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Effect of Zirconium on Mechanical Behavior of Aluminum7075

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Abstract: ***Metal matrix composites (MMCs) are rapid increase in research and becoming attractive materials for advanced aerospace applications because their properties can be tailored through the addition of selected reinforcements. The addition of reinforcement materials like metals or ceramics into metal matrix improves its mechanical properties like tensile, hardness and fatigue compared to other conventional materials. In this work Zirconium is used as reinforcement in Al 7075 and metal matrix composites are prepared by using stir casting process. In this four specimens are considered (100 % Al, 99%Al+1%Zr, 98%Al+2%Zr, 97%Al+3%Zr) for finding the tensile strength and hardness properties. The tensile strength of the specimens is to be carried out on MCS60 UTE 60. The Hardness test is to be carried on Vicker's Hardness tester for finding the Hardness property.***

Keywords: Composite specimen, Metal matrix composites, Stir casting process, Al7075

1. Introduction

Aluminum metal matrix composites (MMC) are suitable materials for many applications because of their good plays mechanical and physical properties. In addition of different materials with different composition like Zirconium, graphite, Magnesium and Silicon etc., he concluded that Metal Matrix composite strength is increasing more than usual [1]. In his work he fabricated A356.1 Aluminium alloy reinforced with 0.5%, 1.0%, 1.5%, and 2.0% of Nano sized ZrO2 through stir casting technique. The results obtained by him indicated that 2% reinforcement composite has improved mechanical and wear properties compared to base metal [2]. In his work he studied corrosion behaviour of MMCs of Al 6061 alloy reinforced with ZrO2 by varying wt% of ZrO2 (2.5%, 5% and 7.5%) prepared through stir casting. He found that the corrosion rate decreases with increase in wt% of ZrO2 compared to base metal [3]. He prepared 50 nm size nano composite comprising of aluminium metal matrix reinforced with silicon carbide particles through stir casting route as per the ASTM b577 standard. The effect of pouring temperature and filler material content was studied on mechanical properties of aluminium composite and the results were analyzed by ANOVA. His results showed a negligible effect of pouring temperature on mechanical properties while composition has significant effect. An increase of 65% in tensile strength and 101.5% improvement in toughness was observed with filler content of 0.8 % and 0.6 % by weight consecutively. The maximum increase (65.5%) in tensile strength was observed when silicon carbide content is 0.8% and pouring temperature is 800 °C. Ductility of the composite decreases as filler content is increased [4]. In his work ha has fabricated AMMCs comprises of Molten Al356.2 and Zirconium nano particles of different proportions such as 10, 15 and 20 wt% through stir casting at 750°C. He found that microstructure and mechanical properties of Al356.2 and Zirconium nano particles of 15wt % has homogenous reinforcement particles and thus it enhanced the mechanical properties [5]. In his work, he analyzed creep behavior and microstructure of Aluminum alloy (LM25) reinforced with Zirconium di-oxide (ZrO2) particulate composites by varying proportions of Zirconium-di-oxide from 0% to 9% prepared by stir casting. With the increase in addition of ZrO2 with LM25 the creep strength of the composite material increases, but 3% particle reinforcement has no appreciable effect on creep properties. SEM micrographs revealed that the presences of ZrO2 particles in Aluminium alloy matrix are uniform [6].

He prepared Al-12Si-xZrC MMCs using High-energy mechanical alloying method by varying wt% from 0to 15% in steps of 5.the prepared composites were sintered in a muffle furnace at a temperature of 550°C, followed by cooling up to room temperature. His results indicated that with increase in reinforcement content wear rate decreases and coefficient of friction increases [7]. He fabricated MMCs , A356 aluminum alloy reinforced with 0.75%, 1.5% and 2.5% Al2ZrO5 nanoparticles were fabricated through stir casting technique. The composite with 1.5% Al2ZrO5 exhibited improved values of hardness and compressive strength with values of BHN 61 and 900 Mpa respectively [8].

