Journal of Materials and Environmental Sciences
ISSN : 2028-2508
CODEN : JMESCN

J. Mater. Environ. Sci., 2018, Volume 9, Issue 1, Page 26-31

https://doi.org/10.26872/jmes.2018.9.1.4

http://www.jmaterenvironsci.com

Synthesis and Characterization of Zircon/Graphite and Flyash/Graphite Reinforced Aluminium7075 Alloy: A Comparative Study

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Received 31 Mar 2017,
Revised 28 Aug 2017,
Accepted 31 Aug 2017

Keywords

- ✓ Al 7075
- ✓ Flyash
- ✓ Zircon
- ✓ Graphite
- ✓ Hardness
- ✓ Tensile Strength
- ✓ Density

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Abstract

In this paper, a comparative study of the mechanical properties and microstructures of two different particulate reinforced hybrid composites of Aluminium 7075 - Flyash and Zircon is conducted. Graphite is the chosen as the minor reinforcement for both the composites. The composites were fabricated by stir casting process, by varying the wt% of Zircon and Flyash from 3% to 7% at a step size of 2 wt%. Tensile strength and micro hardness analysis were carried out using Universal Testing Machine and Vickers Hardness Tester respectively. Scanning Electron Microscope image was used for microstructural study. Results indicate that the hardness of Zircon reinforced Aluminium 7075 alloy is increased to 5% with reinforcement, but the tensile strength reduces beyond 7% reinforcement. The tensile strength of the Flyash reinforced composite increases with increase in wt% of reinforcement, but hardness declines beyond 7% addition of reinforcements. The amount of porosity and density is increased due to non-wettability and high density of Zircon. Tensile strength increases with increase in wt% of reinforcement, but hardness declines beyond 7% addition of reinforcements. The amount of porosity and density is increased due to non-wettability and high density of Zircon.

1. Introduction

Aluminium alloys are widely employed in aerospace and automobile industries owing to their light weight and high strength to weight ratios. The mechanical properties of these alloys can be further tailored by the addition of reinforcements to the parent alloy. Mechanical properties like hardness, tensile strength, stiffness, wear resistance etc can be improved by the addition of the reinforcements to the alloy matrix. Conventionally used reinforcements are over expensive and they render difficulty in the primary and secondary fabrication process. Among the reinforcements, particulate reinforcements are preferable because it is cheaper and it can avoid directionality, which is seen in fiber reinforcements. Among the Aluminum alloys, Al 7075 is widely used in aerospace structural applications and in the manufacture of automobile components like fasteners, bicycle frame, chassis plate etc. Particulates such as red mud, flyash, zircon and other industrial wastes act as substitutes for traditional ceramic materials such as carbides and nitrides. Flyash is an industrial waste from the thermal power plant and it possesses very low density. This low cost reinforcement contains elements such as Al_2O_3, Fe_2O_3 and TiO_2. Using Flyash as reinforcement in the matrix has two fold advantage. Firstly, it improves the material properties owing to the content elements. Secondly, it effectively uses Flyash, which is one of the major polluting elements in the atmosphere thrown out by thermal power plants, thereby reducing the carbon footprint of the fabrication process [1,2]. The addition of flyash to Aluminium alloy reduces its Magnesium content which improves its strength [3]. Zircon is also one such co-product obtained from heavy mineral sand deposits. It has high thermal stability, making it suitable for manufacture of refractory tiles, heat shields in spacecrafts etc. It has properties like low thermal expansion, high melting point, low thermal conductivity, chemical inertness etc, which makes it another desirable reinforcement in the Aluminium industries. Recently, Zircon reinforced Aluminium composites have gained importance especially in the field of automotive materials. Some of the factors considered during fabrication are - the proportion of Zircon, density and size of

Zircon particles [6].The stability of Zircon is high even at very high temperatures. Additionally, low thermal conductivity makes it suitable for industries such as abrasive, refractory and foundry. An internal stress which develops from the Aluminium-Zircon interface increases the hardness [7]. The chemical composition of Flyash and Zircon are given in Tables 1 and 2.

