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# Influence of heat treatment on hardness and ultimate tensile strength of aluminium 7075 based Metal Matrix Composite reinforced with Tungsten carbide and zircon sand particulates

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***Abstract :*** Al7075 Alloy based Metal matrix composites are created in the current work employing a liquid route metallurgical process with varying amounts of zircon sand and tungsten carbide reinforcing particles. According to ASTM standards ASTM E8 and ASTM E10, respectively, tensile testing and hardness tests are conducted. The microstructure of materials that have undergone heat treatment exposes reinforcement that has been bonded to the matrix more effectively, which has increased mechanical properties. The increased mechanical properties of the ceramic reinforced particles could be attributed to the homogenous distribution and bonding of the reinforcement in the matrix.

***Keywords:*** Al 7075, Composites, Tungsten carbide, Zircon Sand, Heat treatment

## I. INTRODUCTION

Due to their low weight, high specific strength, and efficient heat transfer, aluminium alloys and their composites are suitable replacements for components manufactured of ferrous alloys. Either continuous or sporadic reinforcements can be used to create an Al-based metal matrix. Discontinuous reinforced Al matrix composites have received a lot of attention because of their isotropic properties. Comparatively speaking, the discontinuous reinforced Al metal matrix composite demonstrates superior isotropic characteristics. Despite the fact that there have been many studies on Al matrix composites, there have been few investigations on hybrid Al metal matrix composites.The significance of mechanical qualities and machining behaviours led to thorough research in this area. A survey of the literature indicates that Al metal matrix composites become harder as ceramic particle reinforcements are added. Competitors without reinforcement have lower tensile and hardness strengths than hybrid composites. Al alloys' mechanical properties, including as hardness, tensile strength, compressive strength, and ultimate tensile strength, improved with the introduction of reinforcements [2–9].

Many researchers have found the machinability of hybrid metal matrix composites based on aluminium to be an intriguing topic. Metal matrix composites are created via machining operations such as turning, drilling, milling, shaping, grinding, etc. as well as some unconventional machining techniques. It has been found that a faster cutting speed leads to a better surface polish when processing hybrid metal matrix composites, and vice versa. If a higher finish must be attained with a low cutting speed, a low depth of cut and minimum feed are excellent conditions. Additionally, it has been observed that the addition of solid lubricants improves a composite's capacity to be machined and the lifespan of the cutting tool [10–12].It is possible to reduce the weight of MMCs while also enhancing their stiffness and strength by using different monolithic matrix materials. Significant drawbacks for continuous fibre systems include low transverse and interlaminar shear strength, foreign object impact damage, mechanical/chemical property incompatibility, high fibre and processing expenses, and foreign object impact damage.A number of elements must come together for a metal matrix composite to be transformed from an advanced composite material to a cost-effective application for the commercial market, including a large material production capacity, dependable static and dynamic properties, cost-effective processing, and a change in design philosophy based on experience and in depth durability evaluation.

[1].Aluminum's poor wear resistance has led to a reduction in its tribological applications; however, aluminium matrix composites supplemented with ceramic particles have demonstrated notable improvements [2–9]. Few research have been done on aluminium alloy, ZrSiO4, and WC, but several have been done on the manufacture of secondary phase particle reinforced materials [10–15]. The aluminium alloy employed in the current study exhibits good casting and fluidity during the production of aluminium matrix composites. The impacts of ZrSiO4 and WC reinforcing particles on the mechanical characteristics of this alloy have been examined and compared in the current study.

## II. OBJECTIVES OF PRESENT WORK

Al 7075 reinforced with tungsten carbide and zircon sand is subjected to mechanical tests like tensile and hardness tests. These reinforcements have a high Strength and Hardness in comparison. The major goal of this research is to create particulate metal matrix composites made of Al 7075 Tungsten carbide, and zircon sand, with Tungsten carbide and zircon sand serving as reinforcement materials. Liquid route metallurgy is used to prepare specimens in various weight percentages. To assess tensile and hardness qualities, test specimens are created.

## III. EXPERIMENTAL DETAILS

In our experimental work, the following procedures are used.

1. Material choice
2. Preparation of the composite
3. Testing

### 3.1 Material selection

Metal matrix composites were created using the Al 7075 alloy as the matrix material, Tungsten carbide 10µm sized reinforcement particles, and Zircon Sand 40µm sized reinforcement particles.

