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Characterization of Graphite and Zirconium Oxide on Al-7075 Metal Matrix Composites (MMCS) Fabricated by Stir Casting Technique

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ABSTRACT

This work investigates the mechanical properties of Aluminium Metal Matrix Composites reinforced with Zirconium Oxide and Graphite. The composite material has been prepared by Stir casting technique. Al-7075 as matrix metal, Zirconium oxide and graphite as reinforcements. Zirconium Oxide and Graphite both have been mixed in different proportions in the Aluminium Matrix. Both reinforcement constituents were added in different combinations, so as to investigate the effect of each of these two and their individual effects. Density test, Micro hardness test and Compression test were carried out on the developed hybrid composites to study the mechanical properties of composites. Micro structural studies were carried out on Al-7075 and all composites. Samples were prepared and tested as per ASTM standards. Significant improvement in micro hardness and Compressive strength was found with an increase in Zirconium dioxide in weight percentage of composites. Micro structural study reveals the uniform distribution of reinforcements ZrO_2 and graphite in as cast and Al-7075 metal matrix composites.

KEYWORDS: *Zirconium oxide, Graphite, Al- 7075, Metal matrix composites, stir casting*

INTRODUCTION

Available monolithic materials have limitations with respect to achievable combinations of strength, stiffness, and density. In order to overcome these shortages and to meet the increasing engineering demands of modern technology, metal matrix composites are gaining importance. The areas of applications of composite materials are growing rapidly and have even found new markets [1-3]. The current objective is to make them durable in tough conditions to replace other materials. Basically, Composites are the combination of two or more dissimilar materials (different in composition, characteristics and sometimes inform) which exist in different phases and are insoluble in each other. One or more discontinuous phases are, therefore, bound in a continuous phase to form a composite. Among the phases, one is the matrix phase which contains the reinforcements in order to improve its own properties. The aluminum composites are widely used in the fields of Automotive Industry (Body, Brake pads, Driveshafts, Fuel tanks, Hoods, Spoiler, clutches), Aerospace (Nose, doors, struts, fairings, out board and inboard flaps etc), Sports (Tennis, Bicycles, Badminton), Constructions, marine industries and biomedical applications etc.[4-6]. Therefore in the present investigation the aluminum matrix reinforced with different volume % of SiCp, Graphite and Zirconia has been considered. These reinforcement materials have been chosen because of their better mechanical as well as tribological properties. Zirconia is one of the important ceramic which is used as a biomaterial that has a bright future because of its high mechanical strength and fracture toughness. Graphite and Silicon carbide have low densities. Silicon carbide has high strength, high hardness and excellent thermal shock resistance. Both graphite and Zirconia have high wear resistance also [7-8]. In this investigation the mechanical, as well as wear behaviour of these hybrid composites, are evaluated in order to distinguish the best material for suitable engineering applications.

MATERIALS

The matrix material used for the experimental work is aluminum 7075 in which varying amount of zirconium oxide and graphite have been added. The average particle size of the Zirconium Oxide and graphite are 50 μm and 50 μm, respectively. The chemical composite of 7075 is given in table 1.

Table 1: Composition of Aluminium 7075

Component	Amount (wt. %)
Aluminium	balance
Manganese (Mn)	0.3%
Iron (Fe)	0.5%
Copper (Cu)	1.3%
Magnesium (Mg)	2.1%
Silicon (Si)	0.01%
Zinc (Zn)	5.3-5.7%
Chromium (Cr)	0.18%
Others (Total)	0.05- 0.15%

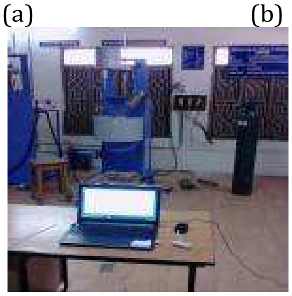
Zirconium dioxide (ZrO_2), sometimes known as zirconia is a white crystalline oxide of zirconium. Graphite is used widely as an engineering material over a variety of applications. Applications include thrust bearings, piston rings, vanes and journal bearings. It is very unique in that it has both properties of a non-metal and metal. It is flexible but not elastic, has a high electrical and thermal conductivity.

EXPERIMENTAL PROCEDURE

The process of stir casting was performed for preparing Aluminium metal matrix composite. 1 Kg of aluminum 7075 was melted in the resistance furnace in which temperature was raised up to 850°C. The graphite and Zirconium Oxide particles were preheated to 250°C for the duration of 2 hours to remove the moisture content. Different amounts of graphite and Zirconium Oxide particles were added to the molten metal. The melt was maintained at a temperature of 790°C and was stirred with the help of a mild steel stirrer. The stirring was carried out for 4 min at an impeller speed of 400 rpm. Finally, the melt with the reinforced particulates was poured into the metallic die and left for solidification.

