International Journal of Advance Research and Innovation
Vol. 4(4), Oct-Dec 2016, pp. 153-157
Doi: 10.51976/ijari.441625

Article Info
Received: 25 Sept 2016 | Revised Submission: 20 Oct 2016 | Accepted: 28 Nov 2016 | Available Online: 15 Dec 2016

A Study on Machanical and Tribological Properties of Aluminum Metal Matrix Composite Reinforced with TiO_2 and Graphene Oxide

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AsBSTRACT

Graphene and its derivatives have been comprehensively studied as an innovative material for various engineering applications. These materials have excellent mechanical properties such as high strength to weight ratio, stiffness, and modulus of elasticity. In present work, attempts were made to incorporate the graphene oxide in various compositions (0.5. 0.75 and 1.0 wt.%) to newly developed AA7075 - TiO2 reinforced aluminum metal matrix composites. Stir casting technique was used to fabricate the AA7075 - TiO2 - Graphene oxide composite. The newly prepared composite specimens were subjected to microstructure, hardness, tensile, and wear examinations. Microstructure examination reveals uniform distribution of reinforcements. Hardness, ultimate tensile strength and wear resistance of prepared composites increased with increase in reinforcement percentage in matrix.

Keywords: *AA7075; Stir Casting; TiO2; Graphene Oxide; Hardness Test; Pin on Disc Wear*.

1.0 Introduction

Materials are significant part of our day to day life. Materials are more deep-rooted in our culture than most of us distinguish about it. Building, transportation, textile, communication, entertainment, and food processing etc., are depending on different materials. Early civilizations have been grouped by the level of the material's development stages as Stone Age, Bronze Age, and Iron Age. The development of diverse technologies which make our life much more contented than before, has been very much connected with several different type of materials that are developed over the years. Many of the engineering applications in the world today require materials with usual combinations of properties that cannot be met by conventional metals, alloys, ceramics and polymers [1]. There is an ever-increasing need for advanced materials with high physical, mechanical and tribological properties. This is very much true for the materials that are crucial in the aerospace and automotive industries. In the world today, aerospace engineers are in pursuit of structural materials those have high strength and low density. Strong materials are relatively dense, also increasing the strength or stiffness, generally results in a decrease in impact strength [2]. Composite materials were synthetically shaped by combining two or more materials, which usually have different properties. Metal matrix composites (MMC) have emerged as an important class for structural, wear, thermal and electrical applications, primarily because of better strength to weight ratio and strength to cast ratio when compared with equivalent commercial alloys [3]. Metal matrix composites properties are depends on the matrix material, reinforcement material and composite fabrication techniques. Aluminum is used as a key metal matrix constituent in the production of composite material for improved mechanical properties combined with low density. Aluminum metal matrix composites (Al-MMC) containing particulate reinforcement are considered as the hopeful solution for imparting better wear resistance to aluminum. Most of the researchers tried to reinforce aluminum and aluminum alloys with ceramic particles to improve their properties [4]. SiC, Alumina, CuO, B4C, TiB2, TiO2, TiC, Graphite, granite dust, bamboo leaf ash, rice husk ash etc. were used as particulate reinforcements in varying proportions, by numerous researchers. Among these

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SiC and Alumina were extensively used as reinforcements and their effect on aluminum material matrix composites was studied. A key challenge for lightweight materials is the ability to produce an efficient component at acceptable mechanical properties [5]. There are numerous methods that are available to produce composites. Generally used methods for fabricating composites are Stir casting (Liquid metallurgy) technique, Powder metallurgy technique and Compo-casting method. Hybrid composites possess better properties when compared with single reinforced composites as they combine the advantages of their constituent reinforcement [6].An attempt was made to fabricate aluminum metal matrix composite reinforced with TiO2 particles and graphene oxide through stir casting technique. The mechanical and tribological properties were studied for the fabricated composite specimens.

2.0 Experimental Details

2.1 Materials

Aluminum 7075 alloy was chosen as matrix material for present work. Aluminum 7075 alloy has beneficial application in aircraft, marine, and automotive industries. Aluminum 7075 is a precipitation hardening alloy, containing zinc as its major alloying element. TiO2 and Graphene Oxide (GO) were used as reinforcement materials. Three different weight percent of Graphene Oxide (0.5%, 0.75% and 1.0%) and fixed weight percent of TiO2 (10%) were used in the experiments. Composition of matrix and properties of reinforcements are shown in table 1, 2 and 3 respectively. Figure 1 shows the alloy ingots and reinforcement materials respectively.