Table 1: Chemical composition of FlyAsh

Elements	SiO_2	Al_2O_3	Fe_2O_3	CaO (Lime)	MgO	SO_3
wt%	55	26	7	9	2	1

Table 2: Chemical composition of Zircon

Elements	ZrO_2	SiO_2	Al_2O_3	TiO_2	Fe_2O_3
wt%	65.90%	32.54%	1.15%	0.27%	0.04%

Stir Casting is one of the most common fabrication techniques employed in the manufacture of Metal Matrix Composites. It can be adopted easily and is very economical compared to other methods. Factors such as wettability, solidification rate, mixing strength etc. decides the solid dispersion in Aluminium. The position of the stirrer and its geometry are also deciding factors [8, 9]. The stirring movement during the fabrication process and the presence of Magnesium in the alloy improves its wettability. The Magnesium content in Al 7075 is found to improve its wettability [3].

A composite can be termed as hybrid if it consists of three different materials. To a get better combination of properties, it is recommended to incorporate small proportion of two different reinforcements and is noticed to be better than increasing the proportion of a single reinforcement [10]. Graphite is used as a minor reinforcement owing to its self-lubricating property. Because of this property, it is used in producing cylinder liner, piston and in making structural and functional parts in the transportation industry. Employing self-lubricating composites would restrict the usage of petroleum based lubricants, thereby reducing the carbon footprint of the manufacturing process. If the proportion of graphite content is increased, porosity and cracks that may be formed in the composite may lead to deterioration in the mechanical properties [11].

Although numerous research works have studied the effect of Flyash in Aluminium composites, there has not been any which compares the properties of Flyash in Al7075 Metal Matrix Composites [3]. This forms the basis of the experimental analysis conducted in this paper. Here, fine-sized Flyash/Graphite and Zircon/Graphite combination is chosen as reinforcement for Al 7075. The two hybrid composites are fabricated using stir casting process. The mechanical properties of the two different composites are compared.

1. Experimental Procedure

Al 7075 alloy is chosen as matrix to which Flyash and Zircon particles are added as major reinforcements. Graphite is chosen as minor reinforcement. The chemical composition of Al7075 and the properties of constituent elements are given in Table 3 and Table 4 respectively.

Table 3: Chemical Composition of Aluminium 7075

Element	Aluminium	Zinc	Magnesium	Copper	Chromium
Content%	90	5.5	2.4	1.5	0.22

Table 4: Properties of Constituent elements

Properties	Al 7075	Zircon	Flyash	Graphite
Density (kg/m^3)	2750	3900	2100	2300
Thermal conductivity (W/mK)	130	3.5	1	25
Melting point (^oC)	483	2200	1400	3527

2.1 Alloy Preparation

Al 7075 rods are placed in the crucible and are melted completely. The reinforcements (zircon and graphite) are pre-heated in a muffle furnace for 30 minutes. The preheated reinforcement particles of varied wt% as given Table 5 are introduced into the crucible which is supplied with Argon gas. The stirrer rpm is increased to 500 rpm and is kept constant for 5 minutes. After this hold time, the molten metal is poured to the die and is allowed to solidify. The temperature of the stirring is fixed at 770^{o}C throughout the entire process. The samples are then machined as per the ASTM standards. The crucible used for the alloy preparation and the cast alloy Al 7075 are shown in Figures 1 and 2 respectively.

Table 5: Composition of reinforcement in the samples

Sample No	Al 7075 (wt%)	Zircon (wt%)	Graphite (wt%)
1	95	3	2
2	93	5	2
3	91	7	2
Sample No	**Al 7075 (wt%)**	**Flyash (wt%)**	**Graphite (wt%)**
4	95	3	2
5	93	5	2
6	91	7	2

Figure 1: Crucible used for alloy preparation

Figure 2: Cast Al 7075 samples

2.2 Tensile test

The tensile test specimens are made as per the ASTM E8-15 standard. Each specimen has a gauge length of 50mm and a diameter of 12.42 mm. Universal Testing Machine is used for measuring tensile strength of the prepared specimens. Tensile test specimens are shown in Figure 3.

2.3. Hardness test

For Hardness test, the test samples were polished initially with a disk polisher, followed by various grades of emery paper. Vickers micro hardness method is adopted and a 10kg load is applied for 15 seconds. Measurements were taken at different points in a specimen and the average value is calculated, which was concluded as the hardness value for the specimen. The device used for Vickers hardness measurement is Mitutoyo shown in Figure 4.

Figure 3: Tensile test sample

Figure 4: Vickers Hardness Testing Machine-Mitutoyo

2.4. Density and Microscopic examination
The density of each specimen is measured by adopting Archimedes principle. The Scanning Electron Microscopic (SEM) images for reinforcements and each composite are considered for examining the microstructure of reinforcement elements in the composite.

