ANALYSIS OF REINFORCEMENT OF NANO AL_2O_3 ON MECHANICAL PROPERTIES OF MAGNESIUM METAL MATRIX NANO COMPOSITE

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ABSTRACT:Magnesium based metal matrix composites (MMCs) offer potential for advanced structural applications with high specific strength and modulus, as well as good elevated temperature resistance along with light weight and for marine applications. The Magnesium and its alloys have excellent ductility but reasonable strength makes it widely used in the field of automotive, aerospace. The reinforcements added to MMC will improve the properties of the composite like shear strength, tensile strength, hardness, and wear behavior. Discontinuously reinforced magnesium matrix composites are fast emerging as engineering materials and competing with common metals and alloys. They are gaining significant acceptance because of higher specific strength, specific modulus and good wear resistance as compared to ordinary unreinforced alloys. The microstructural characteristics studied in order to comprehend the mechanical response showed significant grain refinement due to grain boundary pinning effect of
nano-Al_2O_3particles which resulted in strengthening of Mg. In the present work, magnesium Alumina composite developed using a stir casting technique is studied for Tensile strength, compressive strength and angle of twist by using the universal testing machine and torsion testing machine. The Tensile strength and angle of twist of the composites are investigated at room conditions by varying percentage of alumina nanoparticles by weight 2% to 8% with increment of 2%.

KEYWORDS Magnesium metal matrix nano composite, Fabrication technique, Scanning electron microscope, Mechanical properties (Tensile strength, compressive strength, Angle of twist)

1.INTRODUCTION:

An increasing demand for lightweight structural materials in recent years has met with simultaneous surge in the development of magnesium metal matrix composite [1,2]. Aerospace, automobile, electronic, bio-implant and consumer product related industries has been seeking for metallic magnesium composite based structural materials for performance critical application. The magnesium is available in huge quantity in natural resources i.e. 8th most common element in earth crust and 3rd most common element in dissolved seawater minerals [2] of magnesium on earth is considered to be the lightest metal with high potential for structural application. Magnesium metal matrix composite mostly used because of their lightweight, and the higher preference of magnesium based materials over other lighter metals like aluminum and titanium is due to the possession of relatively good strength, castability, machinability, dimensional stability, damping capacity, electromagnetic radiation resistance and low power consumption [1,3].

In recent decades, there has been an increasing demand for advanced structural application materials with excellent weight saving potential in order to satisfy the growing economic and environmental condition such as fuel price inflation, greenhouse gas emission [4,5]. Mainly in the automotive and aircraft industries, and aerospace industries the current research works are more interesting on the extensive utilization of magnesium metal matrix composite which offers superior combination of properties [4,6]. Magnesium (with density 1.74 g/cc), which is about 75% lighter than steel and about 35% lighter than aluminium attracts more focused extensive research in terms of weight saving potential in critical engineering applications. For example, cylinder block of the V6 cylinder engine the replacement of cast iron by magnesium (Mg) would reduce the weight from 86 kg to 30 kg [7]. Similarly, the possible replacement of other structural components by Mg would contribute to around 100 kg reduction in weight which could reduce the fuel consumption by 500 ml per 100 km and the fuel emission by 5% [8,9]. Besides weight savings, magnesium composite also exhibit a range of influential properties such as excellent damping capacity, castability, machinability and dimensional stability.