### 3.2 Composite preparation

With WC content in the composites changing from 1 to 7 percent by weight in steps of 2 percent by weight and $ZrSiO_4$ from 0 to 8 percent by weight in stages of 2 percent by weight, 10 µm WC and 40 µm $ZrSiO_4$ were used as reinforcement. The WC particles were added to the melt through a vortex created in the melt by the employment of an alumina coated stainless steel stirrer during the fabrication of the composite materials using the liquid metallurgical technique. The stirrer must have an alumina layer to prevent ferrous ions from transferring from the stirrer material into the molten metal. The stirrer, revolving at 550 revolutions per minute, covered about two-thirds of the depth of the molten metal. Prior to being degassed for three to four minutes with pure nitrogen, the liquid melt's vortex got the preheated (773K) WC particles and $ZrSiO_4$. The resulting slurry was poured into heated permanent moulds using a tilt pour.

### 3.3 Heat Treatment

Specimens are heated for 24 hours at 530°C to achieve uniform grain structure, improve the material's properties, and achieve good bonding between the matrix material. After solution treatment and quenching hardening, the specimens are aged to a temperature of 175°C over a range of ageing hours. Each composition consists of 5 specimens, with the exception of the specimen that was cast as it was. To attain the required balance of ductility and hardness, the remaining 4 specimens are aged for varying lengths of time 1 hour, 3 hours, 5 hours, and 7 hours.

### 3.4 Tensile test

The tensile test was used to analyse the mechanical behaviour of the matrix alloy and cast composites. The ASTM E8 Standard was used to test the Cast MMCs. In a uniaxial tensile test, an axial load is applied along the axis of the standard tensile specimen. This is a fundamental and common tensile test used to assess the hardness and ultimate tensile strength of a material. The specimen was created in accordance with ASTM specifications. The tensile strength test was carried out in Peenya, Bangalore, by Advanced metallurgical laboratories

### 3.5 Brinell Hardness Test

A material's surface hardness reveals how resistant it is to these actions, including abrasion, scratching, and cutting. The specimens of the matrix aluminium alloy and composite material were subjected to hardness tests using a Brinell hardness testing machine to ascertain their hardness. The samples were polished metallographically before being placed through the hardness test. Under carefully regulated circumstances, mechanical force is delivered to the specimen for about 30 seconds. On each sample, measurements were made at five distinct locations to check for findings repeatability. The main screw, a dial gauge, and a loading system make up the Brinell Hardness Tester. The indenter, which is a steel ball of 10 mm diameter (D) under a weight of 500 kg (P) put into the specimen for a specified time and measuring the mean diameter (d) of the impression left on the surface after the load is removed, is widely used to test aluminium and other softer alloys.

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

BHN = Brinell hardness number

F = Imposed load in kgf

D = Diameter of the spherical indenter in mm

Di = Diameter of the resulting indenter impression in mm

## IV. Results and Discussion

The samples underwent solution heat treatment after being machined in accordance with ASTM requirements. The produced composites mechanical characteristics have been studied.

