

# **Fabrication & Characterisation of Mg-MWCNT & AZ31-MWCNT Nanocomposites**

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**ABSTRACT:** This paper discus with manufacturing of Mg-MWCNT & AZ31-MWCNT based nanocomposites by Stir casting route. MWCNTs with variable percentage of 0.33 wt%, 0.66 wt%, and 0.99 wt % into Mg alloy AZ31 matrix. The effects of varying percentages of MWCNTs on Mg-MWCNT & AZ31-MWCNT are studied by using mechanical properties such as density, porosity and hardness. The characterization reveals gives the better mechanical properties for AZ31-0.99 wt% MWCNT amongst all composites. The reason behind the increase is due to proper mixing of MWCNT into Mg alloy matrix. The density and hardness measurements show that lighter nanocomposites can be produced with the incorporation of MWCNT into Mg & AZ31 alloy with higher strength.

**KEYWORDS:** Magnesium, AZ31, Composite, MWCNT, Stir casting technique.

## **I. INTRODUCTION**

Magnesium alloys have been increasingly used in the automotive industry in recent years due to their lightweight. The density of magnesium is approximately two thirds of that of aluminum, one quarter of zinc, and one fifth of steel [1]. As a result, magnesium alloys offer a very high specific strength among conventional engineering alloys. In addition, magnesium alloys possess good damping capacity, excellent castability, and superior machinability. Accordingly, magnesium casting production has experienced an annual growth of between 10 and 20% over the past decades and is expected to continue at this rate [2]. The density of Magnesium is only 65% of the density of commonly used aluminum alloys in the aerospace industry and therefore can be a breakthrough technology if used for low weight airframe structures. However to use this low weight material several mechanical properties have to be increased and the technological behavior improved. The energy crisis and global inclination to reduce green house gas emissions have been catalytic in directing the attention of research scientists to look for light weight materials [3]. Magnesium Matrix Composites (MMCs) have been attracting much attention as light weight materials due to their high specific strength, good castability, good machinability, high damping capacity, and its availability as a natural mineral. Magnesium materials are also 35% and 75% lighter compared to aluminum and iron based materials, respectively [4].

Magnesium Matrix Composites are the class of Metal Matrix composites composed of magnesium as matrix material that is reinforced with intermetallic or ceramic fiber, whiskers or particulates like SiC, Al<sub>2</sub>O<sub>3</sub>, and CNTs etc. In the past decade, Al based MMCs have been the main research focus because of their excellent lightweight applications. In more recent years, the superior stiffness-to-weight ratio of Mg based composites has made them attractive in weight saving applications for the aerospace, electronics, automobile and sports equipment industries [5]. The most commonly used particulate reinforcement in Mg is micron-size SiC, due to its low cost and easy availability. Addition of micron-size SiC particles to Mg will generally lead to enhanced yield strength, modulus, hardness, fatigue and wear resistance, better damping properties and thermal stability. However, the presence of hard and brittle SiC ceramic particles in Mg inevitably leads to a decrease in ultimate tensile strength and ductility of Mg. The main reasons for the reduced ultimate tensile strength and ductility during tensile tests are: (i) particle cracking and (ii) particle-matrix interfacial failure. The

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

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decreased tensile strength and ductility of the Mg-SiC composites can result in an abrupt failure of the material at a lower strength and smaller deformation [6].

## II. MATERIALS AND METHODS

Following fig 2.1 shows the experimental set up of the vacuum stir casting furnace. Experimental procedure is discussed as follows:



Fig 2.1- Set up of vacuum stir casting furnace

Magnesium (Mg) with 99.5% purity, aluminium(Al) and zinc (Zn) powder with 99% purity supplied by M/S Kastwel Foundries, Ahmedabad, India are used as the matrix material. The MWCNTs produced by Nanoshell (USA), supplied by Intelligent Materials Pvt. Ltd., Chandigarh are used as reinforcement material. Stir casting process is used to synthesize Mg-MWCNT & AZ31-MWCNT composites [7]. The synthesis of reinforced magnesium involved heating a graphite crucible with magnesium, Aluminium, Zinc and carbon nanotubes placed in alternate layers to 750<sup>0</sup>C under Ar gas atmosphere. The heated slurry is stirred at 450 rpm for 10 min using a twin blade mild steel impeller to facilitate the uniform incorporation of carbon nanotubes in the magnesium and AZ31 matrix.