Table 1: Composition of the Alloy used for Present Work

Element	Al	Zn	Mg	Cu	Cr	Fe	Mn	Si	Ti
Weight %	89.5	5.6	2.5	1.6	0.23	0.37	0.06	0.12	0.02

Table 2: Properties of TiO2

Molecular formula	Molar mass	Density	Melting point	Boiling point
TiO_2	79.866 g/cm^3	4.23g/cm^3	1843°C	2972 °C

Table 3: Properties of Graphene Oxide

Carbon Purity	~99%
Average number of layers	3-6
Thickness	0.8~2 nm
Surface area	>350 m^2/g
Lateral dimension	5-10 μm

Fig 1: Aluminum 7075 Alloy ingot, TiO2 Powder and Graphene Oxide Powder

2.2 Fabrication of composite castings by stir casting technique

The stir casting technique was employed to prepare composites. Stir casting method is considered to be most economical and convenient method to fabricate metal matrix composite with discontinuous particulates. In this process, aluminum 7075 alloy was first melted in a 3-phase electric resistance furnace to a temperature of 750˚C, using graphite crucible of 12" size. Degassing treatment was made using Hexachloroethane (C2C16) tablets. Stirring was carried out at 220 rpm up to 5 minutes, which results in formation vortex in the melt. Preheated TiO2 and graphene particles at 250˚C were added one by one slowly and steadily into the vortex, while continuing stirring for 5-10 minutes. The molten metal at 750˚C was poured into preheated, pre-coated permanent metallic finger mould and allowed for solidification. After taken out from mould, the specimens were machined as per ASTM standards to carry out microstructure, hardness, tensile and wear tests. The prepared composites were designated as A1 – Al-

10%TiO2-0.5%GO, A2 – Al-10%TiO2-0.75%GO, A2 – Al-10%TiO2-1.0%GO.

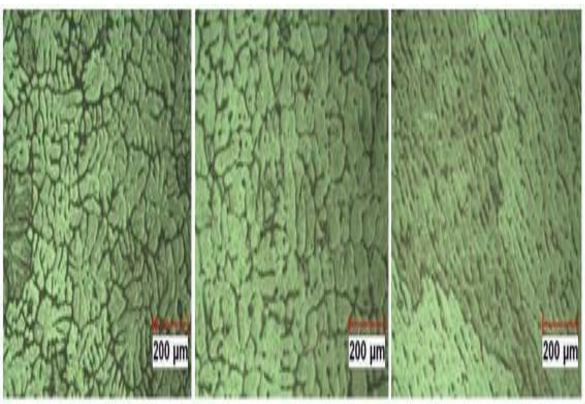
3.0 Results and Discussions

3.1 Microstructure examination

Figure 2 shows the microstructure of the different composition metal matrix composites. Figure 2 (a) reveals the formation of dendritic structure. Microstructure forms fine inter-dendritic precipitate in aluminum solid solution. Porosity can be seen in the section. From figure 2 (b), it can be seen that microstructure consists of equiaxed grain structure. It can be observed that grain size is reduced, because breaking of dendritic structure during fabrication of composite. Minimal porosity was observed in the section, this might be because of gas entrapment during solidification. From figure 2 (c), its observed that microstructure consists of a mixture of columnar and dendritic structure. Segregation was not seen in the section. No porosity was also seen in the section.

Fig 2: Optical Micrographs at 100X Magnification of Fabricates Composites (a) Al-10%TiO2-0.5%GO (b)Al-10%TiO2-0.75%GO (c) Al-10%TiO2-1.0 %GO

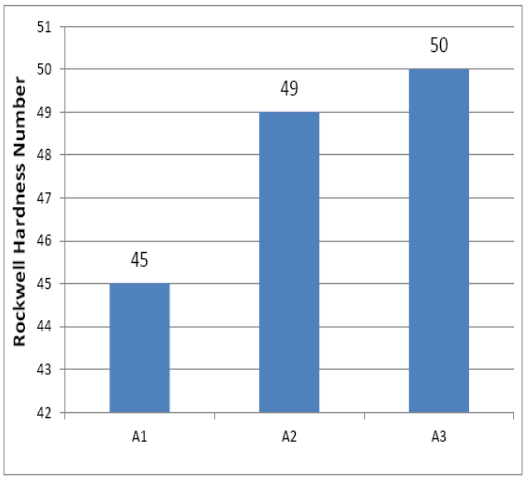
(a) (b) (c)



3.2 Rockwell hardness testing results

Figure 3 shows a comparison between hardness of the prepared composite specimens. From the chart it is evident that hardness value increases with increase in graphene oxide weight percentage in composites. Increase in hardness value is due to elimination of porosity in the prepared composites. From microstructure it is evident that there is no porosity in AA7075-TiO2-1.0GO composite, hence increase in hardness was observed.

