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Mechanical Properties of AA7075-Nano ZrO_2 Reinforced Matrix Composites

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Zircon reinforced composites are referred as an unique composite that exhibits relatively improved mechanical properties like high tensile strength and micro hardness compared to pure AA-7075 base metal. The present work aims to investigate that influence of reinforcement of ZrO_2 nanoparticles are mechanical properties of AA7075 alloy and composites prepared through stir casting method. Samples are fabricated through varying the weight percentage of ZrO_2 2 and 4 wt%. All the fabricated castings were heat treated at 100 ^{o}C for 24 h. Mechanical properties of AA7075 and composites were observed in particulars of density, porosity, micro hardness and tensile properties. The grain size and crystal structure of ZrO_2 was confirmed by XRD. Increased reinforcement contents enhances 15.92% of micro hardness and 28.46% of tensile strength was noticed. However, the increasing of particle concentration of reinforcement leads to diminishing of the percentage elongation.

***Keywords*:** AA-7075, Nano ZrO_2, Stir casting, Mechanical characterization.

1. Introduction

Composite materials are the most promising material in exhibiting enhanced mechanical and technological properties compared to conventional materials for many real time engineering applications. Al metal matrix composites have been the subject of passion for many scientists as they overcome the drawbacks of ferrous materials. MMC's combine the metallic properties of matrix materials with ceramic properties of reinforcements and lead to rises tensile and compressive strengths and higher operating temperature capabilities [9]. V R K Rao et al. [1] observed that the tensile and wear properties are improved with TiC particulates and frictional coefficient reduction with rising sliding velocity. Baradeswaran et al. [2] reported that the addition of 5 wt. % of graphite and 2-8 wt. % of Al_2O_3 to base metal decreasing the frictional coefficient.

2. Materials and Methodology

2. 1. Materials

AA7075 is the base metal, in which Zinc major alloying element, which exhibits good casting properties and reasonable strength. It is strong, with good fatigue strength and average machinability, but is not weldable and has less resistance to corrosion than many other alloys. Table 1 and 2 shows chemical composition of AA7075 and ZrO_2. ZrO_2 particles of 20 nm size are used as reinforced at 2% and 4% weight and it is as shown in Fig. 1 (b). It is observed as monoclinic and cubic structure.

Table1. Chemical constituents of AA 7075

zinc	Ti	Si	Mg	Pb	Cr	Fe	Mn	Cu	Sn	Al
5.3	0.2	0.4	2.1	0.029	0.1	0.5	0.3	1.1	0.012	balance

(a) (b) (c)

Fig.2.(1) AA 7075 Round bar pieces, (b).ZrO_2 powder form, (c). Magnesium turnings

Table 2 .Chemical constituents of zirconium dioxide powder

ZrO_2	Fe_2O_3	TiO_2	SiO_2	Others
99.6	0.001	0.008	0.10	0.38

2. 2. Experimental procedure

The synthesis of the composite was carried out by stir casting. By using electric furnace AA7075 were taken into a graphite crucible and melted. At the temperature of 800°C, a vortex was build using mechanical stirrer. To improve wettability magnesium turnings as shown in Fig. 1(c) were added to the alloy. While stirring, the preheated particulates of ZrO_2 at 120 °C for 2 hr. The molten metal was stirred at 800 rpm for 4 minutes under inert gas environment to ensure uniform distribution of particulate in base metal and the poured into metallic die.

(a) (b) (c) (d)

Fig.2. (a) Electric furnace for casting (b) Stir casting (c) Pouring molten metal into Mould (d) Casted fingers

3. Results

3. 1. XRD Analysis

The XRD pattern of ZrO_2 nanoparticles are shown in Fig. 3. All the diffraction peaks are indexed to the monoclinic zirconia. However, the characteristics reflections for cubic phases are located and hence the diffraction pattern of ZrO_2 could be attributed to the monoclinic and cubic phases [3, 4]. The peaks indicated with “diamond” symbol for monoclinic ZrO_2 (m-ZrO_2) with while the “dot” symbol for cubic ZrO2 (c-ZrO_2). The average grain size was measured by using Debye Scherer’s formula and was calculated as 21.01 nm.