He fabricated MMCs Al 6061 alloy as matrix and Zirconium Oxide as reinforcement using stir casting method by varying wt% of Zirconium Oxide from 2% to 10% insteps 2%.the investigation concluded that the fracture toughness is highest at 6% reinforcement of ZrO2 and hardness is found to be more at4% reinforcement .The yield strength and the ultimate strength of the composite is reduced as the weight fraction of ZrO2 is increased in the matrix. Microstructure shows reasonable homogeneous distribution of ZrO2 particles in the composite [9]. He synthesized Al-4.5Cu/ ZrSiO4 particulate composite through stir casting ,varying the percentage ZrSiO4 in the range of 5-25wt%.the studies revealed that addition of ZrSiO4 reinforcements, increased the hardness value and apparent porosity by 107.65 and 34.23%

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respectively and decrease impact energy by 43.16 %. As the weight percent of ZrSiO4 increases in the matrix alloy, the yield and ultimate tensile strength increased by 156.52 and 155.81% up to a maximum of 15% ZrSiO4 [10].

Table 1: Chemical Composition of Aluminum Al7075

Element	Percentage	Element	Percentage
Si	0.4	Cr	0.28
Cu	2	Ni	-
Mg	2.9	Zn	6.1
Mn	0.3	Ti	0.2
Fe	0.5	Zr	-
		Al	Remainder

Table 2: Properties of Al 7075

Properties	Density g/cc	Melting point ^{0}C	Tensile Strength MPa	Fatigue Strength MPa	Hardness Hv.
Al 7075	2.8	483	220	160	60

Table 3: Properties of Zirconium

Properties	Density g/cc	Melting point ^{0}C	Boiling Point ^{0}C	Bending Strength MPa	Compressive Strength MPa	Vickers Hardness Hv
Zirconium	5.81	2700	5500	600 – 1400	3500 -5600	1250 – 1300

Table 1,2and3 respectively give the chemical composition of 7075,properties of Al7075 and properties of Zirconium.

2. Preparation of Al-Zr Composites and Specimens

Stir casting process is a simplest and cost effective liquid state fabricating method of metal matrix composites, in which a distributed phase is mixed with a molten matrix by means of mechanical stirring which ensures a more uniform distribution of the reinforcing particles. Therefore Stir casting process is used for the preparation of Al-Zr composite. The Procedure used is as follows:

- Aluminum material 7075 was placed in sand mould and heated to its standard melting point.
- The aluminum 7075 material was heated in stir casting machine and the cotton is placed at the top of lid so that no temperature is lost to surroundings of furnace and also to the environment. The temperature in the stir casting machine was set up to 760°c so that total aluminum material block melts into liquid state
- Fig1 shows the Picture of stir casting machine used for the preparation.
- Zirconium nanoparticles (powder) were preheated up to 326^{0}C in muffle furnace so that the zirconium nanoparticles can mix with aluminum 7075 materials very effectively.
- The preheated zirconium powder was poured into molten metal as per the composition at 760°c while stirrer is on. The zirconium powder is added only as per composition calculated taking density as base value.
- 1%,2% and 3% of Zro_2 by weight was added to Al7075 to obtain different compositions.
- The mixture of both molten aluminum and added zirconium as per compositions was stirred the stirrer of stir casting machine. This stirring was carried for 2-3 minutes so that a total nano particle of zirconium powder was perfectly mixed with molten aluminum.
- After finely mixing the composition the molten composition was reinforced from sand mould(casting machine) and molten metal was poured directly into the already prepared pattern.
- The patterns were allowed to cool for some time at room temperature so that patterns can easily removed.

Figure 1: Stir Casting Machine

3. Mechanical Behaviour of AL7075 with Zirconium

3.1 Tensile Test

The Prepared specimens were tested to find their tensile strength. Specimens prepared as per ASTM-D-638 III Standard. Fig2 shows picture of a specimen used for Tension testing. All the Tensions test were performed on MCS60 UTE 60 machine.

Figure 2: Specimen for Tensile testing as per ASME standards

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Table 4: Tensile Properties of Metal Matrix composite Specimens

S no	Material composition	0.2%proof strength (N/mm^2)	Tensile strength (N/mm^2)	% Elongation
1	100%AL	134.69	218.115	0.540
2	99%Al+1%Zr	135.26	221.12	0.550
3	98%Al+2%Zr	136.12	225.53	0.552
4	97%Al+3%Zr	136.89	227.125	0.561

Table 4 represent the Tensile Properties, 0.2% proof strength, Elongation of Metal Matrix composite Specimens with various percentages of Zirconium.