In this context, it found that the incorporation of nanoparticles reinforcements into magnesium has positively influenced the ductility of magnesium metal matrix. The recent review article [10] comprehensively shows that the beneficial role of reinforcement various nanoparticles ceramic on the mechanical properties of Mg and Mg alloys. It concluded that the reinforcement of ceramic particles such as SiC, Al_2O_3, SiO_2 and Y_2O_3, which mostly used as nano reinforcements, to improve the strength and ductility of magnesium and magnesium alloys. In this review article referred to nano composite [10] generally exhibited superior mechanical properties and they were prepared using the processing methods such as liquid state processing based on disintegrated melt deposition (DMD) method, and solid state processing based on blend-press-sinter technique, ultrasonic assisted liquid processing, acoustic cavitation and friction stir processing. Hassan and Gupta et. Al. [11] used both the solid state and liquid state processing methods to develop superior magnesium metal matrix nano composites containing various oxide reinforcements such as SiC, Al_2O_3, SiO_2 and Y_2O_3. Choi et al. [12] synthesized reinforcement of nano particles on Mg composites by using the ultrasonic cavitation method and reported that the SiC nanoparticles have improved the strength properties of Magnesium composite without prominent effect on ductility. Also other researchers have reported similar mechanical property enhancement due to nano scale reinforcement addition [13,14–15]. In this context, the effect of reinforcement nano scale boron carbide particle addition on the of pure magnesium for microstructural evolution and tensile response was recently reported and the results showed that the incorporation of nano scale B_4C particles to Magnesium have resulted in texture randomization and significantly improved the tensile strength [16]. From this background, it can be clearly understood that the efficient uniform dispersion of nano scale reinforcements improves the mechanical properties of Magnesium. V. Sridhar et.Al. [17] presents the synthesis and mechanical study of magnesium reinforcement nano alumina powder with variation in volume percentages of alumina. The magnesium metal matrix nano composite develop by varying 3 amount of nano particle (i.e. .35, .7 and 1.4 volume percentage) by the powder metallurgy method. And also the reinforcement of the nanoparticles in to meta matrix improves the density of the composite [18]

M Habibnejad-Korayema et. Al.[19] uses stir casting fabrication technique for reinforcement of nanoparticles in to the metal matrix composite . different percentage of weight of alumina nano particles were added to pure magnesium and AZ31 magnesium alloy. A uniform distribution of the Al_2O_3 nanoparticles with an average diameter of 100nm. Refined the grain structure of cast and decrease the coefficient of thermal expansion, thus improving the dimensional stability of both pure magnesium and AZ31 alloy.

KAINER K U. et. Al. [20] studied the reinforcement of Ceramic alumina nanoparticles into the aluminium alloy metal matrix by using liquid processing route in particular stir casting method. Ceramic nanoparticles reinforced by varying percentage 6% to 12% by weight in step of in step of 3%. For each composite, ceramic nanoparticles preheated to the 200^0c to increase the wettability of the nanoparticles. Then microstructural characteristics of composites are investigated by SEM photograph that is taken by the scanning electron microscope, it is found that alumina nanoparticles distributed uniformly with agglomeration at some place. Mechanical properties are highly sensitive to the microstructure and these are indirectly related to solidification parameters and processing conditions. G.G. sozhamannam et. Al. [21] studied that, the Sic (silicon carbide) nanoparticle reinforced with the aluminium metal matrix at the different temperature and different holding time by using the stir casting method. Because by changing the temperature and holding time distribution of nanoparticles in composite matrix changes and then make a comparision in mechanical properties of the different specimen. The distribution is examined by microstructure analysis, hardness distribution and density distribution. From the microstructure analysis it is found that there is increase in particles clustering corresponding to an increase in processing temperature and also the clustering tendency is more in the higher holding time than in the low holding time. The ultimate strength of composite increases when processing temperature increases from 700-800^0C and then decreases from 800-900^0C

In this work the study of Tensile strength, Compressive strength and angle of twist of the Mg- Al_2O_3 composite sample varying various composition like:

(i.) Pure Magnesium
(ii.) Mg+ 2% of Al_2O_3
(iii.) Mg+ 4% of Al_2O_3
(iv.) Mg+ 6% of Al_2O_3
(v.) Mg+ 8% of Al_2O_3
(vi.) Mg+ 10% 0f Al_2O_3

After determining the experimental value of the mechanical properties the composite the comparison is done between these value of mechanical properties. In this work we focused on particulate composite formation by reinforcement of Al_2O_3 nano particles in to magnesium matrix by using stir casting method. Micro structural study of composite were characterized with scanning electron microscopy (SEM).

2. EXPERIMENTAL PROCEDURE:

The matrix material used in this study is pure magnesium with 99.92% purity. And used nanoparticle is Al_2O_3 (alumina) with purity: 99.85%, 100% alpha phase average particle size 150nm (from BETSSA and SEM), specific surface area (SSA) – $10m^2/g$. These Al_2O_3 particles with varying amounts of 2,4,6 and 8wt % are used as reinforcing material in preparation of composite. Fig. of raw material that are used for preparation of composite are given below.