3. Results and Discussions

3.1.Tensile test
The variation of tensile strength of Al 7075 reinforced with Zircon/graphite and Flyash/Graphite particles are shown in Figures 5. The results indicate that Zircon and Graphite reinforced alloy have maximum tensile strength of 139 MPa at 9 wt. % of reinforcement which is inline with the previous literatures [5]. On the other hand the tensile strength of flyash/graphite reinforced aluminium 7075 alloy is increases upto 7 wt. % and decreases further at 9 wt.% of reinforcement. This validates the trend obtained by previous researchers [1] that the tensile strength increases with addition of Flyash upto an optimum wt% and then decreases.
This shows that the interface is devoid of pores upto certain wt. % and also the Flyash yield better strength than Zircon as per the study. However both composites possess low tensile strength compared to the parent alloy as the ceramic particles induces brittleness. The percent elongation is more in case of Zircon reinforced composites. The value of percentage elongation decreases with increase in strength.

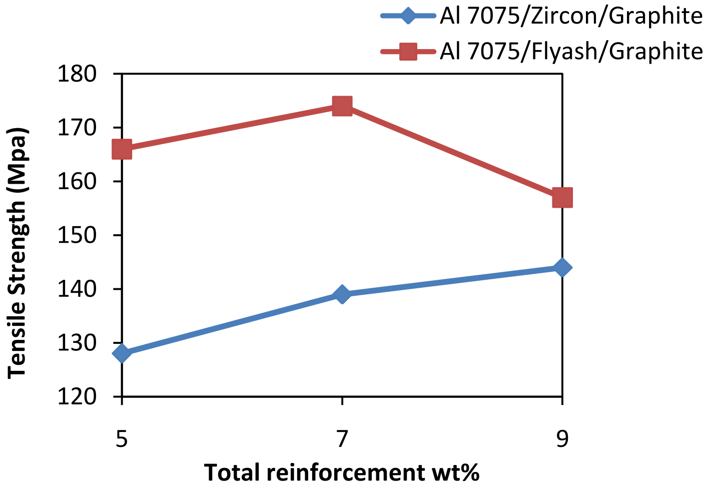

Figure 5: Variation of Tensile Strength with reinforcement wt%

3.2 Hardness test

From the Vickers Hardness test results obtained for Zircon/Graphite and Flyash/Graphite reinforced Al 7075, it can be observed that the composites reinforced with Zircon shows an increase in hardness of 5% from 147 HV to 155 HV [6].

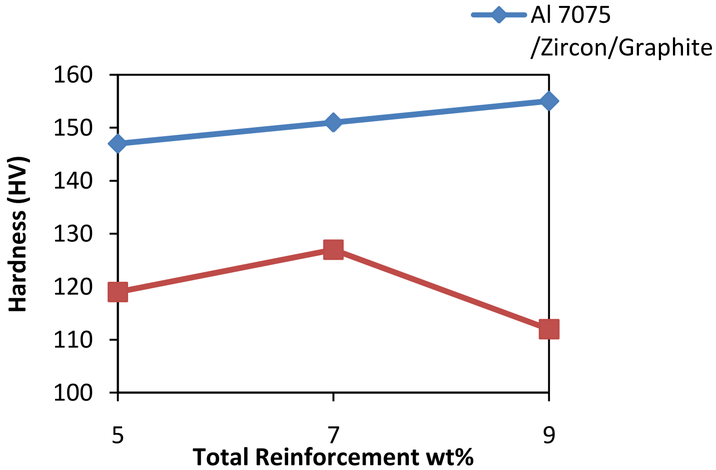

Figure 6: Variation of Hardness with reinforcement wt%

This could be due to the presence of hard Zircon particles and also the presence of magnesium in the alloy, which aids in good bonding. The hardness value of Flyash/Graphite reinforced composite is slightly less compared to Zircon/Graphite reinforced composite. Even though the hardness increases upto 7%, it decreases on further addition of the reinforcements. The trend is similar to that found in the literatures [3].

3.3 Density

A decreasing trend in density is observed for the Flyash/Graphite with increase in the amount of reinforcement which validates the results observed in previous works [3]. It reaches even lower than density of non-reinforced alloy because of low density of both reinforcements. The density of Zircon/Graphite composite increases with an increase in the weight of the reinforcements as can be observed from Figure 7. This increment is controlled as fine particles of Zircon are used instead of coarser particles for this study.