3. 2. Density

The AA7075 and composite densities are determined by using Archimedean's principle. By using the rule of mixture the theoretical values of densities are determined.

$$\rho_{MMC} = (m) / ((m\text{-}m1) \times \rho_{H2O} \text{ ----------- } 1$$

Density of composite can be estimated from the Eq. 2.

$$\rho_{\text{composite}} = V_r\, \rho_r + (1\text{-}V_r)\, \rho_m \text{ ----------- } 2$$

The porosity of the test materials were also determined from the following equation.

$$\text{Porosity(\%)} = (1\text{- (experimental density / theoretical density)}) \times 100 \text{ --------- } 3$$

Michael et al. [6] reported that the increasing in reinforcement leads to the decreasing of density and fracture toughness. A Vasantha Kumar et al. [7] studied that the increasing in Titanium dioxide leads to the increasing of density. K. Ravi kumar et al. [5] reported that increase in ZrO_2 and CSA composites at the beginning decreased and then increased. It was observed that the addition of ZrO_2 into the AA 7075 significantly increased the density and porosity are shown in Fig. 4. This is due to the fact that the high density of ZrO_2 5.68 g/cc.

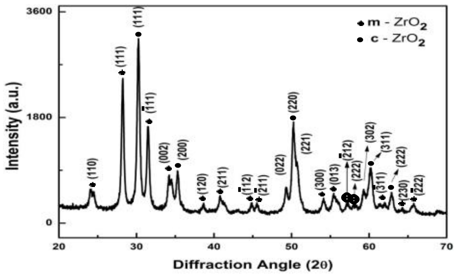


Fig. 3 XRD pattern of ZrO_2 Nanoparticles

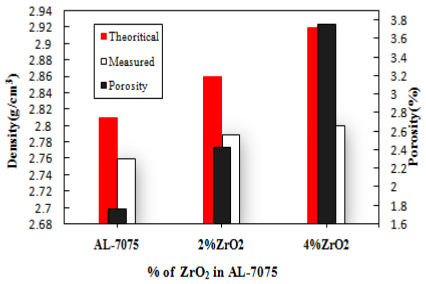
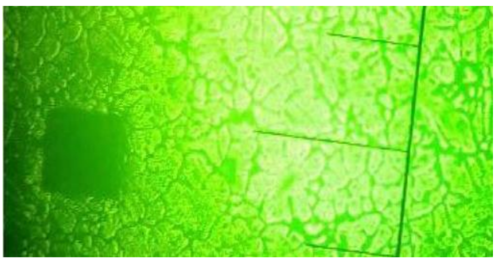


Fig.4. Density variation of Composite

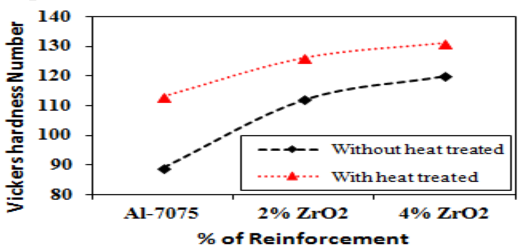
3. 3. Micro hardness

Hardness is the resistance of a material to plastic deformation, usually through indentation. Vickers micro hardness number was estimated for the polished specimens of AA7075 and its composites using Vickers micro hardness tester. Fig.5. (a) Shows the form of indentation. If we take an average of three readings for each hardness values at various locations to circumvent the possible effects of particle discrimination. The VHN for composites reinforced with ZrO_2 were found to be increased compared to base metal, the enhancement in the hardness may be attributed to the existence of fixed and hard zirconium in ZrO_2. The grain size of the reinforcement is also one of the sense for the development of hardness. Related conclusions were observed by [2, 8] authors. The hardness was increased from 113 for AA7075 alloy to 126 and 131 VHN for 2% and 4% of ZrO_2 with heat treated as shown in Fig. 5. (b) A comparison is also made between with and without heat treated specimens and it is noticed that 15.92% hardness is increased for with heat treated specimens.



