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Development and Characterization of Al7075 Alloy Reinforced with Tungsten Carbide (WC) and E-glass fiber

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ABSTRACT

A composite having Aluminum alloy Al7075 as a matrix and Tungsten Carbide (WC) and E-glass fiber as reinforcements has been developed. The percentages of WC and E-Glass were varied in the ranges 2-6% and 1-5% respectively. The test samples were prepared as per ASTM standards. Tensile test was carried out on UTM to measure yield strength, Ultimate tensile strength and % Elongation. Hardness test was carried out on a BHN tester to know the hardness of different specimen. It was found that increase in both WC and E-Glass contents increases ultimate tensile strength (UTS), yield strength, and hardness but there is gradual decrease in % elongation as UTS increases. Values of these properties varied from specimen to specimen, i.e. UTS increased from 262.03 N/mm^2 to 296.4 N/mm^2, Yield strength from 258.4 N/mm^2 to 285.3 N/mm^2, hardness from 85.3 BHN to 99.2 BHN, and % elongation decreased from 7.2 to 4.5. From these values it is well clear that increasing the WC and E-glass fiber contents in the composite would result in increase in UTS, YS, Hardness, but decrease in % elongation.

Keywords: *MMC, Al7075, WC, E-glass fiber, die casting, mechanical properties, characterization.*

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1. INTRODUCTION

It is important to have high service life of the component, operation reliability, low friction in bearings, bushes, piston rings, brake pads, driving mechanisms, clutches, couplings, gears, and moving parts etc. The working condition of these parts differs in various aspects like sliding speeds, loads environmental conditions and other parameters. No single metal can meet all the required properties; so it is necessary to develop a composite material that could have all combinational property satisfying our engineering requirements. Metal matrix composite has enhanced mechanical properties than pure metal [1].

Al7075 is an aluminum alloy with Zinc as the primary alloying element. It is strong with strength comparable to many steels and has good fatigue strength and average machinability but has less resistance to corrosion than many other Alalloys. *Al7075 consists of Al 88.35%, Si 0.4%, Fe 0.5%, Cu 1.6%, Mn 0.3%, Mg 2.5%, Cr 0.25%, Zn 5.6%, Ti 0.2% and*

expected impurities of around 0.05%. It has got the mechanical properties such as Brinell Hardness number(BHN) 150, Ultimatetensile strength 273 MPa, yield strength 145 Mpa, % elongation 9-10%, and density is 2.81 g/cm^3.Tungsten carbide and E-glass fibers are considered as reinforcement in this research work due to their unique individual properties. Tungsten Carbideis extremely hard, ranking 9 on Mohrs scale and with a Vickers number of 1700–2400. Characteristics and properties of WC are melting point 2875^{O}C, Young's modulus 551 MPa, bulk modulus 632 MPa, Poisson's ratio 0.31, Ultimate tensile strength(UTS) of 344.9 MPa and its density is 15.75 g/cm^3.E-Glass fibers are useful thermal insulators because of their high ratio of weight to surface area. The increased surface area makes them much more susceptible to chemical attack. By trapping air within them, blocks of glass fiber make good thermal insulation, with a thermal conductivity in the order of 0.05 W/(m·K). Its mechanical properties are- Tensile strength 2870 MPa, compressive strength 1080 MPa, density of 2.58 g/cm^3 and young's modulus of 85 GPa.Presence of E-glass fibers in the composite increases the thermal insulating property as it is a very good thermal insulator. Tungsten carbide is approximately double the density of steel nearly midway between that of lead and gold [3][4], i.e. 15.75 g/cm^3. Therefore, the higher the percentage of WC the higher will the density of composite.

It is clear that the each material mentioned above has got unique properties and their combination would give a single material with the package of enhanced properties. The main objectives of this research is to enhance the mechanical properties of Al7075 by forming an hybrid composite material by combining Tungsten and E-glass fiber [casting process] in different proportions. Also, to study the effects of E-glass fiber and WC on Al 7075 alloy by conducting various mechanical tests.

2. EXPERIMENTAL METHODOLOGY

Die casting and machining processes are carried out during the specimen preparation.Al7075 ingots are placed in the furnace and heated up to 800^{o}C. After reaching to its molten state, calculated amount of WC and E-Glass fibers are added into the furnace and stirred thoroughly by zirconium coated spoon in order to ensure that the elements are uniformly distributed. Molten material is forced into the mold cavity at high pressure. Once the mold cavity is filled, the pressure is maintained until the casting solidifies.

