MECHANICAL AND MICROSTRUCTURE STUDIES OF TWO STEP STIR CASTED AA7150-TIC NANOCOMPOSITE

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Abstract - This research deals with AA7150-TiC nanocomposite and its mechanical properties for fracture surface studies under tensile testing conditions. Two step stir casting and vortex methods were employed to fabricate AA7150-TiC nanocomposites. Titanium carbide was selected as reinforcement and added into a molten liquid with various weight percentages such as 0.5, 1.0, 1.5, and 2.0 wt% to find the effect of reinforcement and optimal percentage for enhancing certain characteristics such as hardness and strength of nanocomposites. Addition of 1.0 wt% of reinforcement showed better mechanical properties. At optimal percentage, an Optical Microscope was used to analyze the grain boundaries, average grain size, as well as compare these with monolithic and 2 wt%TiC. Scanning Electron Microscope for fracture surfaces was used to find the nature of failure and EDS for the chemical composition of nanocomposites.

Keywords - Stir Casting, AA7150, Microstructure, Mechanical Properties, Nonocomposites, TiC.

I. INTRODUCTION

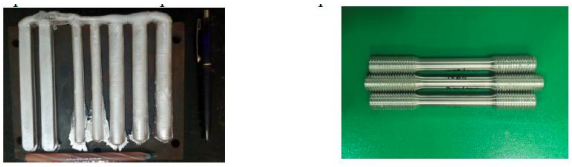
Aluminium alloy nanocomposites have achieved high popularity in various technical sectors and are playing a major role in aerospace and automobile structural applications due to their superior properties such as mechanical strength, corrosion resistance and strength to weight ratio [1]. In such attempts, the 7xxx series alloys (Al-Cu-Mg-Zn) meet the above properties and are widely using for critical structures in aerospace applications due to low weight, high toughness, strength, and fatigue resistance [2-4]. The hard phase particulate reinforced composites have paved a novel path to develop high wear resistant and strength of material [5]. The investigation of nano titanium carbide (TiC) particle reinforced to aluminium alloy metal matrix based composites has not been adequately researched and it has come into popularity only recently due to its low coefficient of thermal expansion (CTE), high melting point, superior hardness and wear resistance [6,7]. The size of the particles ranging from micro to nano level scale, increases the mechanical properties but it tends to increase the clusters and agglomerations [8-10]. It is also an important task to produce homogeneous distribution of nano scale reinforced particles in dense liquid metals to attain the required properties [11].

The preparation cost of the nanocomposites using different methods is quite expensive as compared to liquid metallurgy route and two step stir casting is chosen for manufacturing particle reinforced composites due to maximum yield with minimum investment, low wastage and damage [12,13]. In this procedure, nanoparticles are added into the molten aluminium alloy matrix using vortex technique [14,15] to avoid the floating of nanoparticles and two step stir casting process is performed to improve the wettability. Therefore, it reduces the porosity of the composites and the cost of final product [16].

This paper deals with aluminium 7150 alloy with various weight percentages of titanium carbide nanoparticles as reinforcement to produce the nanocomposites by using two step stir casting process. The mechanical and microstructural characteristics are studied for nanocomposites. The optical microscope (OM), scanning electron microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDS) are used to analyze the grain boundaries, particle distribution, fracture surface of tensile sample, and chemical composition of the nanocomposites under optimal conditions for determining mechanical properties.

II. MATERIALS AND METHODS

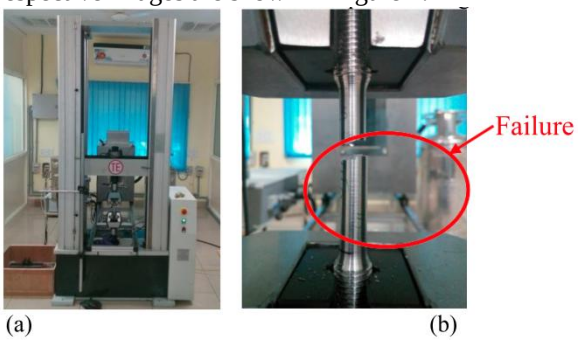
7150 aluminium alloy was selected as matrix material and purchased from Venuka Engineering Private Limited, Hyderabad, India. Titanium Carbide nanoparticles were obtained from Platonic Nanotech Private Limited, Jharkhand, India, with a purity >99.9%, density 4.90g/cc and average particles size of 30-50nm. To fabricate the TiC reinforced nanocomposite, two step stir casting technique was adopted and it involves 20min of time. Each step took 10min to achieve the homogeneous dispersion of reinforcements in liquid metal. The preheated (500^{O}C) titanium carbide nanoparticles were added with various reinforcement weight percentages (0.5, 1.0, 1.5, 2.0 wt%) into the aluminium metal pool by using vortex method and mechanical stirring action was then performed. The degassing tablet (C2Cl6) was used to degas from the molten liquid and 1%Mg added for wettability improvement of nanoparticles into a melt pool.