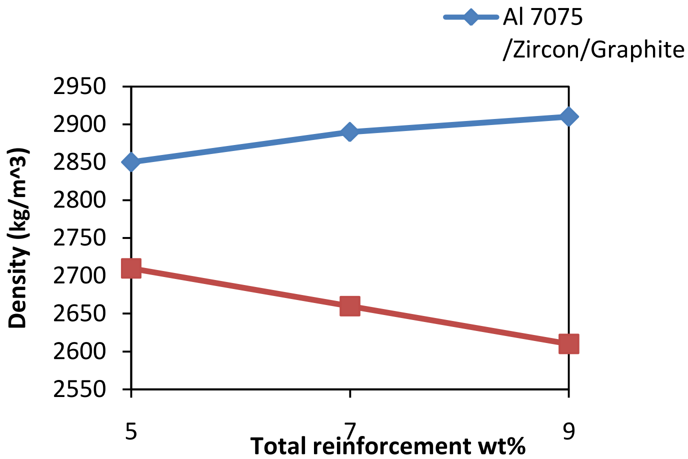

Figure 7: Variation of density with reinforcement wt%

3.4 Microstructure Analysis

Microstructure of the reinforcements used in this study is shown under suitable magnification. Fine particles of size ranging from 1-50 microns are used as reinforcement which can be observed from the SEM images shown (Figure 8) Flyash particles are spherical in shape whereas the Zircon and Graphite particles have irregular and platelet-like shapes respectively.

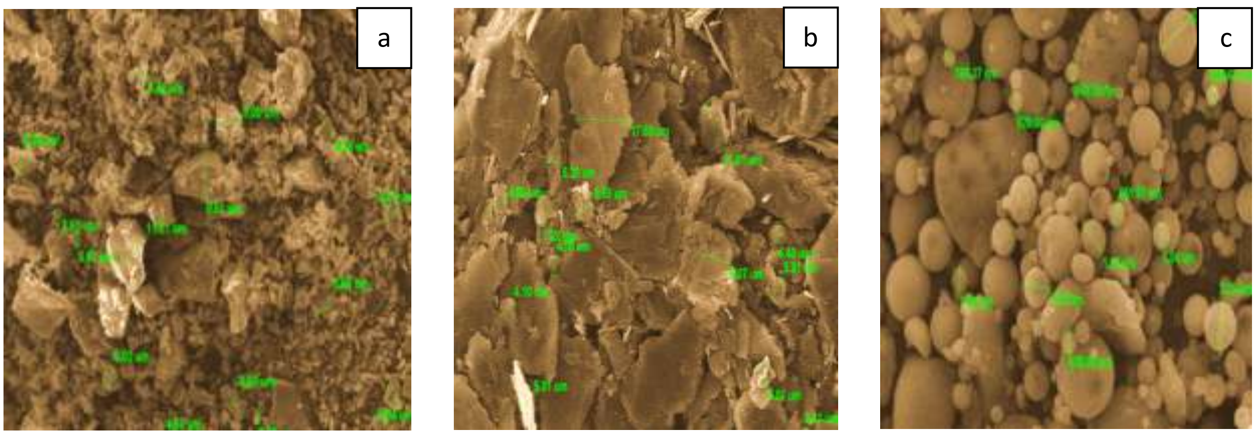

Figure 8: SEM image of (a) Graphite (b) Zircon (c) Flyash particles with size (Magnification – 1000x)

When the Zircon content is increased, the Zircon particles form clusters which leads to porosity of the composite (Figure 9 b, 9 c). Though dendrites are not clearly visible, the growth of dendrites is arrested which can be witnessed from the increased hardness for Zircon reinforced composites. The filler particle size appears to be larger than particle size of matrix Al 7075 due to increase in solidification rate.Better dispersion of particles in uniform manner takes place in the case of Flyash/Graphite composites. Cluster formation is avoided as the Flyash tends to homogeneously spread over the matrix (Figure 10 a). However with increasing filler amount porosity increases (Figure 10 b, 10 c) pores can be identified by means of black pits formed during the fabrication process.

