of tungsten carbide 3% with 2% of fly ash.
- Heat treatment process resulted in the alteration of needle like structure which formed very small bits of tungsten to spherical form.
- The composite with 2% Fly ash and 3% Tungsten carbide has highest UTS and ductility reduces with addition of WC.

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