Fig.1 of Raw material

2.1 Stir casting:

The magnesium Al_2O_3 metal matrix nano composite was prepared by stir casting process. For this we took different composition i.e.

- Pure magnesium
- 1 kg magnesium + 2o gram of Al_2O_3
- 1 kg magnesium + 40 gram of Al_2O_3
- 1 kg magnesium + 60 gram of Al_2O_3
- 1 kg magnesium + 80 gram of Al_2O_3

The alumina nanoparticles were preheated before to remove the moisture content which is present. Commercially pure magnesium was melted in the furnace and melting temperature was raised up to 710°C. the melt temperature was maintained at temperature about 690°C during the addition of the nanoparticles. then the melt was stirred by the mechanical stirrer (zirconia coated steel impeller) and stirring was maintained 5 to 7 minute after the addition of alumina nanoparticles in to magnesium metal. The dispersion of alumina nanoparticles was achieved by the vortex method. the with reinforced particulates were poured in to the preheated mould. The pouring temperature was maintained 670°C. the melt was then allowed to solidify in the mould.

2.2 Scanning Electron Microscope (SEM)

The scanning electron microscope (SEM) is a type of electron microscope in which focussed electron beams of high energies scans the solid surface and form micrographs. The interaction between the electron beams and the atoms present on the sample surface generate signals that enables us to analyse properties like morphology, composition, electrical conductivity, topography etc. Various kinds of signals can be produced by an SEM ranging from secondary and back-scattered electrons to characteristic x-rays. The high resolution of SEM helps in obtaining images of specimens with varying sizes from those visible to the naked eye to those of nanometric dimensions. [16] The microstructure of the α- Al2O3 obtained were characterized using a JEOL JSM-6480LV scanning electron microscope (SEM). [17] The JEOL JSM-6480LV scanning electron microscope was equipped with an INCAPentaFET-x3 X-ray microanalysis system with a high-angle ultra-thin window detector and a 30 mm2 Si (Li) crystal.

Fig 2 of JEOL JSM-6480LV scanning electron microscope.

2.3 Universal Testing machine

The tensile strength and compressive strength of the pure magnesium and metal matrix nano composite are evaluated on universal testing machine. Tensile and Compressive strength investigation was carried out to find the effect of percentage of reinforcement of the nanoparticles on the pure magnesium metal matrix. The specimen of the universal testing machine are given below. The maximum capacity of the universal testing machine is 10 ton of ALFRED J. AMSLER & CO. SACHAFFHOUSE (Switzerland).

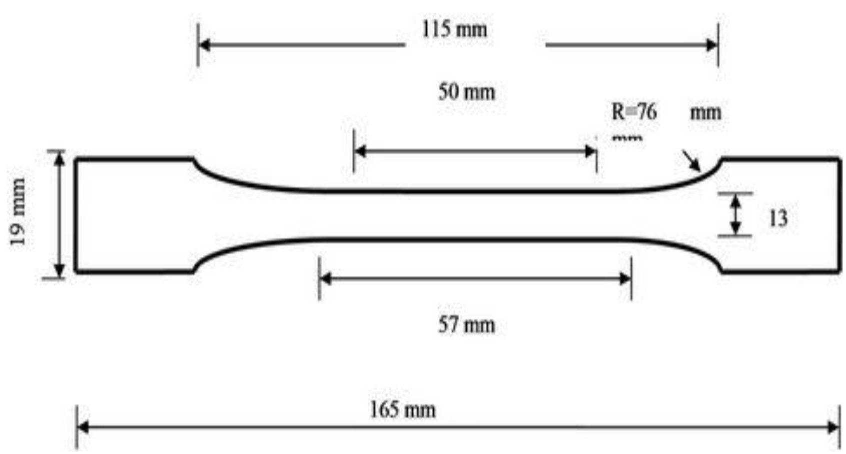


Fig 3 of specimen of UTM machine

Fig 4 of UTM machine

2.4 Details of torsion testing machine

The angle of twist of magnesium metal matrix nano composite are evaluated on torsion testing machine. The test specimen placed on the torsion testing machine and torque is applied. The effect of the reinforcement of nanoparticles on pure magnesium metal matrix with different percentage on the shear strength is evaluated. The TT type torsion testing machine serves for conducting test in torsion for this study and it was located at the material testing laboratory of Department of Mechanical Engineering, JEC Jabalpur, India. The machine is equipped with pendulum dynamometer, a recording device for registering torque-twist diagram. The accuracy of the torque indication is ±1% of true torque. Angular velocity of 1.5°/min was used as torsion test speeds. TT type torsion testing machine is shown in Figure. Specimen of the torsion testing machine given below.

