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Mechanical Characterization of Aluminium -Titania Metal Matrix Composites

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Abstract. Researchers investigated the mechanical properties of Aluminium Metal Matrix Composites (AMMC) with several reinforcements and negligible work has been administered on analysing the mechanical characteristics of AMMC with rutile nanotitania reinforcement material. Metal matrix composite with Aluminium 6061 metallic element as matrix material and nanotitania as reinforcement with 0.5, 1.0, 1.5 and 2.0 weight percentages was fabricated through stir casting method followed by die casting and heat treatment. Consequent exploration on mechanical characteristics viz. micro hardness, tensile, compressive and impact strength were carried out. The fabricated samples were examined using scanning electron microscopy and analysed. The outcomes exhibited enhanced mechanical characteristics for 1.0 weight percentage nanotitania reinforced aluminium6061 metal matrix composite material.

Keywords. Aluminium Metal Matrix Composites, nanotitania, stir casting, heat treatment.

1. Introduction

Composites are a combination of two or more individual materials with distinct characteristics when combined together result in a material possessing characteristics that vary from that of the individual composition. The individual components of composites are a continuous matrix and one or more discontinuous reinforcements. The matrix provides the bulk form for the final product and it also encloses the reinforcements within it. The reinforcements either fully or partially bear the load applied on the composites [1]. The properties of the composites depend on the individual properties, shape, orientation and the amount of reinforcements added within them. Owing to their high fatigue and corrosion resistance, high strength to weight ratio, greater reliability composites are commonly applied in radars, rocket engines, jet engines, turbine blades, fan blades, helicopter rotor shafts, automobile engines, bodies, connecting rod etc. [2].A composite which has either a particle or fibre reinforced within a matrix of pure metal or metallic alloy is called as metal matrix composite. Commercial aluminium, magnesium, titanium alloys are commonly used as matrix materials and particulate or fibres of silicon carbide, titanium oxide or aluminium oxide is commonly used as reinforcements [3]. A further improvement in the fabrication of composites is the addition of nano sized reinforcements in the matrix resulting in nano

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composites. The major advantage of nano composites is that they possess higher mechanical strength, toughness and thermal properties compared to other composites [4].Aluminium metal matrix composites are the materials which contain aluminium as a matrix and reinforcements of different materials ranging up to 70 % volume fraction. The reinforcements can be continuous or discontinuous fibres, whisker or particulates and can be added to satisfy the requirements of several industrial components by varying the types of matrix and reinforcements [5]. Aluminium metal matrix composites find foremost submissions in the auto and aero industries, thermal management, industrial and recreational fields such as aircraft fuselage owed to their exceptional wear resistance, thermal and electrical characteristics and high structural efficiency, car brake disc, light metal diesel piston etc. [6].

Stir casting is commercially accepted as a low-cost technique producing AMMCs. Its benefits include uncomplicatedness, suppleness, and its capability in large volume production. This process is the utmost cost-effective of several existing ways for AMMCs fabrication. It permits fabrication of large dimensional components [7]. However fabrication of aluminium metal matrix through stir casting under non optimal process conditions leads to defects such as porosity, poor wettability, and non-uniform distribution of reinforcements [8].

Throughout the manufacture of composites through stir casting, the key factor is the mechanical stirring and dispersion of the reinforcements into the molten matrix. The consequential molten alloy along with ceramic reinforcements, can then be utilized for permanent mould casting, sand casting or die casting [9]. The addition of higher modulus and higher strength refractory particulate reinforcement in a ductile metal matrix leads to the development of a new class of material having mechanical properties halfway between that of the ceramic reinforcement and matrix alloy [10,11].

The major challenges of fabricating composites through stir casting are the ability to maintain its wettability and also the segregation of reinforcement materials. Wettability can be achieved by using wetting agents and also by preheating the reinforcement particles to remove absorbed gases from particle surfaces [12,13]. The segregation of reinforcements in composites is due to the difference in the densities between the matrix and reinforced particles. This can be avoided by the incorporation of reinforcing phase in semi-solid condition, the geometry of the mechanical stirrer and the location of the mechanical stirrer in the melt. The mechanical and microstructural properties of the aluminium metal matrix nanocomposites are found to vary by the type of reinforcement material, weight fraction of the reinforcements, size and orientation of reinforcements [14,15].