Fig 3: Rockwell Hardness Test Results Where A1: Al-10%TiO2-0.5%GO, A2: Al-10%TiO2-0.75%GO, A3: Al-10%TiO2-1.0 %GO



3.3 Tensile test results

Tensile test results for prepared specimens show the increase in true ultimate tensile stress (UTS), engineering ultimate tensile stress (UTS) and peak load. Increase in tensile values is due to presence of reinforcements in the matrix. These reinforcements could be hindered the crack propagation in matrix.

Addition of reinforcements leads to brittle fracture, which is evident from the graphs obtained from software PC2000 Bench Tensometer. Variation of true UTS, Engineering UTS and Peak load with composites are plotted in Figure 4 and 5 respectively.

3.4 Wear test results

Weight loss recorded on composites specimens at different loading conditions (1 kg and 2 kg) are as shown in figure 6. Pin on disc dry wear test revealed that addition of reinforcements lessens the wear loss.

Wear loss were decreases with increasing reinforcement percentages in the matrix material. The beneficial effect of wear resistance was more for AA7075-10%TiO2-1.0GO.

The decreased wear could be because of increase in hardness value of AA7075-10%TiO2-

1.0GO. The wear resistance increases as the material become harder.

Fig4: Variations of True Stress and Engineering Stress with Composite Specimens

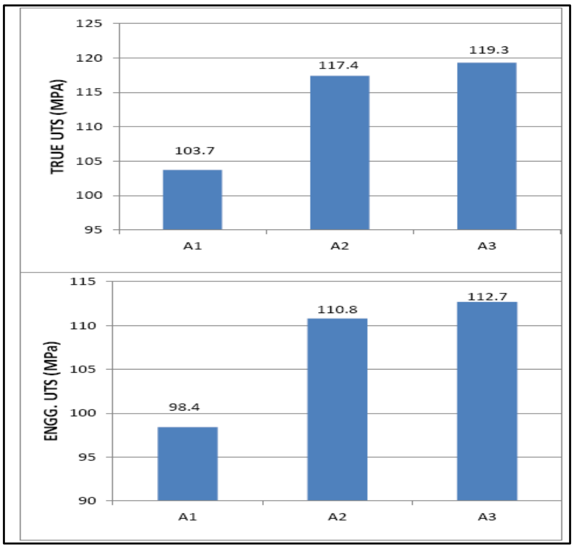


Fig 5: Variation of Peak Load with Composite Specimens

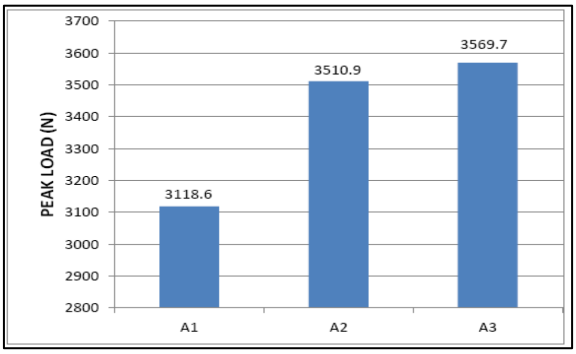
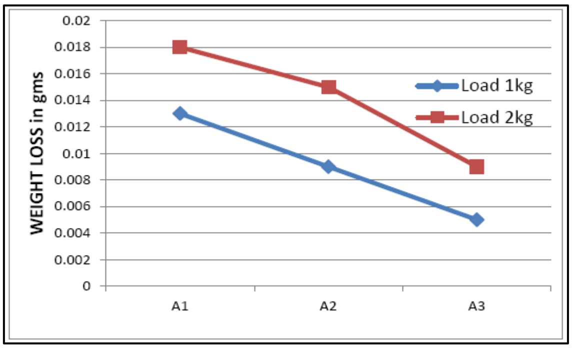


Fig 6: Comparison of Weight Loss with Composite Specimens at Various Load Conditions



4.0 Conclusions

Following conclusions were derived from the results and discussions.

- Aluminum metal matrix composites reinforced with titanium dioxide (TiO2) and graphene oxide (GO) were successfully fabricated through stir casting technique.
- Microstructure studies reveal that there is fairly uniform distribution of reinforcements. Microstructure of AA7075-10%TiO2-0.5%GO and AA7075-10%TiO2-0.5%GO composites showed dendritic and equiaxed structure with minimal porosity, where as AA7075-10%TiO2-1.0%GO showed columnar structure with no segregation and porosity.
- There is an improvement in hardness values for prepared composites. AA7075-10%TiO2-1.0%GO has high value of 50HRB among the composite fabricated.
- Tensile properties of fabricated composites show improvement with increment in reinforcement addition. The ultimate tensile stress for AA7075-10%TiO2-1.0%GO composite is 112.7MPa. Improvement in tensile property could be due to the resistance offered to crack propagation by reinforcements.
- Pin on disc wear test results showed wear loss were increased with increase in load applied on the specimen. Wear loss was minimal for AA7075-10%TiO2-1.0%GO for both load conditions.

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