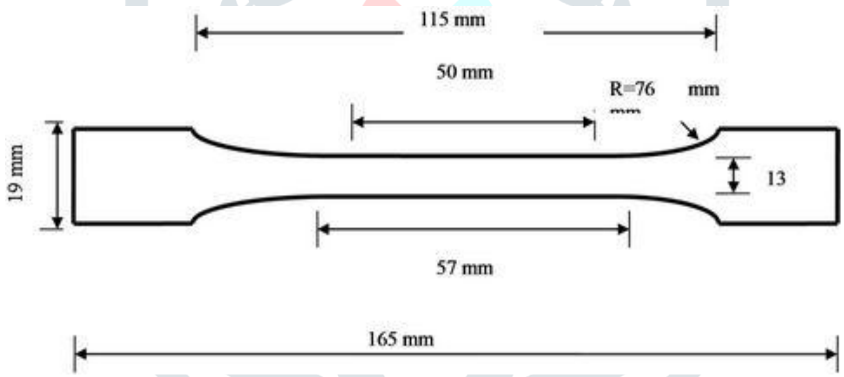


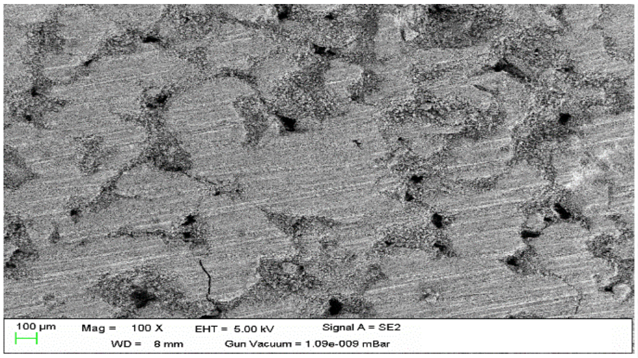
Fig 5 of specimen of torsion testing machine

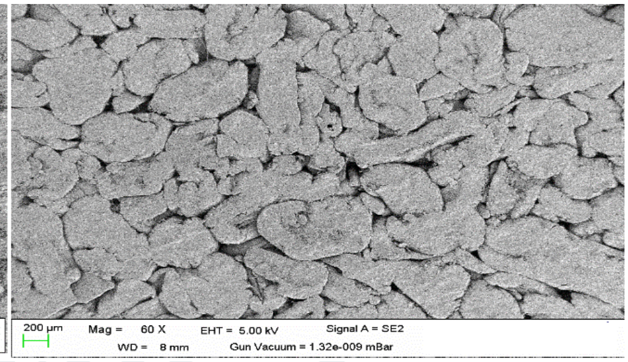
Fig.6 of Torsion testing machine

3. RESULT AND DISCUSSION

3.1 Microstructure

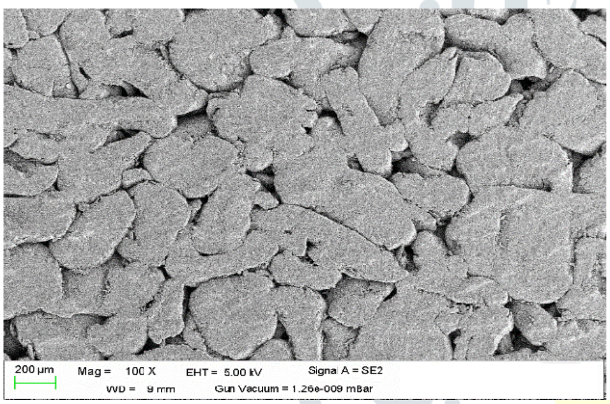
Fabrication of metal matrix composite with alumina particles by casting process is usually difficult because of the very low wettability of alumina particles and agglomeration phenomena which result in non- uniform distribution and poor mechanical properties. The below figure indicate that most of the alumina particles were present in the form agglomerates and clusters both at the grain boundary and in the grain interior indicating a reasonable distribution of cluster/ agglomerated alumina particles in magnesium metal matrix. The alumina particles were present both individually and in Al_2O_3. Hence in view of uniform distribution of alumina particles and intermetallic the micro structure can be considered to be homogenous in case of below four compositions. However, the alumina and intermetallic were found to be well dispersed in the Mg metal matrix.