The impeller is coated with zirconium ceria alloy powder pest to avoid iron contamination to the molten metal. The melt is then released through an orifice at the base of the crucible to metallic mould. A 40mm diameter ingot was obtained following the deposition stage [8]. Monolithic magnesium & AZ31 is synthesized using procedure similar to that employed for the reinforced material except that no carbon nanotubes were added. The ingots obtained using the Stir casting processes are machined to a diameter of 10mm and length 25mm. This machined samples are used for investigation of various mechanical properties [9].

## III. CHARACTERIZATION OF MECHANICAL PROPERTIES

Following fig 3.1 & fig 3.2 shows the fabricated composites of Mg-MWCNT, AZ31-MWCNT composites respectively. However fig 3.3 & fig 3.4 shows the machined specimens of Mg-MWCNT & AZ31-MWCNT composites for density, porosity & hardness test.



Fig 3.1



Fig 3.2

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Fig 3.3

Fig 3.4

Fig 3.1 & Fig 3.2 shows the fabricated composites of Mg-MWCNT & AZ31-MWCNT having diameter 40 mm & length 100 mm are fabricated by using stir casting technique. The Mg-MWCNT composite shows less pores and voids as compared to AZ31-MWCNT composite. Further these composites are machined for mechanical testing. Fig 3.3 shows the specimens of Mg-MWCNT & AZ31-MWCNT Composites. These specimens are machined by using lathe machine having diameter 10mm & length 25 mm. Specimens of Mg-MWCNT & AZ31-MWCNT composites shows that after machining they are having less cracks and having better surface finish is obtained. These machined specimens are ready for density & porosity test. Fig 3.4 shows the specimens of MG-MWCNT & AZ31-MWCNT Composites for Hardness test. These specimens are having diameter 30 mm & 10 mm thickness are machined by using Lathe machine which is having circular shape & flat surface, so as to mount on the Vickers hardness testing machine. After machining these specimens are polished by using emery paper so as to obtained smooth surface. Polishing of specimens is required to show the clear indentation on it.

### 3.1 Density Measurement

Following fig shows the Experimental setup for density test a) Weight of specimen in air b) Weight of specimen in liquid



(a)

(b)

Experimental density ( $\rho$ ) measurements are calculated in accordance with Archimedes's principle on specimens of pure Mg, AZ31 Mg alloy and Mg-MWCNT, AZ31 Mg alloy-MWCNT composites fabricated by using stir casting route. The experimental setup is as shown in fig a & fig b. Water is used as the immersion fluid. The specimen is first weighed in air, and then immersed and weighed again in a liquid with a known density, and the density of the specimen is calculated.

The experimental density of the specimen is calculated from equation,

$$\rho_e = \frac{W_a * \rho_x - W_x * \rho_a}{W_a - W_x}$$

Where,  $\rho_e$  = Experimental density of the specimen

$\rho_x$  = Density of the auxiliary liquid.

$\rho_a$  = Density of the air.

$W_a$  = Weight of specimen in air.

$W_x$  = Weight of specimen in the auxiliary liquid.

The theoretical density of the specimen is calculated from equation.

$$\rho_{th} = V_r \rho_r + (1-V_r) \rho_m$$

Where,  $\rho_{th}$  = Theoretical density ( $g/cm^3$ )

$V_r$  = Volume fraction of the reinforcement.

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$\rho_r$  = Density of the reinforcement material.

$\rho_m$  = Density of the matrix material

### 3.2 Porosity Measurement

Porosity of the specimens are calculated from the theoretical and experimental densities, using the following equation,

$$\text{Porosity} = (\rho_{th} - \rho_e / \rho_{th} - \rho_a) * 100$$

Where,  $\rho_{th}$  = Theoretical density of the composite.

$\rho_e$  = Experimental density of the composite.

$\rho_a$  = Density of air.

### 3.3 Hardness Measurement

Hardness is measured using Vickers hardness tester with a load setting of 10N and dual time of 15sec.