### 4.1 Effect of Heat Treatment on Hardness of Al 7075 alloy based composite

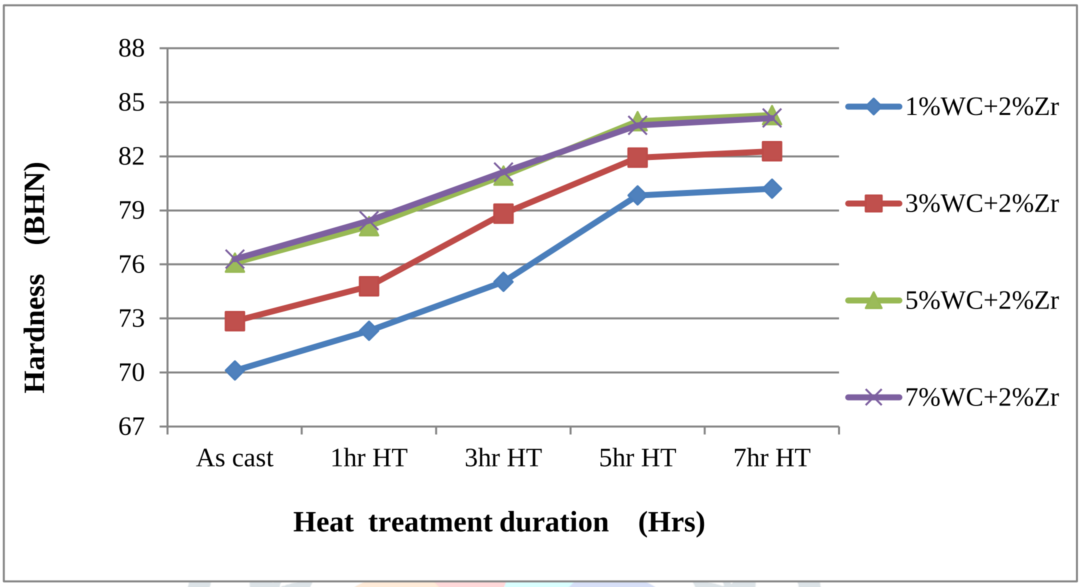

Figure 1 Variation of % composition of Tungsten carbide with 2% zircon sand

Particle reinforced Al MMCs are discovered to have better toughness than monolithic alloys. One can see from the graph above that the hardness of the composite (Al7075+1%WC+2%$ZrSiO_4$) without heat treatment is 70.1 BHN, whereas the value increases to 76.29 BHN for (Al7075+7%WC+2%$ZrSiO_4$). In the instance of heat treatable Al-alloys and their composites, the hardness of composites rose to 84.12 BHN for (Al7075+7%WC+2%$ZrSiO_4$) for 7 hours after heat treatment by lowering the tendency to crack and enhancing precipitation hardening. The composite with heat treatment has a hardness that is 12 percent higher.

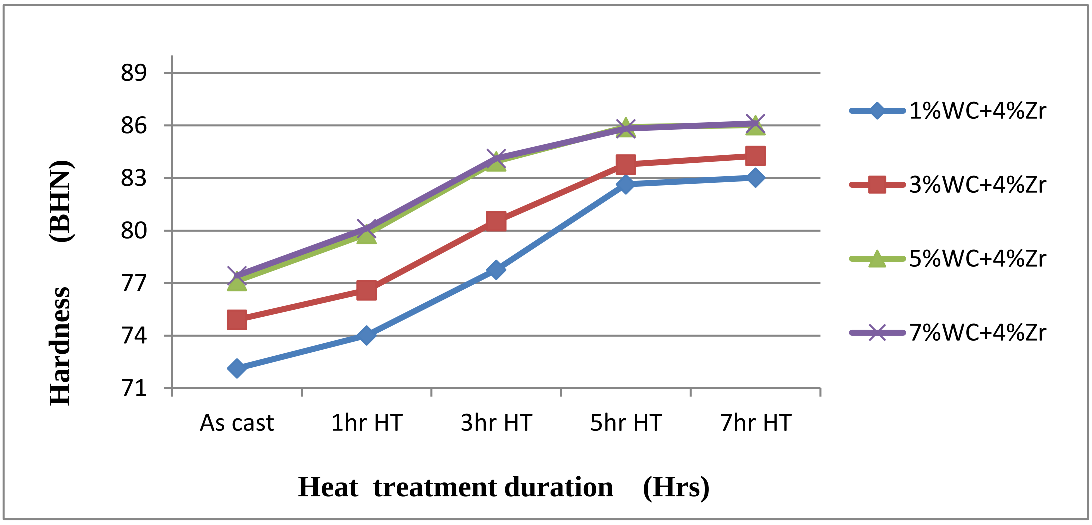

Figure 2 Variation of % composition of Tungsten carbide with 4% zircon sand

One can see the hardness of the composite material that has not been heated from the graph above. (Al7075+1%WC+4%$ZrSiO_4$) has a calculated value of 72.13 BHN, while (Al7075+7%WC+4%$ZrSiO_4$) has a calculated value of 77.43 BHN. As for heat treatable Al-alloys and their composites, by lowering the tendency to crack and enhancing precipitation hardening, the hardness of composites increased to 86.12 BHN for (Al7075+7%WC+4%$ZrSiO_4$) for 7 hours after heat treatment. Finally hardness is 15% higher than the unheat treated composite.