(a) (b)

Figure 1. (a) Solidified samples in mold (b) Tensile test samples

The fabricated liquid was poured into preheated (500^{O}C) die steel mold and allowed to cool for 24hrs at atmospheric temperature. The solidified AA7150-TiC samples were machined as per ASTM standards such as ASTM E8M small for tensile test and the respective images are shown in Figure 1.



(a) (b)

Figure 2. (a) UTM machine (b) Failure of tensile specimen

Mechanical properties such as tensile strength were tested using Universal Testing Machine (Model: WDW 100S Blue Star) as shown in Figure 2. and micro hardness test was done using vicker hardness tester (Make: Econometer VH 1MD, 2Kgf). The microstructure of the composites have been studied by employing three techniques such as optical microscope (Olympus MX63), scanning electronic microscope (Tescon, Vega 3LMU), Energy Dispersive X-Ray Spectroscopy (Oxford Instruments, UK).

III. RESULTS AND DISCUSSION

The micro hardness test was conducted on AA7150-TiC nanocomposites by using vicker hardness tester. The experimental results are graphically represented in Figure 3. It was found that the hardness of AA7150-TiC nanocomposite increases (33.4% as compared to monolithic) with increase in titanium carbide nanoparticles content of upto 1.0 wt% and superior at 1.0 wt% (174 HV) than that of monolithic alloy due to the hard nature of titanium carbide particles.

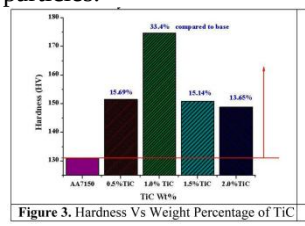


Figure 3. Hardness Vs Weight Percentage of TiC

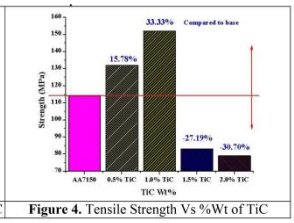


Figure 4. Tensile Strength Vs %Wt of TiC

Titanium carbide particles in Aluminium 7150 alloy offers protective layer to soft aluminium alloy, which results in lower deformation and protest the cutting of slides and penetration on the nanocomposite surface [17]; further increment of weight percentage leads to decrease in hardness due to agglomerations, clusters and voids, as shown in Figure 5.

The ultimate tensile strength for various weight percentages of nanocomposites are represented in graphical way and it is shown in Figure 4. From the graph, it was found that the ultimate tensile strength of the nanocomposites increases (33.3%) with titanium carbide nanoparticles and the mechanical properties of AA7150-TiC nanocomposites improved mainly due to stress transformation from the matrix material to reinforced hard phase titanium carbide particles.

This transformation is because of Orowan mechanism by which a dislocation bypasses the dense obstacles, where a dislocation plays substantially to leave a dislocation loop around hard phase particle [18]. This dislocation and nano titanium carbide interactions lead to improvement in strength of the titanium carbide reinforced nanocomposite up to 1.0 wt%. Further improvement of nano titanium carbide particle content leads to reduction in strength of nanocomposites due to agglomerations and clusters. These are mainly due to larger interfacial area (size of the particles in nano level scale),presence of many surface atoms and it leads to large surface energy potential for agglomerations [19]. Therefore, the results show decrease in strength and hardness of theAA7150-TiC nanocomposites.

MICROSTRUCTURE ANALYSIS

The microstructure results of AA7150-TiC nanocomposite samples are carried out at optimal and lower mechanical properties (1.5 wt% and 2.0 wt%) and compared with the monolithic alloy. The grain refinement was observed through an optical microscope and the average grain size of nanocomposites calculated by linear intercept method at monolithic, 1.0 wt% (optimal properties) and 2.0 wt% (minimal properties) using ImageJ software at different principle directions shown in Figure 5. The values (75.46µm, 46.29µm, and 62.74µm) were measured using average grain size formula (AGS=length of line to number of grains) and it plays a major role in mechanical properties.

The observation from the results shows that the grain size is decreasing (38.66% decrease as compared to monolithic) with increase of titanium carbide nanoparticles content by upto 1.0 wt%. Further improvement of titanium carbide nanoparticles leads to increase in grain size, which results in deterioration of the mechanical properties of the composite materials [20]. The visual observation of the images

also confirms finer grain sizes at 1.0 wt% as compared to its counterparts without the alloy, as confirmed by Figure 5.