2. Materials and Method

Aluminium alloy 6061 with the following composition (in weight %): Silicon - 0.503; Iron- 0.520; Copper - 0.093; Manganese - 0.089; Magnesium -0.933; Tin - 0.040; Zinc - 0.019; Nickel- 0.044; Chromium- 0.138; Titanium - 0.023; rest - aluminium was used as the matrix material and nanotitania of 50 nanometer size was used as reinforcement material.

The AMMCs were fabricated through stir casting. In this process the aluminium is melted above its melting points. The liquid was later cooled to a temperature between the melting and solidus points and maintained in a semi-solid state. At this stage, the preheated reinforcements were added and mixed. The slurry was again heated to a fully liquid state and the melted material was continuously stirred for uniform distribution of reinforcement particles.

When the melt is continuously stirred, its surface is exposed to atmosphere and oxidation takes place. To completely avoid the oxidation process an inert environment is created by the addition of wetting agents such as TiK_2F_6, borax and magnesium. The homogeneous distribution of the reinforcement is influenced by several stirring parameters such as stirring time and speed, size of impeller, impeller blade angle, and position of impeller. In this study an electrical resistance heating graphite crucible furnace with the temperature range of 0-1000° was used to melt the material. A three blade mild steel impeller coated with alumina powder to avoid iron contamination with the molten aluminium metal was used as the stirrer. The impeller was placed 20 mm above the bottom of the crucible. The impeller blades were tilted at 45º. This design prohibited the heavier nanotitania from settling when the melted slurry was stirred for 5 minutes. Furthermore, stirring at an optimized speed of 310 rpm created a vortex in the melt, and this effectively improved the distribution of the particles. The stir casted composite specimens were later heat treated by solutionizing, quenching and artificial ageing. The melt, with incorporated nanotitania, are poured in to a mould rod of 250mm length and 20mm diameter. Figure 1 shows the experimental setup used in this study during the fabrication of composites. The varying combinations of the fabricated composites with the reinforcements are given in table 1.

a) Stirring of molten slurry b) Stir casting setup

Figure 1. (a-b) Stir casting

TABLE 1. THE VARYING WEIGHT PERCENTAGES OF FABRICATED COMPOSITES

Matrix	Reinforcements (Weight percentage)	Fabricated composite
Aluminium-6061	Nano titania - 0.5%, 1.0%, 1.5% & 2.0%	Al6061 – nanotitaniacomposites

3. Results And Discussion

Mechanical properties such as tensile strength, compressive strength, impact strength and micro hardness were measured. The tensile, compressive, impact and hardness test specimens were prepared as per ASTM specifications from the fabricated and heat treated composites. The specimens were loaded at constant rate and the stress and strain diagrams were obtained to study the tensile and compressive behaviour of the composite specimens.

Figure 2a. Tensile test

Figure 2b. Compressive test

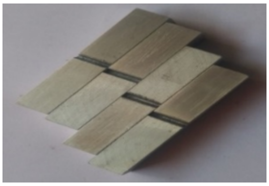


Figure 2c. Impact test

Figure 2d. Hardness test

Figure 2. Specimen for mechanical characterization

Micro hardness of the fabricated composites was measured with a Vickers micro hardness tester using a load of 5 N and a dwell period of 15 seconds and the impact testing was carried out on a Charpy impact tester. The specimen for conducting tensile, compressive, impact and micro hardness testing are depicted in figure 2. (a to d).

The ultimate tensile strength of the fabricated composites increased with increasing volume fraction of nanotitania reinforcement till 1.0 weight percentage. On further increase in the volume fraction of reinforcements the tensile properties decreased as shown in figure 3. The improved strength can be attributed to the fact that the addition of reinforcements might have provided a higher resistance to tensile stresses and the load distribution from the matrix to the reinforcements. Yet on further increase in the volume fraction of reinforcements the properties decreased due to their poor wettability with matrix.

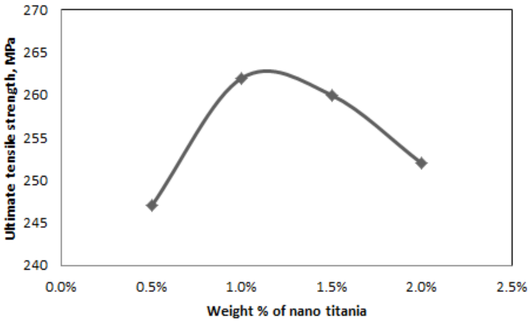


Figure 3. Ultimate tensile strength of nanotitania composites

The ultimate compressive strength of the fabricated composites is shown in figure 4. and the impact strength of the composites is shown in figure 5. The compressive and impact strength increases with the increasing weight fraction of reinforcements owed to the addition of the hard ceramic particles, which act as the hindrances to the motion of dislocation that contributes to the increase in the compressive and impact strength [16-22].