(a)

Fig.5 (a).Micrograph report the form of the indentation



(b)

Fig.5 (b).Graph of ZrO_2 Composition v/s Vickers Hardness number

3. 4. Tensile strength

Universal testing machine (UTM) (Model: 9036TD) is used for tensile testing at room temperature. The specimens of the test were prepared as per ASTM E8 standards and values were used to determine the tensile strength in particulars of elongation. ASTM E8 Standard tensile specimen with dimensions are given in Fig .7 and tensile specimens after testing are given in Fig 8.

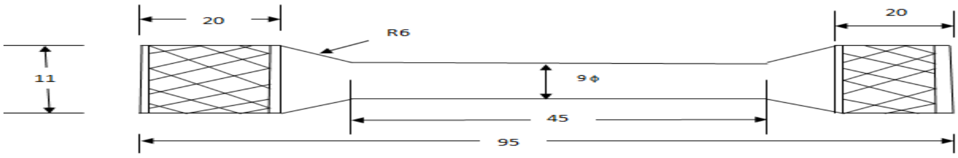
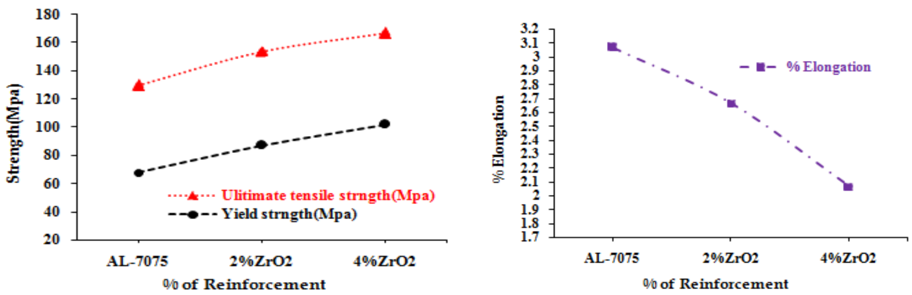


Fig.7 As per ASTM E8Tensile specimen

Fig.8 Tested tensile Specimens

Fig.9. (a) is evident for the enhanced tensile strength and yield strength with increased ZrO_2 in wt. %. Tensile strength of AA7075 is 130 Mpa and it increases to a highest of 167 Mpa for 4 Wt. % reinforced composite. Composites also recorded an enhanced tensile strength of 28.46%, for 4% wt. ZrO_2 reinforced composites compared with AA7075 alloy. Ravi kumar et al. [5] studied that the addition of ZrO_2 particles increases with tensile strength. Madhusudhan M et al [8] observed the increased reinforcement in weight percentage increases with the tensile strength. Increasing the weight percentage of ZrO_2 in base metal leads to progressive decreasing of the elongation of MMC's.



(a) (b)

Figure 9 (a). Tensile Properties with reinforcement content, (b). Elongation (%) Vs Wt. % ZrO_2

Fig.9 (b) shows the experimental elongation of ZrO_2 reinforced AA7075 alloy. 3.07% is elongation of specimen AA7075 this expense is reduced to 2.07% for specimen AA7075 4 wt. % reinforcement. The load bearing capacity and delays crack ignition are enhanced by clean interfaces of composites.

4. Conclusion

Due to good interfacial bonding of Zirconium oxide in aluminium matrix its usage as reinforcement is highly appraisable. Stir casted composites has shown increase in density by 3.9%. Composites also recorded an enhanced tensile strength of 28.46%, hardness of 15.92%, for 4% wt. ZrO_2 reinforced composites. Crack initiation might have taken place because of the presence of ZrO_2 phase in the developed composites.

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