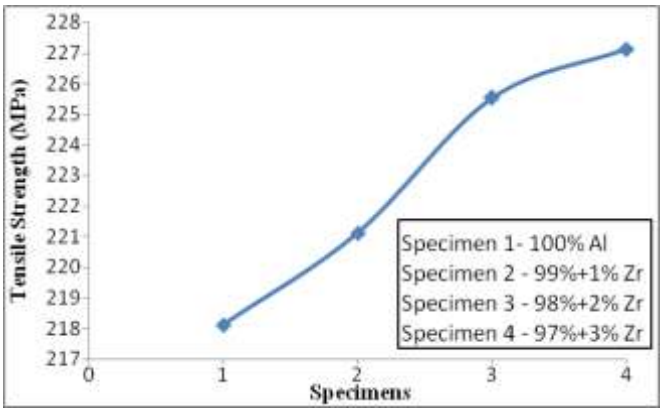

Figure 3: Tensile Strength Vs Material composition

Fig 3 shows that Tensile strength is increasing with the addition of increasing Zirconium Percentage. From all four composite specimens 97%Al+3%Zr tensile strength is Maximum i.e 227.125 N/mm^2.

3.2 Hardness Test

The Prepared specimens were tested to find their Hardness. In order to get the micro hardness of the composite material a special instrument called Vickers micro hardness tester is used. It consists of two lenses which have a variable magnification up to 20X and 50X, a diamond tip is present in the centre of the machine to impact load on the material.

Table 5: Hardness Properties of Metal Matrix composite Specimens

Sl no	Material composition	Hardness VH
1	100%AL	95
2	99%Al+1%Zr	96
3	98%Al+2%Zr	98
4	97%Al+3%Zr	99

Table 5 represent the Hardness Properties of Metal Matrix composite Specimens with various percentages of Zirconium.

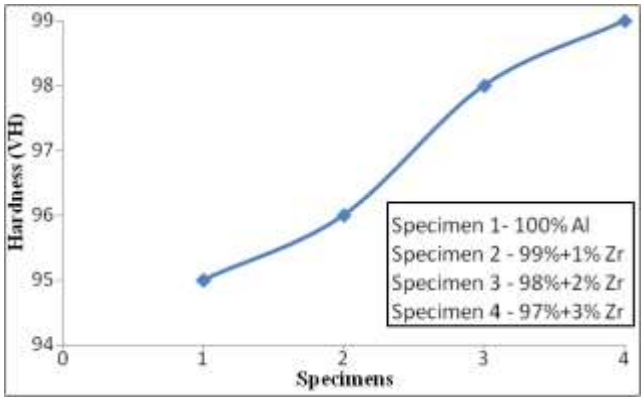

Figure 4: Hardness Vs Material composition

Fig 4 shows that Hardness is increasing with the addition of increasing Zirconium Percentage. From all four composite specimens 97%Al+3%Zr Hardness is Maximum i.e 99vh.

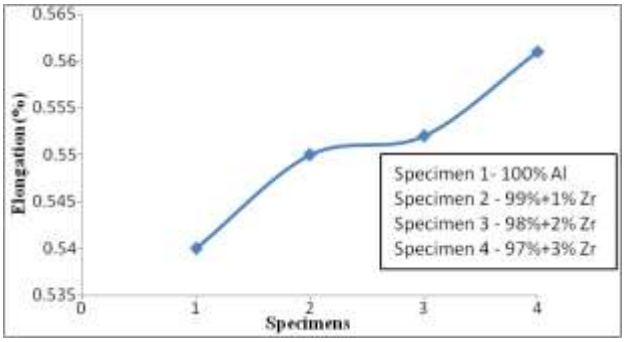

Figure 5: Percentage elongation Vs Material composition

Fig 5 shows that Percentage Elongation is increasing with the addition of increasing Zirconium Percentage. From all four composite specimens 97%Al+3%Zr is Maximum i.e 0.57.

4. Conclusion

The results clearly indicate that both tensile and Hardness properties are improved with increasing percentage of Zirconium in the Al-Zr Composites. From all four composite specimens 97%Al+3%Zr Hardness is Maximum..From all four composite specimens 97%Al+3%Zr Tensile strength is Maximum.

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