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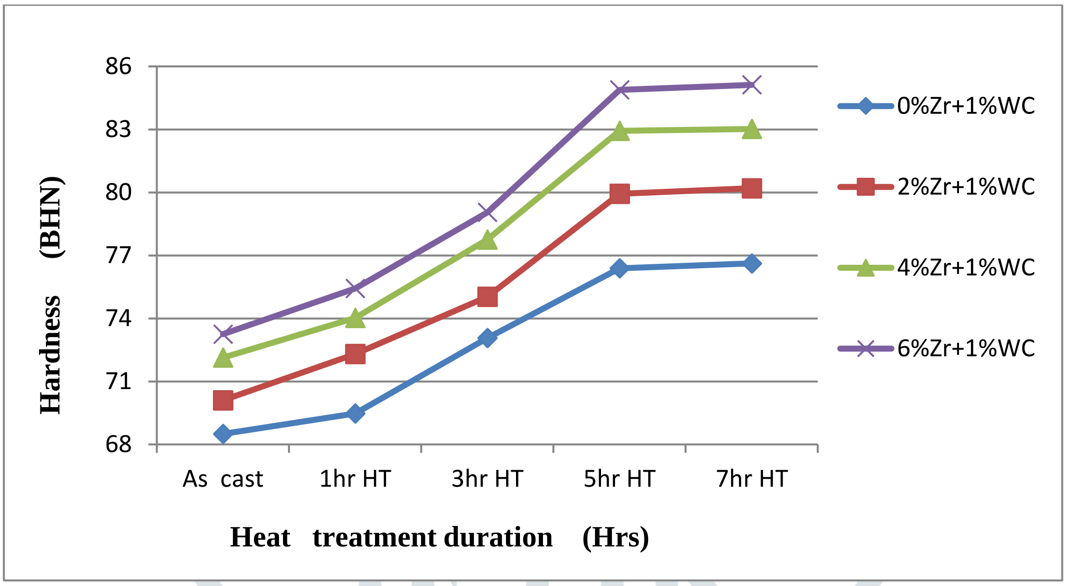

Figure 3 Variation of % composition of zircon with 1% Tungsten carbide

According to the graph above, the hardness of unheated composite (Al7075 +0%$ZrSiO_4$+1%WC) is 68.5 BHN, while the hardness of (Al7075 +6%$ZrSiO_4$+1%WC) is 73.25 BHN. For heat treatable Al alloys and their composites, a reduction in the tendency to crack and an improvement in precipitation hardening caused the composite hardness to increase to 85.12BHN for (Al7075 +6%$ZrSiO_4$+1%WC) for 7 hours after heat treatment. Finally hardness is 17% higher than the unheat treated composite.

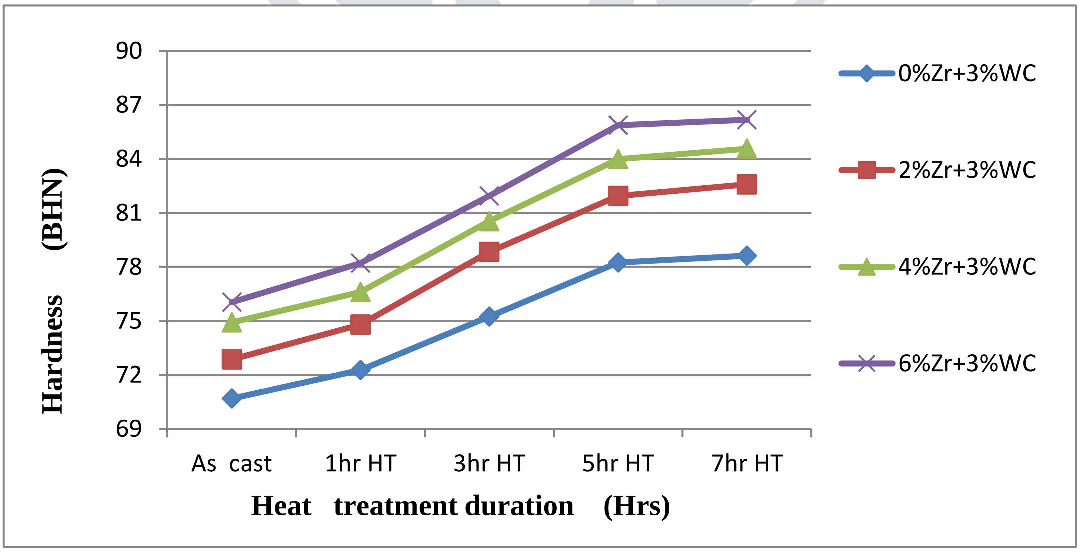

Figure 4 Variation of % composition of zircon with 3% Tungsten carbide

According to the graph above, the hardness of unheated composite (Al7075 +0%$ZrSiO_4$+3%WC) is 70.68 BHN, while for (Al7075 + 6% $ZrSiO_4$ + 3% WC), this value increased to 76.03 BHN. The hardness of composites for heat treatable Al alloys and their mixtures increased to 86.17 BHN for (Al7075 + 6% $ZrSiO_4$ + 3% WC) for 7 hours after heat treatment by lowering the tendency to break and enhancing precipitation hardening. Finally hardness is 17% higher than the unheat treated composite.