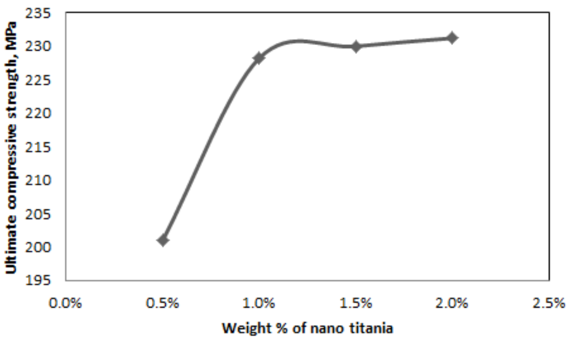


Figure 4. Ultimate compressive strength of nanotitania composites

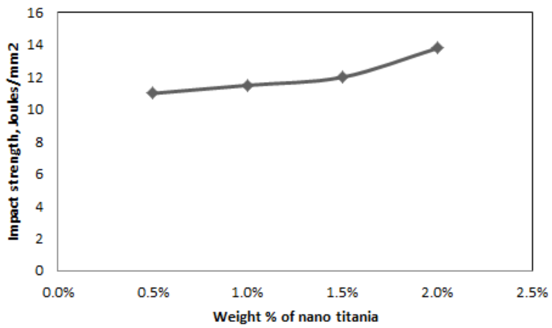


Figure 5. Impact strength of nanotitania composites

The microhardness of the fabricated composites was measured at four different places and their average hardness was calculated. The average Vicker's micro hardness (Hv) values for various weight percentages of the fabricated aluminiumnanotitania composites are indicated in figure 6. It is found that the addition of nano reinforcement increases the hardness of the composite material. This can be attributed to the presence of extremely harder nanotitania reinforcements in Al6061 matrix material which improves its hardness.

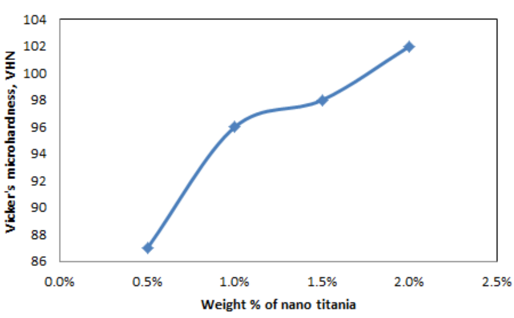
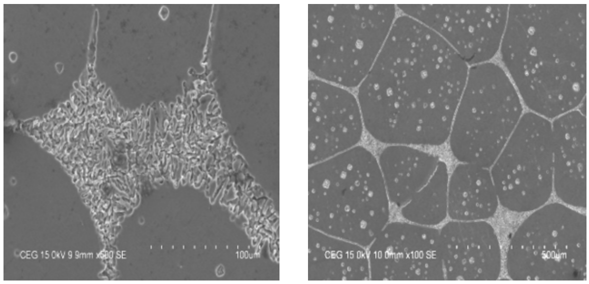


Figure 6. Vickers micro hardness of nanotitania composites

The microstructure of 0.5 and 1.0 weight percentage of nanotitania reinforced aluminium 6061 metal matrix composites are shown in figure 7.(a-b). The most important aspects of the microstructure are the distribution of the reinforcement particles in the matrix. It is apparent from the SEM images that nanotitania reinforcement particulates were distributed uniformly throughout the aluminium 6061 matrix and evidently portrays the interface between the matrix and reinforcement particles.



a. Microstructure of 0.5 wt% nanotitania composite

b. Microstructure of 1.0 wt% nanotitania composite

Figure 7 (a-b). Microstructure of nanotitania – aluminum6061 composite

4. Conclusion

Based on the studies of the fabricated aluminium 6061-nano titania reinforced metal matrix composites the following conclusions can be obtained.

- Nano titania particles can be used as reinforcement material to improve the mechanical properties of the aluminium 6061 matrix material.
- Addition of nanotitania enhances the ultimate tensile strength of composites up to 1.0 weight percent of reinforcement particles.
- Addition of nanotitania augments the compressive and impact strength of the fabricated composites.
- Addition of nanotitania enriches the micro hardness of composites.
- The microstructure of the nanotitania reinforced aluminium 6061 metal matrix composites depicts the unvarying distribution of reinforcement particles in the matrix material.

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