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Studies on Characteristics and Mechanical Behaviour of Carbon Nano Tubes & E-Glass Fibre Reinforced Al 7075 Alloy Matrix Hybrid Composites

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ABSTRACT

Aluminium based matrix composite remain the most explored Metal Matrix Material for the development of MMCs. Meanwhile, there is a growing body of evidence that Carbon-Nano Tube (CNT) are ideal materials for reinforcement in composite materials due to their Nano-scale structure, outstanding mechanical and thermal properties. However good dispersion of CNT was the bottle-neck to convert their attractive properties to CNT reinforced composites. In this study stir-casting technique has been used for homogeneous dispersion of CNT and E-glass fibers in Al-7075. The objective of present investigation is to study the effect of reinforcements on the mechanical properties of CNT and E-glass short fibers reinforced Al-7075 hybrid. In this work experimental study began with mixing of Al-7075 alloys CNT and E-glass using stir casting technique at different weight fraction additions of CNT (0.5wt%, 1wt%, 1.5wt%, 2wt%) and E-glass (1 wt%, 5 wt%). The casted composite specimens were machined as per ASTM standards. The specimens were tested for various Mechanical Properties and are compared with Al-7075

KEYWORDS Aluminium Hybrid MMC, Carbon-Nano Tube, E-Glass, Aluminium 7075

Introduction

Particulate reinforced aluminum alloy matrix composites have received attention over many years due to their excellent yield and tensile strengths, high specific elastic modulus and isotropic properties compared with the conventional alloy materials, which is very good candidate for structural applications in the field of aerospace, automotive and electronics.

The particulate-reinforced metal-matrix composites have emerged as attractive materials for use in a spectrum of applications such as industrial, military and space related. The renewed interest in metal matrix composites has been aided by development of reinforcement material which provides either improved properties or reduced cost when compared with existing monolithic materials. [1-2].

Particulate reinforced metal-matrix composites have attracted considerable attention on account of the following aspects: 1. Availability of a spectrum of reinforcements at competitive costs. 2. Successful development of manufacturing processes to produce metal matrix composites with reproducible microstructures and properties. 3. Availability of standard and near standard metal working methods which can be utilized to produce these materials.

During the last decade, considerable efforts have been made to improve the strength of precipitation hardened aluminum alloy matrix composites, such as developing new preparation technologies with suitable heat-treatments.7XXX series aluminum alloys are lightweight materials that are widely used in the aerospace industry because of their superior specific strength.

Here the lightweight material, Aluminium 7075 is taken as matrix and multi walled carbon nanotubes along with E-glass are taken as reinforcement. Aluminium 7075 is reinforced with different proportions as 0.5wt%, 1wt%, 1.5wt% and 2wt% of MWCNTs and 1wt% and 5wt% of E-glass using Stir Casting technique.

Experimental Details

2.1 Material selection

The aluminum alloy Al-7075 has been selected as the matrix material is more compatible with the reinforcement and has good mechanical property and castability at the alloy level itself. The application of the alloy in automobile and aircraft application itself indicated that it is the proper selection. The material is also having good response to age hardening, heat treatment process and precipitation hardening.

MWNTs include several tubes in concentric cylinders. The number of these concentric walls may vary from 6 to 25 or more. The diameter of MWNTs may be 30 nm when compared to 0.7–2.0 nm for typical SWNTs. Multi-walled Nanotubes: MWCNTs are chosen as reinforcement material. MWCNTs have excellent properties and are being employed in a large number of commercial applications.

Properties	Aluminium	MWCNTs	E-Glass
Density	2.7 g/cm^3	1.6-2 g/cm^3	2.6 g/cm^3
Young's modulus	70 GPa	1.7-2.4 Tpa	73GPa
Thermal conductivity	204.3 W/m K	>3000 W/m K	1.35 W/m K
Melting point	660^{o}C	35000^{o}C	1400^{o}C

Table1. Properties of Aluminium, MWCNT and E-Glass.

Glass fiber has roughly comparable mechanical properties to other fibers such as polymers and carbon fiber. Although not as strong or as rigid as carbon fiber, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent product to form a very strong and relatively lightweight Hybrid Composite.

2.2 Sample Preparation

For composite preparation, the simplest and cost effective route used to cast is stir casting method (liquid casting method) [10]. Aluminium metal matrix (Al 7075) is melted at 850°C in a graphite crucible. When the temperature of the melt is about 30°C above the pouring temperature, the preheated stirrer is introduced in the melt. The agitation of the melt is started and the preheated CNT and E-glass of respective wt. % is introduced. The stirring is continued to ensure a proper mixing and slurry. It is subsequently stirred at 300rpm, by using an impeller attached to the variable speed motor. The slurry of the composites is prepared and poured into the steel moulds to solidify to form Al7075 Hybrid composite.

Stir Casting

Casting Process was carried out to prepare the samples as discussed below.

1. Aluminium 7075 of known weight was melted at 660ºC.
2. After obtaining a melt, pre heated (300 ºC for 30 minutes) CNT & E-glass Fibres were added to it.
3. Mechanical agitation was done to get a homogenous melt.
4. CNT & E-Glass reinforced Aluminium 7075 was obtained by Stir casting.

Figure:1. Furnace with stirring apparatus

Experiment

The test for tensile strength and compressive strength of the prepared cast matrix and their composite were carried out as per ASTM standards. The density of material, that is ratio of weight to volume [11] was obtained by accurately measuring the weight and the volume of the composites. Instron make PC2000 series Universal testing machine was used for the measurement of strengths.