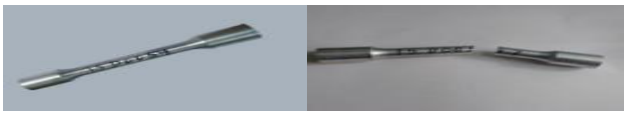
The samples were prepared as per the ASTM standards after reinforcing WC and E-Glass fiber into Al7075 at various proportions. Each casted specimen is further machined with the help of a Lathe as per ASTM standard. Tests were carried out on the samples preparedto get Ultimate tensile strength, Yield strength, % Elongation, and Hardness.Samples and their compositions are given in table 1. Die used for casting and casted specimen are shown in figure 11.and 1.2.

Table 1.1. Proportions of materials considered for specimen preparation

Sl.no.	Al7075	WC	E-glass fiber
1	97%	2%	1%
2	95%	4%	1%
3	93%	6%	1%
4	95%	2%	3%
5	93%	4%	3%
6	91%	6%	3%
7	93%	2%	5%
8	91%	4%	5%
9	89%	6%	5%


Figure 1.1. Die used for castingFigure 1.2.The Castedspecimen

Tensile test: Universal Testing Machine (UTM) is used for conducting the tensile tests.Extensometers measure the key parameters of force and deformation, which is also presented in graphical mode as it is of computer operated machine. The specimen tested are shown in figure1.3.



Before the testAfter the test

Figure 1.3. Tensile test specimen

Hardness Test: Brinell hardness test is considered for determining the hardness number in this work. The Brinell hardness number is obtained by dividing the load used by the actual surface area of the indentation. The result is a pressure measurement, but the units are rarely stated.

The BHN is calculated according to the following formula:

$$BHN = \frac{F}{\frac{\pi}{2} D * \left(D - \sqrt{D^2 - Di^2}\right)}$$

Where BHN = the Brinell hardness number, F = The imposed load inkg, D = the diameter of the spherical indenter, in mm, Di = diameter of the resulting indenter impression, in mm . Specimen used for the test is shown in the figure 4.

Figure 1.4. Tested specimen

3.RESULTS AND DISCUSSION

Results obtained during the various tests arediscussed in this section.The readings taken during the stated tests aretabulated in table 1.2.

Table 1.2. Results obtained during various tests conducted on the specimen

Specimen No.	Combination of Materials			Yield strength N/mm^2	Ultimate tensile strength N/mm^2	% Elongation	Hardness BHN AVG
	Al 7075	WC	E-glass				
1	97%	2%	1%	258.4	262.3	7.2	85.3
2	95%	4%	1%	260.2	271.4	6.8	91.2
3	93%	6%	1%	271.3	282.3	5.8	93.4
4	95%	2%	3%	274.4	287.3	6.9	86.7
5	93%	4%	3%	281.2	293.4	6.2	93.4
6	91%	6%	3%	284.3	295.3	5.4	95.6

7	93%	2%	5%	280.1	291.2	6.5	87.6
8	91%	4%	5%	282.5	294.3	5.9	94.8
9	89%	6%	5%	285.3	296.4	4.5	99.2

Effect of Tungsten Carbide and E-Glass fiber on (a)Ultimate tensile strength, (b)Yield strength, (c)% elongation, and (d) Hardness in Al7075-WC-E glass fiber composite.

Figure 1. 5 consists of graphs that are plotted by varying the % of WC in composite, keeping E-glass fiber % constant and figure 6 has the graphs that are plotted by keeping WC constant and by varying the % of E-glass. From the graphs it is observed that the both WC and E-glass fibers have contribution in increasing the UTS, YS and Hardness. Addition of WC more than 4% up to 6% for 3% and 5% of E-glass will not have much impact on base material to increase UTS as well as YS (refer figures 5 (a) and (b)). And addition of both WC would definitely affect the % elongation, means more the WC and E-glass fiber the lesser is the % elongation. The main reason behind this is, after some extent the addition of WC into the base metal would increases its hardness and would become slightly brittle hence, it slightly starts losing its ductility. Therefore, the optimum amount of WC is 4% (as per the graphs) must be added into the base metal along with the E-glass fiber to achieve higher or required UTS, YS, and hardness, because addition of more than 4% of WC and 3% of E-glass fiber is not increasing the UTS, and YS at greater amounts as it can be seen in the graphs that curves are going flat. But the main advantage of adding more WC and E-glass fibers into the base metal would definitely end up with higher hardness as it is shown in figure 5 (d). Based on the previous graphs it is well clear that E-glass fiber has greater impact on increasing UTS and YS compared to WC (refer figures (a), and (b)) but even E-glass fiber has a limit in taking part to increase these properties. And when it comes to increasing the hardness, E-glass contributes alongwith the WC as it is shown in figure 1.6 (d). There is no such gradual fall in curve in the case of % elongation like as it was in the case of WC.