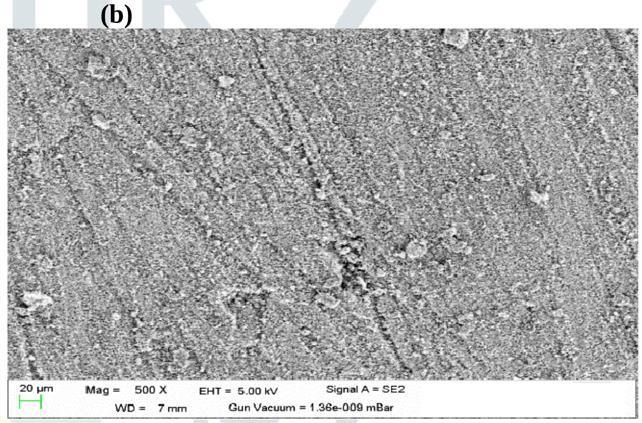




(a) Mg+ 2wt % Al_2O_3 **(b) Mg+ 4wt % Al_2O_3**

(b)





(c) Mg+6wt % Al_2O_3 **(d) Mg+ 8wt % Al_2O_3**

Fig.7 of SEM images with different fraction of Al_2O_3 in Mg metal matrix

3.2 Tensile and Compressive testing result

To investigate the mechanical behaviour of the composites the tensile tests and compression test were carried out using uni-axial tensile testing machine as per ASTM standards. Two specimens were used for each test and average value is reported. Following observation are made from the given tabale and graph of tensile testing and compressive testing.

- Pure magnesium metal matrix have lower tensile and compressive strength.
- The tensile strength and compressive strength of composites are increases as the percentage of reinforcement increases from 2 to 8wt. % of nano-Al_2O_3 particles.
- The highest tensile and compressive strength was observed in case of 8wt. % of Al_2O_3 nanoparticles.
- It is also clear from the given data that ductility of the composite decreases as the percentage of reinforcement of nano-Al_2O_3 particles increases.

The strengthening mechanism for MMNCs has been studied and one of the major attributes is the higher dislocation density in MMNCs . The difference of the thermal expansion coefficients between the matrix and the uniformly dispersed nano-Al_2O_3 could induce high dislocation density, and these nano-Al_2O_3 inclusions can work as the barriers for dislocations movement. It is believed that the properties of MMNCs would be enhanced considerably even with a very low volume fraction due to the high dislocation density of matrix metal.

Tabale.1 variatoin of tensile strength of composites with different wt. percentage of nano Al_2O_3 particles

S.No.	Material Composition	Ultimate Tensile Strength (MPa)	Extent of improvement in UTS value (%)
1	Pure Mg	173.62	_
2	Mg+2% of Al_2O_3	184.71	6.38
3	Mg+4% of Al_2O_3	195.79	12.76
4	Mg+6% of Al_2O_3	210.67	21.34
5	Mg+8% of Al_2O_3	221.65	27.66