(a)

(b)



(c)

Fig.1. (a) Graphite, (b) Zirconium oxide and (c) Stir casting setup

CHARACTERIZATION

Density Measurement

Density of graphite (density = 2.21 g/cc) and zirconium oxide (density = 5.68 g/cc). The theoretical values of densities for base alloy and composites are considered using a rule of mixtures. The bulk densities of the alloy and composites in as-cast and extruded conditions. In the cast condition, composites show lower density values than the calculated values (Rule of the mixture). Further, the difference in densities found to be increasing with increasing reinforcement concentrations. Since composites were prepared by stir cast technique entrapped gases due to vortex formation, were the reasons for lower densities than the calculated ones. And increased stir times with increasing reinforcement contents is a signature of the above discussion, resulting decreased densities. Also, loss of magnesium may be the other reason for the drop in density with increasing reinforcement content. The composites show a relative increase in density in the extruded condition minimizing the porosity. We used Electronic specific gravity balancer to measure the density of alloy and composites.

Vickers microhardness

This test is performed for measuring the hardness values of the prepared specimen at a load of 100 gms. The indenter is first moved down into position on the part surface of the work piece. A minor load is applied and a zero reference position is established. After that the major load is applied for a duration of 10 seconds. The major load is then discharged. However, the minor load is left applied. Three readings were taken on each specimen to eliminate the possibility of error and mean value was taken as the hardness of the composites.

Fig.2. Electronic specific gravity balancer

Fig.3 Vickers micro hardness apparatus

Compression Test

Compression strength tests were carried out on Al MMCs using a computerized UTM machine as per ASTM standard. Compressive strength is calculated by dividing the load at breaking point by the original minimum cross-sectional area. The result is expressed in Mega Pascal's (MPa).

$$\text{Compressive strength} = \frac{\text{compressive load}}{\text{area of cross-section}}$$

Fig.4. UTM Machine

RESULTS AND DISCUSSION

Density Measurement

Density of Al-7075(density = 2.82g/cc) graphite (density = 2.26 g/cc) and zirconium oxide (density = 5.68 g/cc). The theoretical values of densities for base alloy and composites are considered using a rule of mixtures. The bulk densities of the alloy and composites in as-cast and extruded conditions. In the cast condition, composites show a lower density values than the calculated values (Rule of the mixture). The average theoretical and measured density values of the Al-7075 alloy and its respective composites were shown in Fig 5. Adding of Zirconium oxide (ZrO_2) and graphite(C) into the base material in such a case density of the composites was increased compared to the base material.

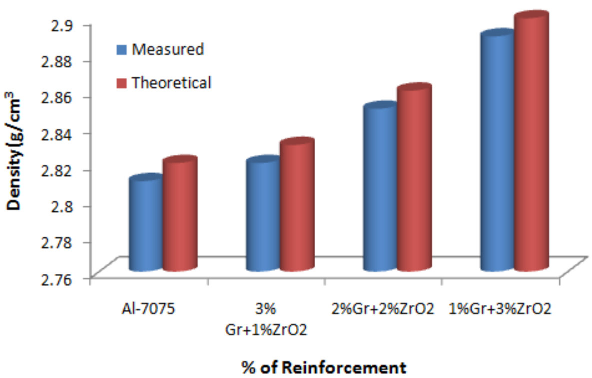


Fig.5. Theoretical and measured density's of Al-7075 and Composites

COMPRESSION TEST

Compression test was carried out on Al MMCs using a computerized Universal testing machine as per the ASTM standard. 4 samples were made by stir casting methods. When the Quantity of graphite decreased and Quantity of ZrO_2 was varied from 1wt% to 3wt%. It was observed that as the concentration of ZrO_2 increased, Compressive load also increased from 78.5 KN to 84.7 KN. When we increased the wt% of ZrO_2 in such a caseload is increased. So, 1% of graphite and 3% ZrO_2 have high compressive strength.

(a)

(b)