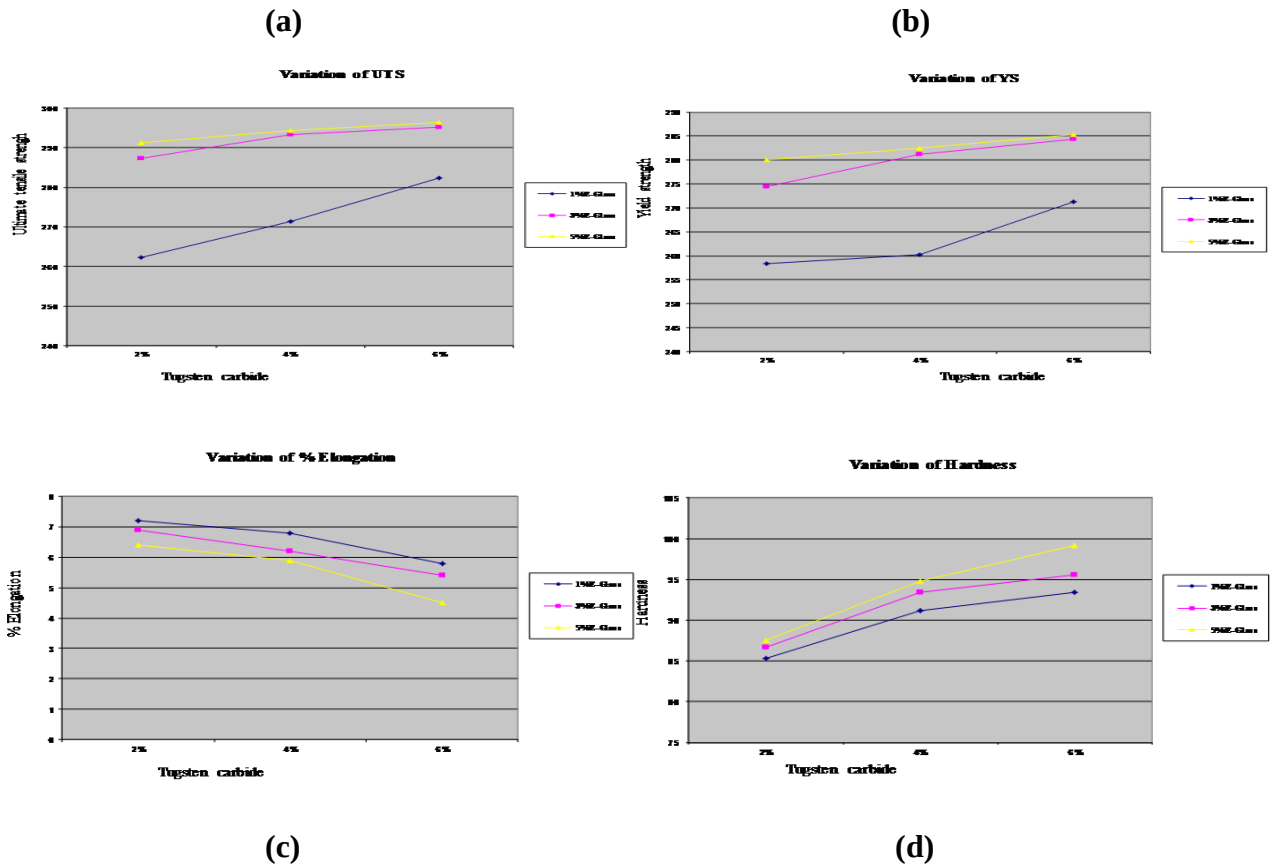


Figure1.5. Effect of Tungsten Carbide on (a)Ultimate tensile strength, (b)Yield strength, (c)% elongation, and (d) Hardness in Al7075-WC-E glass fiber composite.