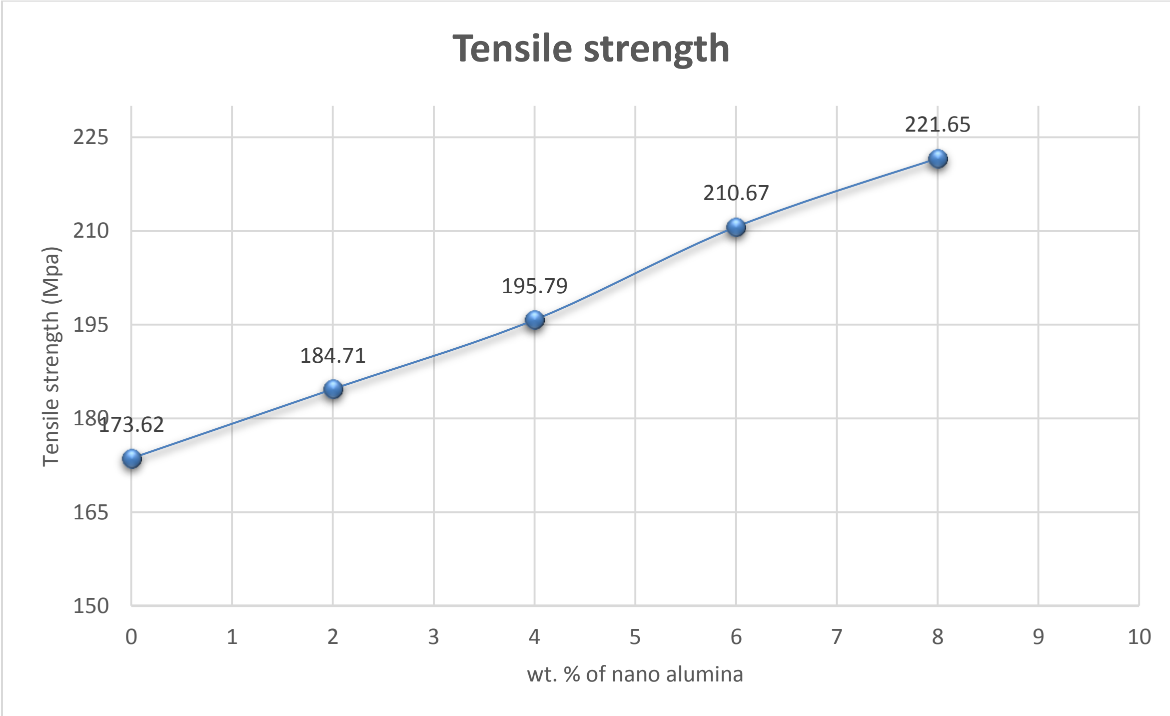


Fig.8 variatoin of tensile strength of composites with different wt. percentage of nano Al_2O_3 particles

Tabale.2 variatoin of compressive strength of composites with different wt. percentage of nano Al_2O_3 particles

S.No.	Material Composition	Ultimate Compressive Strength (Mpa)	Extent of improvement in UTS value (%)
1	Pure Magnesium	265.98	-
2	Mg+2% of Al_2O_3	273.37	2.77
3	Mg+4% of Al_2O_3	284.45	6.94
4	Mg+6% of Al_2O_3	302.92	13.88
5	Mg+8% of Al_2O_3	314	18.05