Tension Test

The tensile testing is carried out by applying longitudinal or axial load at a specific extension rate to a standard tensile specimen with known dimensions (gauge length and cross sectional area perpendicular to the load direction) till failure. The applied tensile load and extension are recorded during the test for the calculation of stress and strain. A range of universal standards provided by Professional societies such as American Society of Testing and Materials (ASTM), British standard, JIS standard and DIN standard provides testing are selected based on preferential uses. Each standard may contain a variety of test standards suitable for different materials, dimensions and fabrication history. For instance, ASTM E8: is a standard test method for tension testing of metallic materials and ASTM B557 is standard test methods of tension testing wrought and cast aluminium and magnesium alloy products.

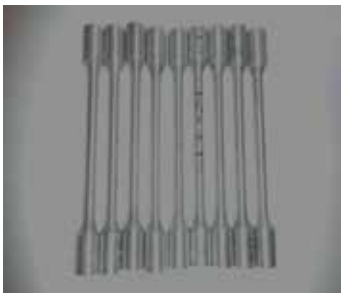


Figure:2. Tensile test specimens (before and after testing)

Compression Test

A Universal Testing machine, also known as a universal tester, materials testing machine is used to test the tensile strength and compressive strength of materials. The specimen of standard dimensions is located between the compression grips that are adjusted manually. Constantly increasing load is applied to the specimen which is being constantly monitored. The load at which fracture occurs is noted down. The percentage increase in area & percentage decrease in length is calculated.

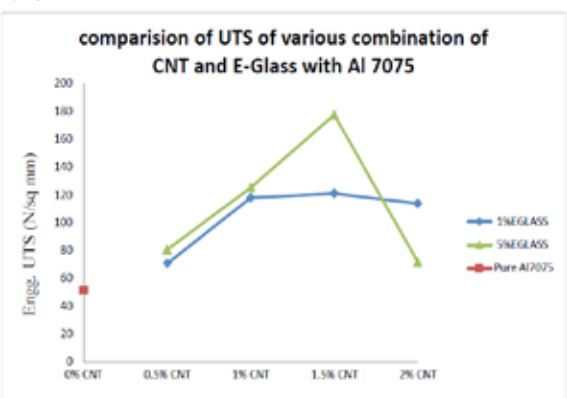
Figure:3. Compression test specimens (before and after testing)

3. Results and Discussion

Both tensile and compression tests are carried out at Ragvendra Spectro Metallurgical Laboratory (RSML), Peeny, Bangalore. All tests are been carried as per the ASTM standards for different compositions i,e: (0.5wt%,1.0wt%,1.5wt%,2.0wt% CNT and 1wt%,5wt% E-Glass)respectively.

3.1 Tension

The graph 1 shows the variation of ultimate tensile strength for different compositions and is compared with the pure Al 7075.



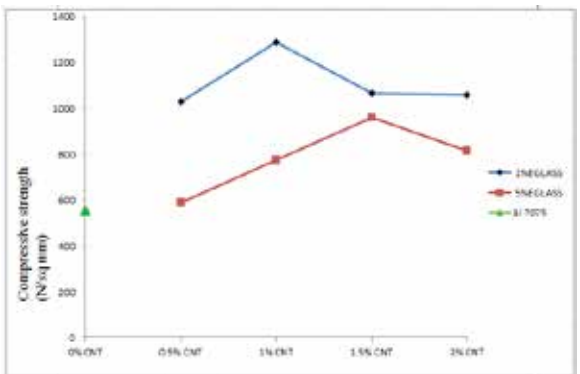
Graph:1. Comparison of UTS of various combinations of CNT and E-Glass fibers with Al7075

From the comparison graph 1 it can be seen that the tensile strength of composites is higher than the unreinforced matrix.

However, with increasing wt% of CNT and E-Glass fibers, tensile strength of the composite increases. Also from the figure it can be observed that the tensile strength increases up to 1.5wt% of CNT and further increase in wt% of CNT results in drop in strength. This is due to the fact that addition of CNT beyond 1.5 wt% to 1.7wt% will result in the formation of clusters, and thus bonding strength decreased between matrix and reinforcement phase.

3.2 Compression

The comparison of compressive strengths for different varying compositions of CNT and E-Glass is shown in the graph 2.



Graph:2. Comparison of compressive strength of various combinations of CNT and E-Glass fibers with Al7075

From graph 2, it can be observed that the compressive strength of the composites are higher than that of their base matrix and also it can be observed that the increase in the CNT contributes in increasing the compressive strength of the composite. Also from the figure it can be observed that the compressive strength decreases with increase in E-Glass fibers. This decrease in strength is due to the long aspect ratio of the fibre which makes it seem so; i.e., because a typical fibre is long and narrow, it buckles easily.

CONCLUSION

The significant conclusions of the studies on Al7075 MMC reinforced with CNT and E-Glass fibers are as follows.

1. Stir casting techniques were successfully adopted in the preparation of 7075 composites containing CNT and E-Glass fibers as reinforcements with varying compositions.
2. The tensile strength properties of the composites are found higher than that of base matrix.
3. However the studies revealed that a maximum of only 1.5wt% of CNT can be added and further addition of CNT will result in the decrease of tensile strength.
4. Compressive strengths found increased with the reinforcement compared to base alloy.
5. The test results also revealed that the addition of E-Glass fibers beyond 1wt% will result in drastic decrease in compressive strength.
6. From the studies in overall, it can be concluded that the CNT and E-Glass remains a decent reinforcement combination with Al 7075 matrix phase. The results also proves that stir casting technique can be effectively used for uniform dispersion of less denser reinforcements such as CNTs.

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