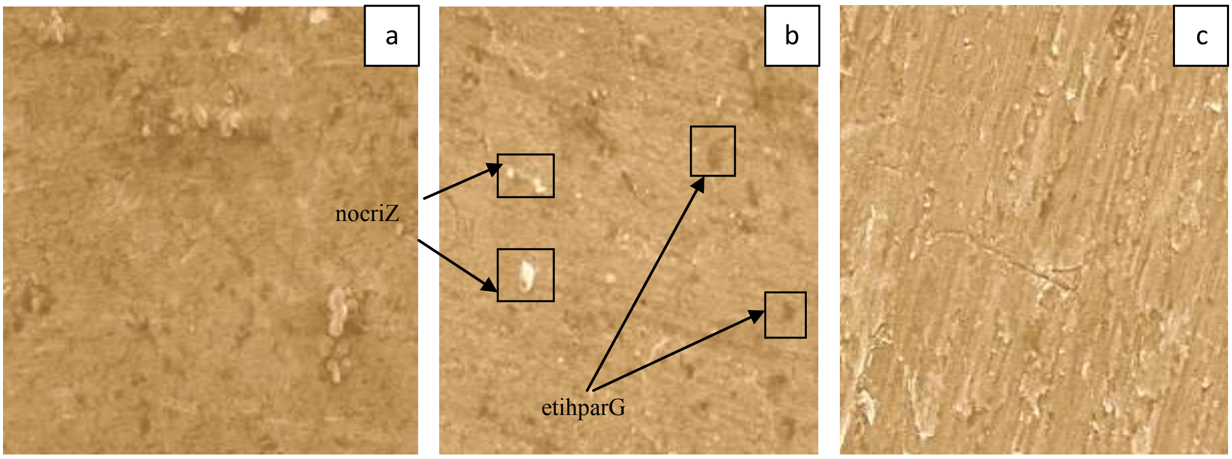

Figure 9 : SEM image of Zircon/Graphite reinforced Aluminium 7075 alloy **-** (a) Sample 1 (b) Sample 2 (c) Sample 3 (Magnification – 1000x)

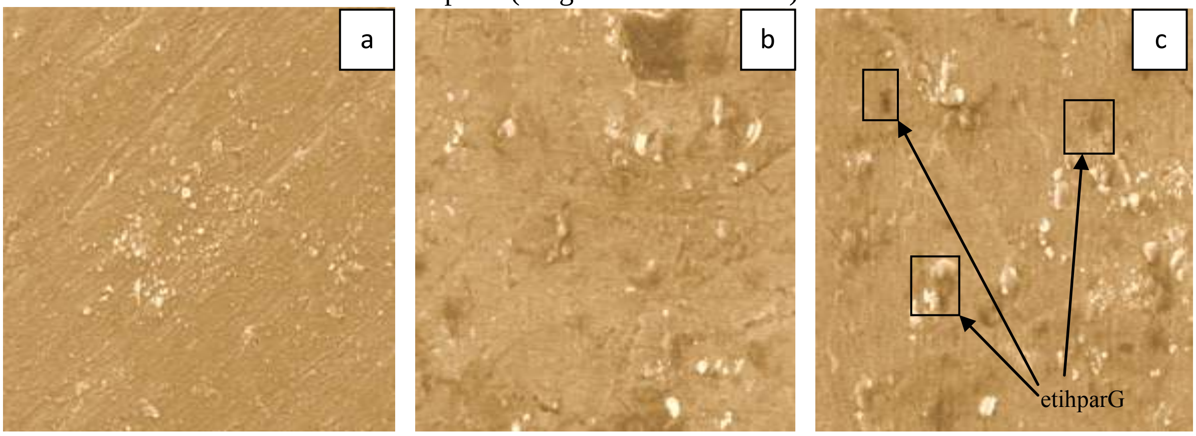

Figure 10: SEM image of Flyash /Graphite reinforced Aluminium 7075 alloy **-** (a) Sample 4 (b) Sample 5 (c) Sample 6 (Magnification – 1000x)

Since the size of the Flyash particle is very small, it is difficult to distinguish in the matrix.

Conclusions

It has been observed that reinforcing Flyash and Graphite into Al 7075 produces more strength compared to Zircon and Graphite reinforcement. Incorporating Zircon and Graphite results in increasing hardness of the parent alloy, despite having weaker interfacial strength than Flyash reinforced hybrid composite. Adding fine Zircon particles to the matrix would increase the density of the alloy without decreasing the hardness. The density of Al 7075/Flyash/Graphite composite is found to be lower than the density of monolithic Al 7075. Porosity and non-wettability is witnessed in Al 7075/Zircon/Graphite composite whereas Flyash/Graphite particles are uniformly distributed along the matrix.

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