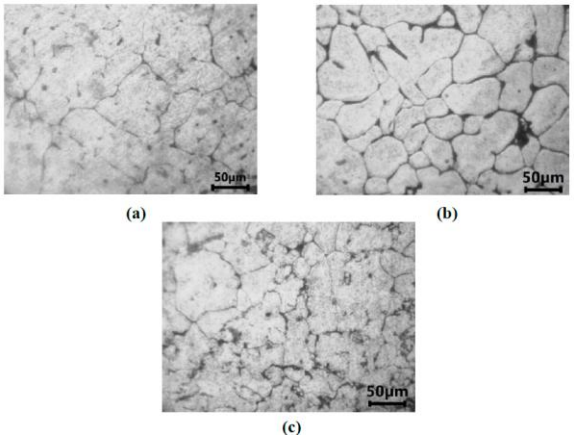


Figure 5. Optical Microstructure of (a) AA7150 (b) 1.0 wt%TiC (c) 2.0 wt% TiC

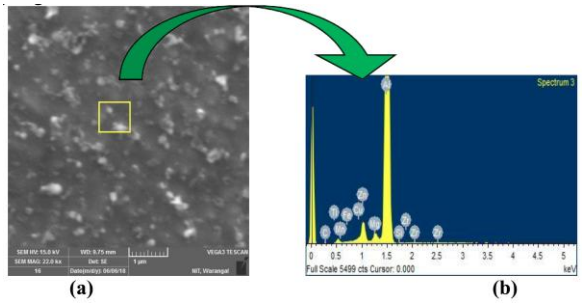
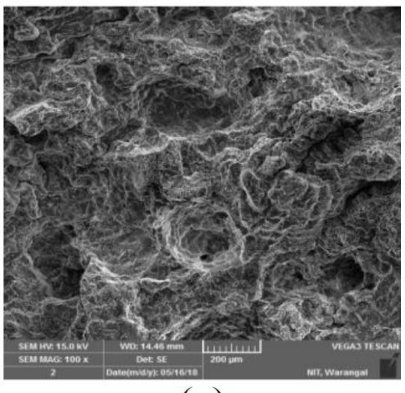


Figure 6. (a) SEM image for particle distribution (b) EDS for elements at 1.0 wt%TiC

The morphology of AA7150-TiC nanocomposite is carried out using scanning electron microscope under optimal mechanical properties (1 wt%) as shown in Figure 6a. The image confirms that the titanium particles are homogeneously distributed and it leads to grain refinement, which results in superior mechanical properties. The Energy Dispersive X-Ray Spectroscopy was used chemically analyse the alloy under optimal conditions and the spectroscopy is shown in Figure 6b and it confirmed that major elements such as Aluminium, Zinc, Copper, Magnesium and minor elements such as Si, Zr, Mn, Fe, and reinforcements such as Titanium and Carbide are present in the nanocomposite.



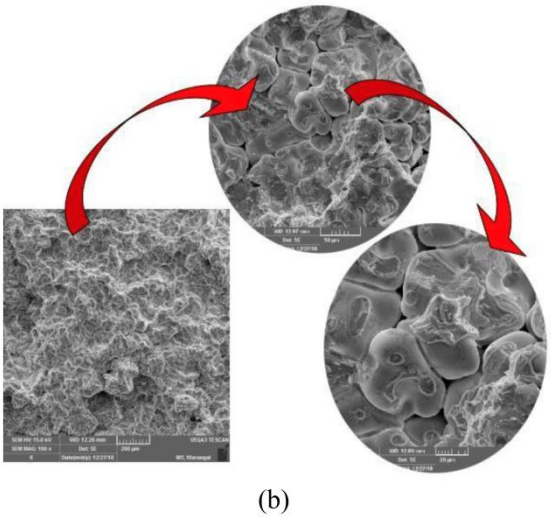


Figure 7. SEM Fracture surface of (a) AA7150 (b) 1.0 wt% AA7150-TiC nanocomposites at 100X, 500X, 1000X magnification

The tensile sample fracture surface at monolithic, as well as maximum strength of AA7150-TiC nanocomposite was captured by using scanning electron microscope at various magnifications and the enlarged microstructure confirms the nature of failure. The respective micro images are shown in Figure 7 and these show a lot of micro voids, cracks, facets and grape shaped dendrites and these micro cracks as well as voids are minimized at 1.0 wt% reinforced titanium carbide (b) compared with monolithic. Hence, they resulted in better mechanical property enhancement while the failure is brittle in nature.

CONCLUSIONS

In this research article, mechanical and microstructural properties of AA7150-TiC nanocomposites were studied and made the following conclusions were arrived at:

- The effect of TiC nanoparticles was observed for enhancement of mechanical properties such as ultimate tensile strength (33.3%) and hardness (3.4%) as compared to monolithic alloy at 1.0 wt%.
- The grain refinement theory using OM confirms finer grain size (46.29µm) at 1.0 wt% and agglomerations at 2.0 wt% of AA7150-TiC nanocomposites.
- SEM and EDX confirm homogeneous distribution and chemical composition of nanocomposite at 1.0 wt%.
- The fracture surface studies of the tensile samples states that the nature of failure is brittle and any further improvement of reinforcements leads to agglomerations and voids.

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