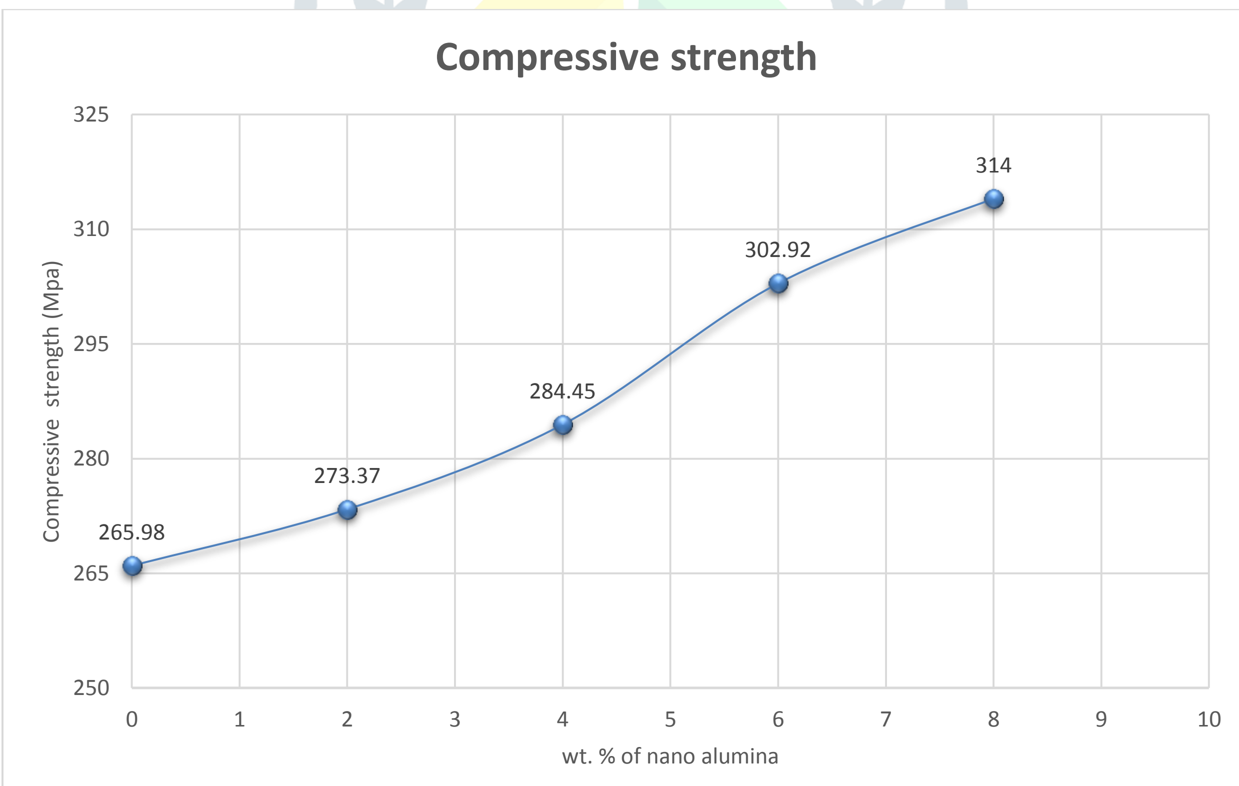


Fig.9 variatoin of compressive strength of composites with different wt. percentage of nano Al_2O_3 particles