Vickers Hardness of the specimen is calculated by using the following equation:

$$\text{VHN} = (1.8544 * P) / (d)^2$$

Where, VHN = Vickers Hardness Number

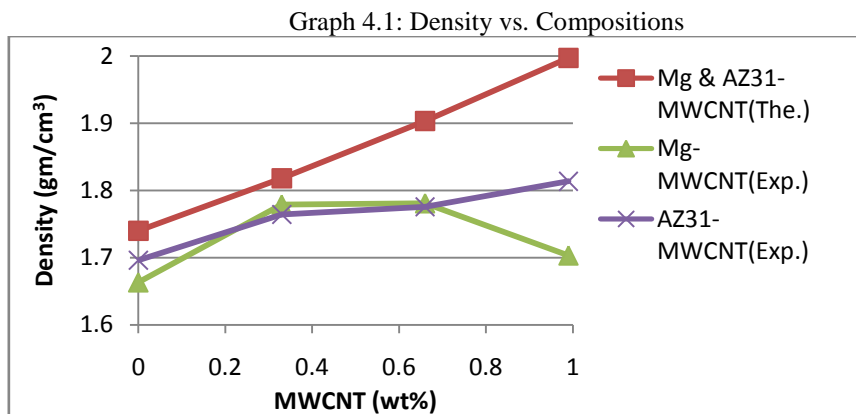
P = Load applied in N

d = Indentation diameter in mm

## IV. RESULTS AND DISCUSSION

### 4.1 Effect of MWCNT content on Density

Graph 4.1 shows the density of the fabricated composites having composition as 0.33wt%, 0.66wt% and 0.99 wt% MWCNT.



It is found that the theoretical density of Mg-MWCNT & AZ31-MWCNT composites goes on increases as % of MWCNT increases. The result also shows that the experimental density of Mg-MWCNT composites goes on increases suddenly up to 0.33 wt% MWCNT, and constant up to 0.66 wt% MWCNT then suddenly decreases by increasing the % of MWCNT. However the experimental density of AZ31-MWCNT composites goes on increases slowly according to increasing % of MWCNT. It is observed that the experimental density of the composites is lower than theoretical density with increasing wt% of MWCNTs. The reason for the lower density is due to the addition of light weight and high volume MWCNTs compared to the matrix material increases the porosity, which subsequently decreases the density.

It is observed that the density values of the composites increases with increasing wt% of MWCNTs. This happens because, during casting and stirring the distribution of dislocations within the matrix of the composites is uniform and there will be higher density near the reinforcing particles. In addition to this effect the reason for the increase in the density is due to the addition of light weight and high volume MWCNTs compared to the matrix material are reinforced, which subsequently increases the porosity. Density measurement results indicate that lighter nano composites have been obtained with the addition of MWCNTs. For AZ31-MWCNT composites density increases due to the presence of some impurities like oxygen, nitrogen, etc

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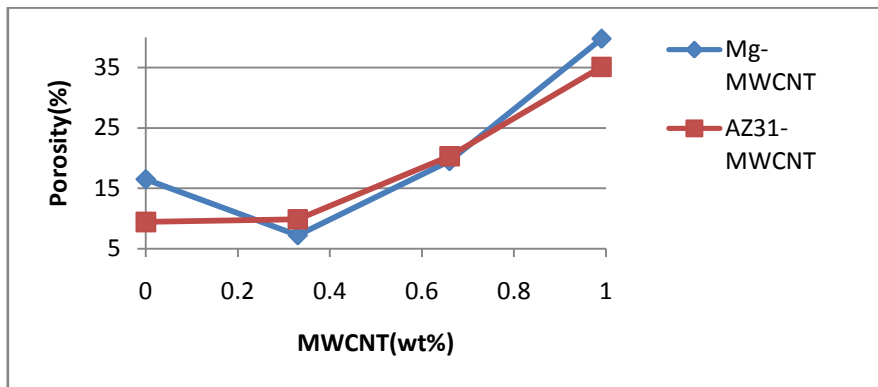
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### 4.2 Effect of MWCNT content on Porosity

Graph 4.2 shows the porosity of the fabricated composites having composition as 0.33wt%, 0.66wt% and 0.99 wt% MWCNT.

Graph 4.2: Porosity vs. Compositions.