### 4.2 Effect of Heat Treatment on UTS of Al 7075 alloy based composite

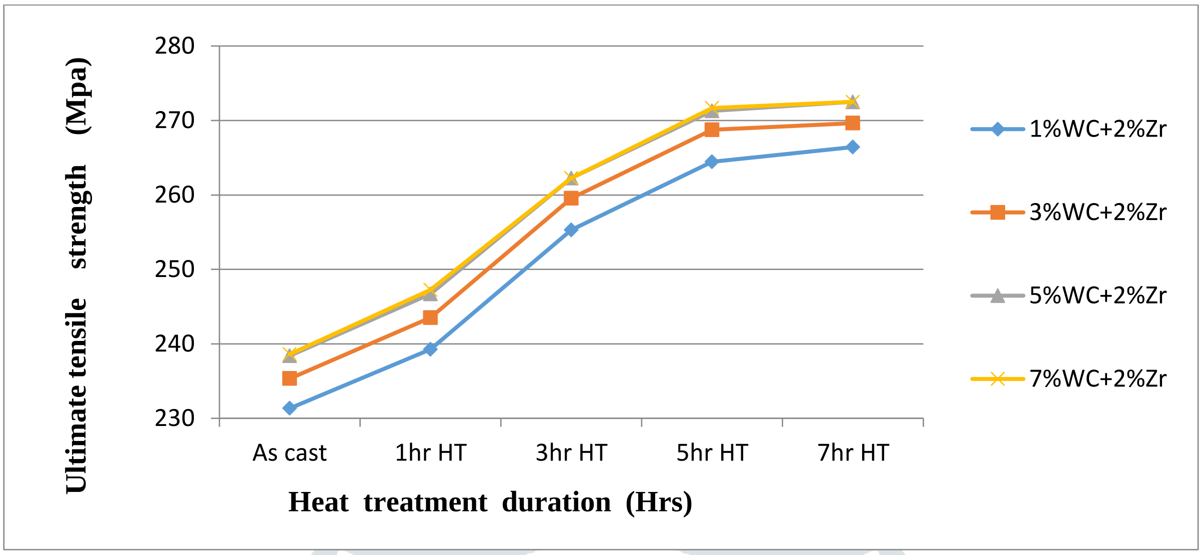

Figure 5 Variation of % composition of Tungsten carbide with 2% zircon sand

The tensile strength of the particle reinforced aluminium Metal Matrix Composite is found to be higher than that of monolithic alloys. Tensile strength for the composite (Al7075+1 % WC+2 % $ZrSiO_4$) without heat treatment is 231.35 MPa while for the composite (Al7075+7 % WC+2 % $ZrSiO_4$), this value increased to 238.61 MPa. The ultimate tensile strength of composites made of heat treatable aluminium alloys and their byproducts increased to 272.51 MPa for (Al7075+7% WC+2% $ZrSiO_4$). By lowering the tendency to break and enhancing precipitation hardening, 7 hours after heat treatment. Finally, tensile strength is 14% greater than the composite that has not been heated.