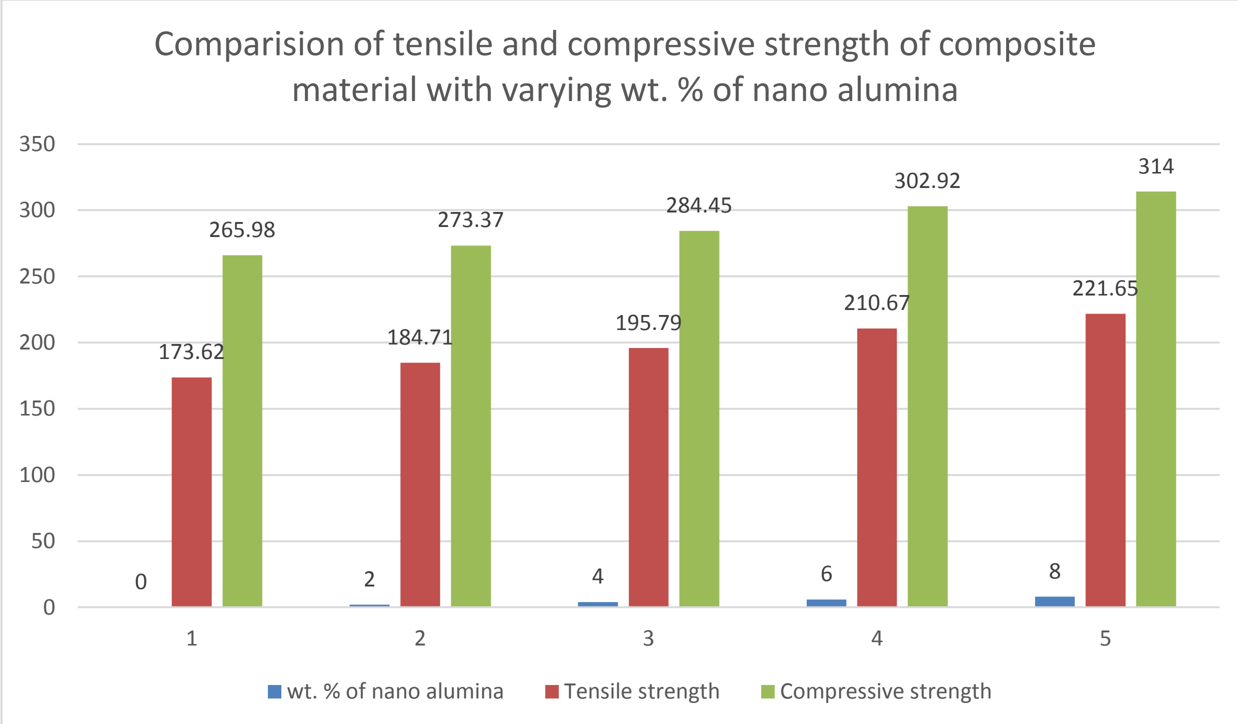


Fig.10 variatoin of Tensile strength compressive strength of composites with different wt. percentage of nano Al_2O_3 particles

3.3 Torsion Testing

Tabale shows the comparison of angle of twist of pure magnesium metal matrix and composite material with composition of 2%, 4%, 6% and 8% of nano Al_2O_3 particles . the angle of twist of composites is lesser then that of pure magnesium metal matrix and the value of angle of twist is decreases with increasing wt. percentage of nano particles and its value minimum for the 8wt.% of nano Al_2O_3 particles. This decrease in the value of angle of twist of composites samples relative to that of pure magnesium metal matrix could be attributed to the redusing grain size and existence of hard nano Al_2O_3 particles acting as obstacles to the motion of dislocation. It should be mention that agglomeration occurs as a result of higher viscosity of the molten metal and increasing tendency to clump the particles together due to high surface tension and poor wetting between the particles and melt.

Table.3 Torque-angle of twist experimental value of pure magnesium

S.No.	Torque(Nm)	Angle Of Twist (Radian)
1	0	0
2	11.2	0.0750
3	23.5	0.1395
4	35.3	0.2180
5	58.9	0.3262
6	56.4	0.3488

Table.4 Torque-angle of twist experimental value of Mg+2% Al_2O_3 nano particles

S.No.	Torque(Nm)	Angle Of Twist(Radian)
1	0	0
2	15.37	0.0680
3	31.75	0.1360
4	48.2	0.2041
5	62.3	0.03035
6	61.5	0.3366

Table.5 Torque-angle of twist experimental value of Mg+4% Al_2O_3 nano particles

S.No.	Torque(Nm)	Angle Of Twist(Radian)
1	0	0
2	16.30	0.0610
3	33.5	0.1238
4	51.25	0.1849
5	65.3	0.2669
6	64.9	0.3053

Table.6 Torque-angle of twist experimental value of Mg+6% Al_2O_3 nano particles

S.No.	Torque(Nm)	Angle Of Twist(Radian)
1	0	0
2	17.35	0.0558
3	35.4	0.1134
4	56.7	0.1762
5	72.1	0.2389
6	69.4	0.2773

Table.7 Torque-angle of twist experimental value of Mg+8% Al_2O_3 nano particles

S.No.	Torque(Nm)	Angle Of Twist(Radian)
1	0	0
2	18.27	0.0488
3	37.5	0.0994
4	59.72	0.1500
5	75.8	0.1971
6	73.1	0.2389

4.CONCLUSOIN

1. Magnesium metal matrix nano (2,4,6 and 8 wt. %) alumina particles composites have been successfully fabricated by stir casting method.
2. From SEM images it is found that the nano particles are uniformly distributed in magnesium metal matrix with some agglomeration and clustering.
3. Tensile strength increases with increases in wt. % of Al_2O_3 nano particles. Mg+8% Al_2O_3 partcles composites with maximum tensile strength 221.65 Mpa.
4. The compressive strength of composites increases with increases in wt. % of Al_2O_3 particles. Mg+8% Al_2O_3 particles composites have the maximum compressive strength of 314Mpa.
5. Increases in tensile and compressive strength with increases in wt. % of Al_2O_3 particles are not uniform because of the some agglomeration and clustering of nano particles.
6. Angle of twist of composites decreases with increases in wt. % of Al_2O_3 particles. And composite with 8% of nano Al_2O_3 particles have lesser angle of twist .

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