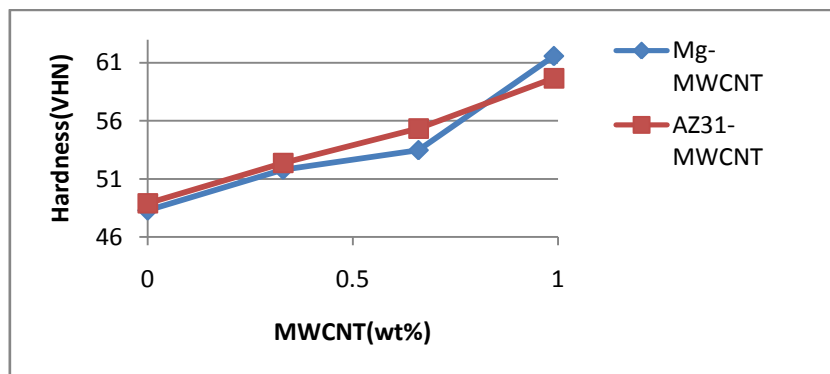


It is found that the porosity of Mg-MWCNT composites goes on decreases up to 0.33 wt% MWCNT, and then increases suddenly as % of MWCNT increases. However porosity of AZ31-MWCNT composites slightly increases up to 0.33 wt% MWCNT, then suddenly increases as % of MWCNT increases. The result also shows that the porosity is lower for AZ31-MWCNT composites as compared to Mg-MWCNT composites. Porosity values are increases in the Mg & AZ31 matrix due to high clustering of CNTs. When more volume of CNTs added in to the Mg alloy matrix, the work of force decreases and leads to a possible reason for the increase in clustering effect which will inevitably lead to increase in porosity and decrease in the density.

### 4.3 Effect of MWCNT content on Hardness

Graph 4.3 shows the Hardness of the fabricated composites having composition as 0.33wt%, 0.66wt% and 0.99 wt% MWCNT.

Graph 4.3: Hardness vs. Compositions.



It is seen that the hardness of Mg-MWCNT composites suddenly increases up to 0.33 wt% MWCNT, then slowly increases up to 0.66 wt% MWCNT & go on increases as % of MWCNT increases. However hardness of AZ31-MWCNT composites goes on increases continuously as % of MWCNT increases. The hardness is higher for Mg-MWCNT composites as compared to AZ31-MWCNT composites. The hardness increases with the increase in % of MWCNT content because as the % of MWCNT content increases it distributes throughout the matrix in more uniform way and there is better transfer of load from matrix to reinforcement. If a little MWCNT is added, the hardness of the composite increases because the MWCNTs fill the micro voids of the Mg particles. However, when



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large amount of MWCNTs are added, the excess MWCNTs that remain after filling the micro voids form conglomerates with the Mg particles. This conglomeration interrupts the casting and causes defects. Based on these results, higher the MWCNT content, the amount of wear also increases due to the separation of conglomerated particles that have a weak bonding energy with the surface.

The increase in hardness of the Mg-0.99 wt% MWCNT & AZ31-0.99 wt% MWCNT composites in the present study can be attributed to: (a) intermetallic particles of lower size and roundness ratio in the matrix, (b) reasonably uniform distribution of harder MWCNT in the matrix, and (c) higher constraint to localized matrix deformation during indentation due to the presence of intermetallic particles (having lower size and roundness ratio) and nano particles. The amount of increase in the hardness in the present work is high and hence found significant to affect the ductility of the material compared to that of pure Mg.

## V.CONCLUSIONS

1. The Mg-MWCNT & AZ31-MWCNT nanocomposites have been successfully synthesized using the stir casting technique.
2. It is observed that the density values of the composites increases with increasing wt% of MWCNTs. This happens because, during casting and stirring the distribution of dislocations within the matrix of the composites is uniform and there will be higher density near the reinforcing particles.
3. The reason behind the increase in porosity is due to the clustering effect of CNTs. When more volume of CNTs added in to the Mg alloy matrix, the work of force decreases and leads to a possible reason for the increase in clustering effect which will inevitably lead to increase in porosity.
4. The hardness increases with the increase in % of MWCNT content because as the % of MWCNT content increases it distributes throughout the matrix in more uniform way and there is better transfer of load from matrix to reinforcement.

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