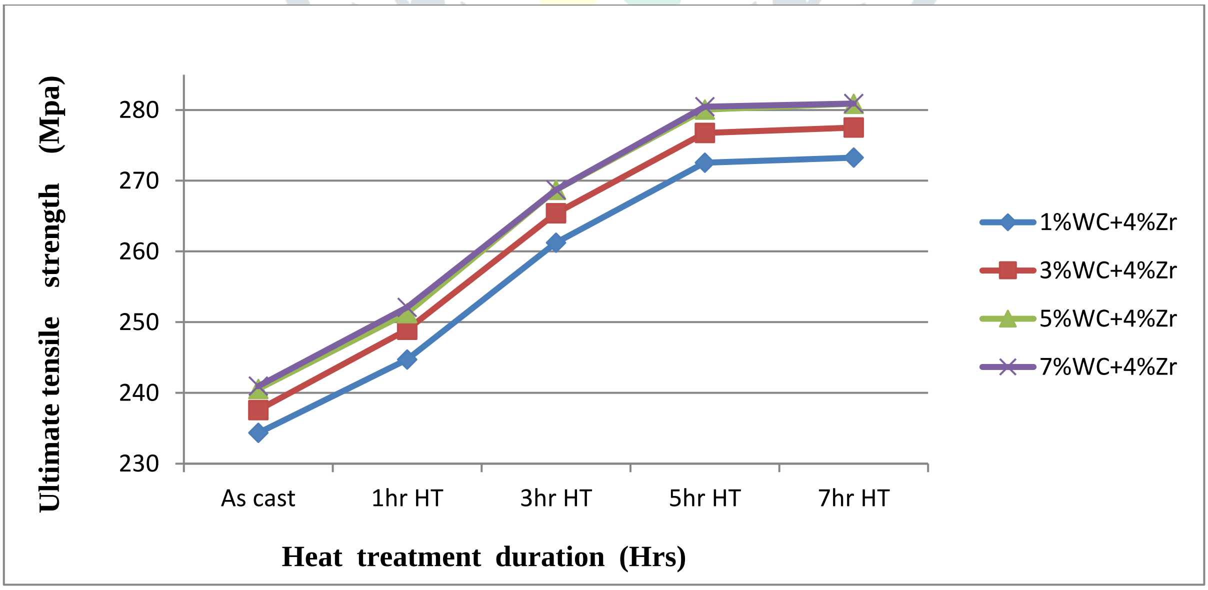

Figure 6 Variation of % composition of Tungsten carbide with 4% zircon sand

Tensile strength of unheated composite (Al7075+1%WC+4%ZrSiO4) is 234.35 MPa, and this value increased to 240.96 MPa for (Al7075+7%WC+4%ZrSiO4) according to the graph above. The ultimate tensile strength of composites for heat treatable Al alloys rose to 280.92 MPa for (Al7075+7%WC+4%ZrSiO4) 7 hours following heat treatment by lessening the potential to break and enhancing precipitation hardening Finally, tensile strength is 17% greater than the composite that was not heated.