Fig.6. (a) Specimen under test, (b) After testing specimens

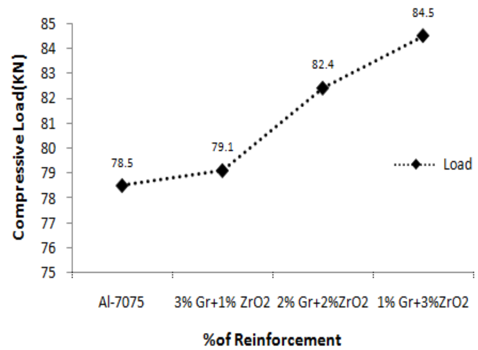


Fig.7. Variation of Compressive load

MICRO HARDNESS

Hardness test was carried out on Al MMCs using a Vickers micro hardness machine with a load of 100 Gms. Four samples were made by stir casting methods. From the graph, it can be observed that as the content of ZrO_2 is increased, the hardness value of the material is also increased. Three readings were considered for each of the samples. Finally, the average of all the three readings was calculated so as to minimize the error in the hardness for each of the samples considered. The highest value of hardness is 125 VHN and the corresponding values of ZrO_2 and graphite are 3% and 1 %, respectively. The lowest value of hardness is 97 VHN and the corresponding value of matrix material Al-7075 respectively. It is observed that the hardness of the Al 7075 metal matrix composite increases with the addition of zirconium oxide. The hardness decreases with the addition of graphite particles to the Al MMC.

Fig.8. Hardness Specimens

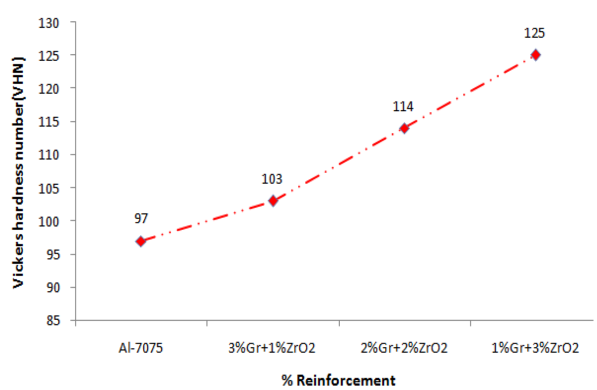


Fig.9. Variation of Vickers hardness Number (VHN)

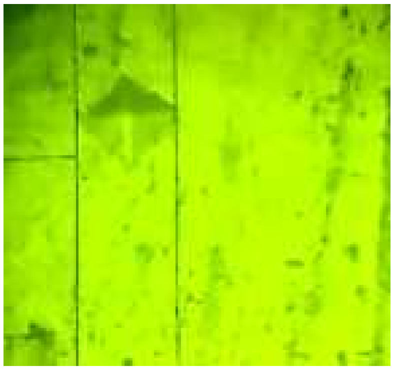


Fig.10. Indentation of hardness specimen

MICROSTRUCTURE STUDY

Microstructure examination carried out by Metallurgical microscope at 200X. Specimen surface was prepared by grinding and polished using 1000 mesh size papers before conducting the microstructural study. Microstructural images are shown in figure.11. it reveals the distribution and size of Zirconium particles in the Al-7075 matrix phase. Image analyzer shows good adhesive bonding and uniform distribution of the Zirconium oxide particles in Al-7075 alloy. Porosity and segregation were not seen in different wt% ZrO_2 and graphite-reinforced Al-7075 MMC.

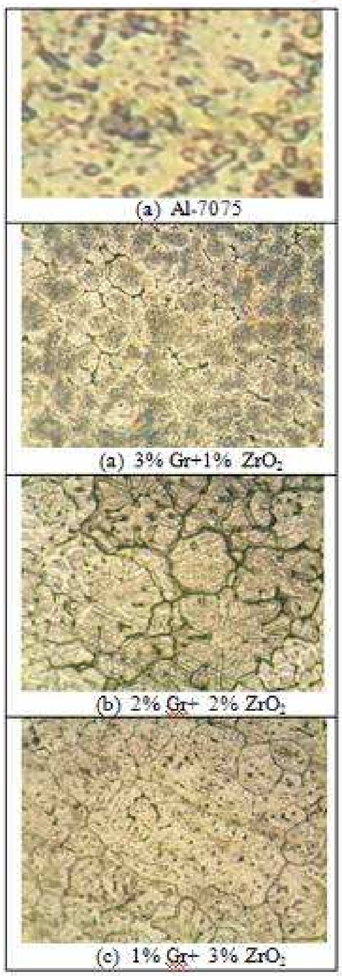


Fig11. The microstructure of Al-7075 and Composites

CONCLUSIONS

The following conclusions have been drawn from the work:

- MMC has been successfully prepared by stir casting technique with a uniform distribution of reinforcement particles in base alloy and also ZrO_2 and graphite particles are successfully reinforced in aluminum alloy with a different wt %.
- The density of composites increased compared to the matrix material. This is due to the fact that the density of graphite is less (2.26 g/cc) as against the density of ZrO2 (5.68 g/cc) and density of the Al-7075 (2.81 g/cc).
- The addition of zirconium affected the Al-7075 MMC positively from the point of hardness, Compressive strength.
- The hardness increases with the increase in contents of ZrO_2 but decreases with increase in graphite content.
- The compressive strength of composites increased compared to the matrix material.

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