(a) (b)

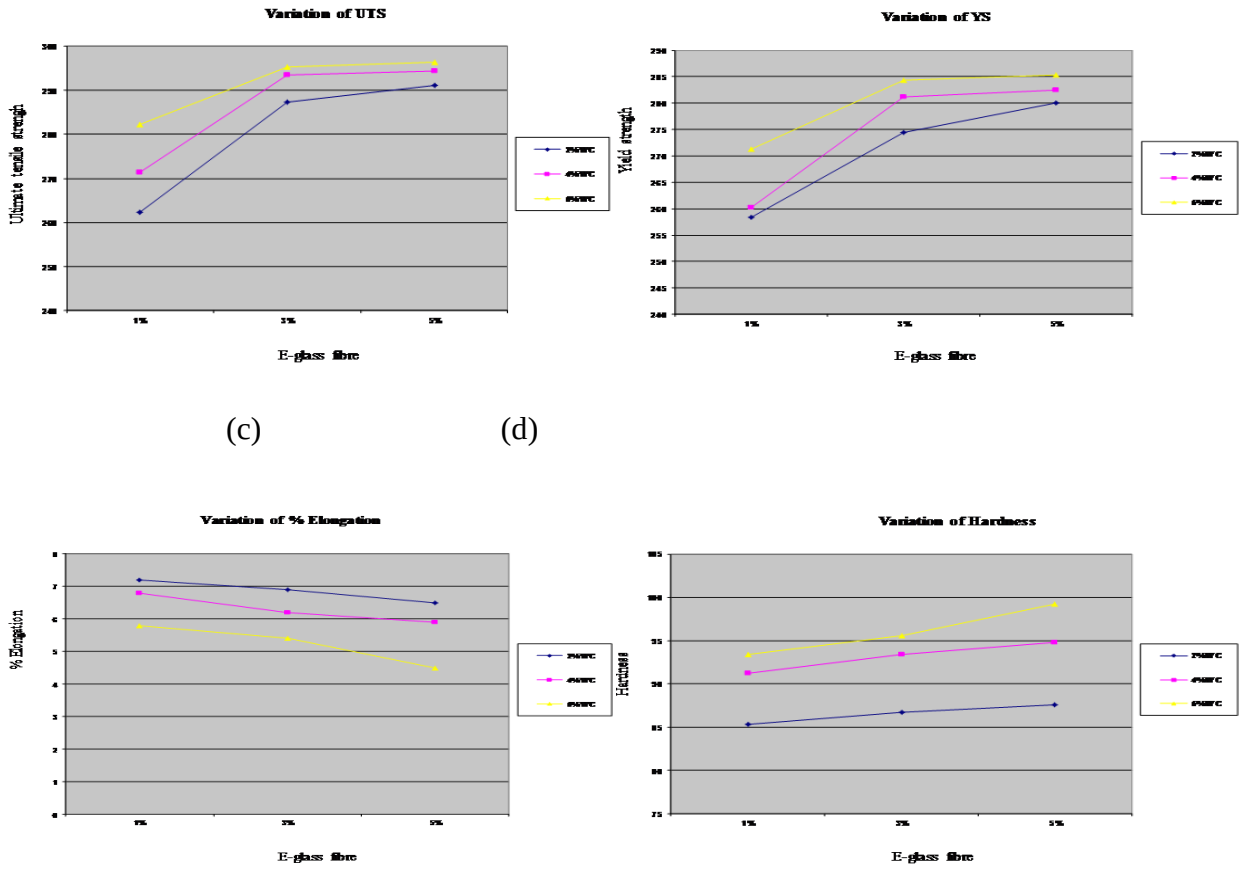


Figure1. 6. Effect of E-glass fiber on (a)Ultimate tensile strength, (b)Yield strength, (c)% elongation, and (d) Hardness in Al7075-WC-E glass fiber composite.

4. CONCLUSIONS

This research work was mainly focusedon enhancing the mechanical property of Al7075 by reinforcing tungsten carbide and E-glass fibers into it. Inclusion of WC and E-glass fiber elements improves the mechanical properties of the composite material like tensile strength, Yield Strength, hardness, and compression strength thereby decreasing the ductility. Highest values of mechanical properties like hardness, UTS, YS, and compressive strength were found at 4 % of WC and 3% of E-glass fiber.

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