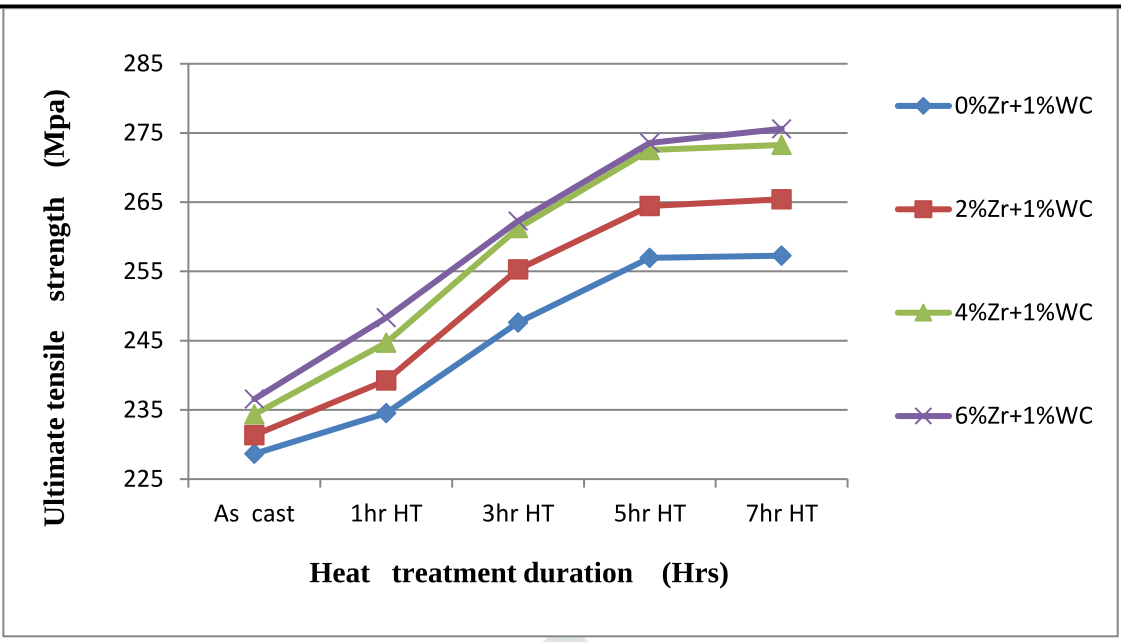

Figure 7 Variation of % composition of zircon with 1% Tungsten carbide

The tensile strength of unheated composite (Al7075 + 0% $ZrSiO_4$ + 1% WC) is 228.65 MPa and that this value increased to 236.56 MPa for composite (Al7075 + 6% $ZrSiO_4$ + 1% WC). The ultimate tensile strength of composites made from heat treatable Al-alloys and their components increased to 275.6 MPa for (Al7075+6% $ZrSiO_4$+1% WC). By lowering the tendency to break and enhancing precipitation hardening, 7 hours after heat treatment. Last but not least, the tensile strength is 17% more than the composite that has not been heated.

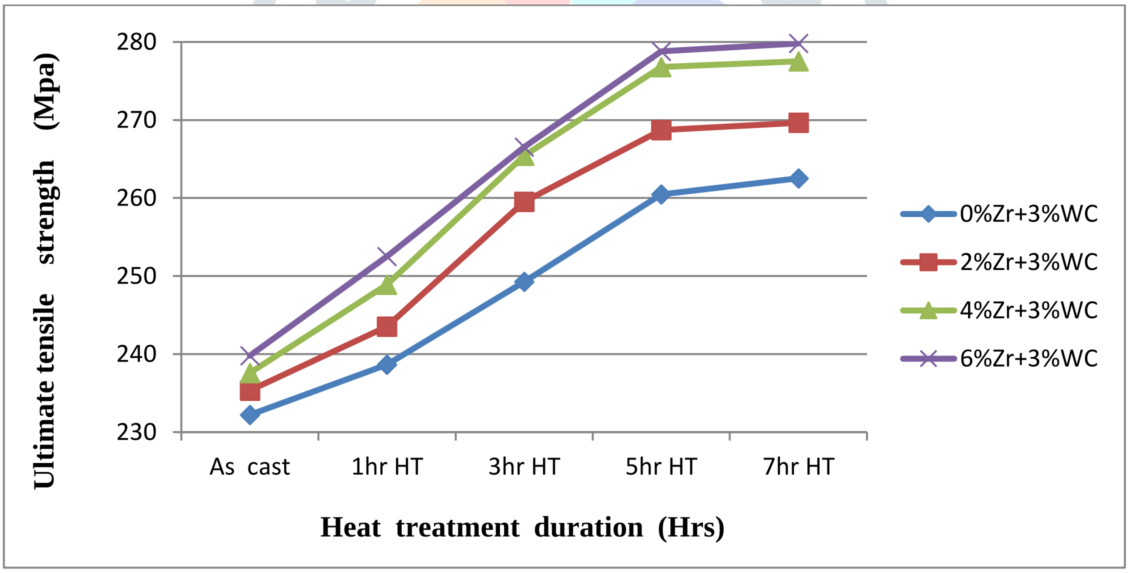

Figure 8 Variation of % composition of zircon with 3% Tungsten carbide

Tensile strength of unheated composite is visible in the graph above. The value climbed to 239.8 MPa for (Al7075 +6 % $ZrSiO_4$+3 % WC), while (Al7075 +0 % $ZrSiO_4$+3 % WC) is 232.21 MPa. In the case of heat treatable aluminium alloys and their composites, the ultimate tensile strength of the composites improved to 279.81 MPa for (Al7075+6% WC+3% $ZrSiO_4$) 7 hours after heat treatment, by lowering the likelihood to crack and increasing precipitation hardening. Finally tensile strength is 16% higher than the unheat treated composite.

## V. Conclusions

With varying weight percentages of tungsten carbide and zircon sand reinforcements with Al7075 as the matrix material, the hybrid composites based on Al7075 were successfully created by stir casting. The following conclusions have been reached within the parameters of the investigation.

1. By making use of stir casting method, Tungsten carbide and Zircon Sand particulates can be successfully introduced in the Al7075 matrix alloy material to fabricate hybrid composite materials.

2. Tensile strength has been increased by 16% hardness was increased by 15% for reinforced and heat treated composites when compared to as cast composites.

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