Experimental Evaluation of Tensile Properties of Magnesium Alloy Reinforced With Chopped Glass Fiber

Mohd Nayeem[1], Babu Reddy[2], Ambadas[3]
[1]Dept of Machine Design Centre for Post Graduate Studies
[2, 3]Assistant Professor, Dept of Machine Design Centre for Post Graduate Studies
[1, 2, 3] VTU, Kalaburagi

***Abstract**- Magnesium is found to be the lightest metal in the world. It is replacing Aluminium in many application for more weight saving. In this research work E-Glass fibres of 3mm length is utilized as reinforcement in fabrication of a Magnesium alloy (AZ91) matrix composite. The Magnesium matrix composites were prepared by stir-casting method at 750 °C. A metal mould which has 6 circular slots of 20mm diameter and 170mm length has been utilized for casting the specimens. The tension specimen ofMagnesium metal matrix composite was prepared by randomly reinforcing E-glass fibres from 0 to 10% by volume in steps of 2%, 4%, 6%, 8% and 10% of the total composite volume. Two specimens of each volume fraction were prepared and tension test was carried out as per the ASTM E8/E8M standard. The reinforcement effect on the tensile strength of the magnesium alloy AZ91 was studied. Improvement in the tensile properties of Magnesium alloy (AZ91) has been noticed with the increase in the volume fraction of E-glass fibre.*

Keywords- Glass Fiber, Magnesium Alloy, Tensile Properties, Stir Casting, Young's Modulus.

I. INTRODUCTION

Composite material is a material formed by two elementary materials that differ in their physical and chemical properties but on combining results into a material possessing characteristics distinct from the individual elementary materials. [1] Composite material have superior properties in comparison to its constituent materials.Composites are replacing conventional materials day by day from very ample range such as automobile industries to aviation industries, medical tools to space exploration vehicle and satellites. Industries in which weight reduction is the prime concern are moving towards the composites material as they offer greater weight reduction and better efficiency. In automobile industries composites provides better structural integrity and crash worthiness and withstand forces of wind in high speed cars. In aircraft industries composites such as carbon fiber reinforced composite and magnesium metal matrix composites are used in the manufacture of wing assemblies, propellers and rotor blades of helicopter etc.

II. LITERATURE SURVEY

Metal matrix composites have found use in numerous parts of everyday life in recent time. Specially in the field of automobile industry, they are used in fiber reinforced pistons, aluminum crank cases and particle strengthened disks of breaks. A reduction in weight favours the broadening the application range, substitution of basic materials and improvement of segment properties. [4]

The magnesium grid composites are potential materials in the field of aviation because of their low thickness, great mechanical and physical properties. But, the application of magnesium alloys is restricted evidently owing to their low creep resistance at elevated temperatures, low strength, low modulus and wear resistance. Thus, Reinforcements are required to get better the properties of the base metals. Some of the materials used for reinforcements are Aluminium Oxide, SiliconCarbide, Carbon fibers, glass fibers and Titanium Carbide. [5]

The E-Glass fibers can be used in the recycle of E-waste materials such as aluminum and magnesium by forming composites. Fiber reinforced composite materials consist of fibers engulfed with the matrix.In this form, both the constituent materials does not lose their physical and chemical properties. Optimal strength and desirable properties are gain when the fibers are continuously aligned straight and parallel in a single direction. To support strength in other directions, construction of laminate structure can be done, with continuous fibers aligned in other directions. E-glass fiber, is low cost, high strength, good reinforcement and easily available in the market. [7]

In stir casting process of metal matrix composite it is found that the holding time between matrix and reinforcement is considered as significant factor. The holding time of the composite of atleast 10 minutes facilitates the particles to get uniformly distributed into the matrix at a temperature of about 800˚C. The liquid matrix has enough viscosity in the temperature range, and velocity of particles flow is little. The similar results are observed in the 20 minutes holding time. [8]

III. CONSTITUENTS USED TO PREPARE METAL MATRIX COMPOSITE

MAGNESIUM ALLOY AZ91 (MATRIX MATERIAL)

Magnesium Alloy AZ91 is the most commonly used magnesium die cast alloy and has brilliant combination of mechanical properties, resistance to corrosion, and high castability. Designers should know about the creep limitations of magnesium alloy AZ91. The tensile strength, yield strength, decreases while ductility increases with the increase in temperature. [9]

Fig. 1 Magnesium Alloy

Table 1.1Composition of Magnesium AZ91

Materials(%)	Al	Zn	Mn	Si	Cu	Mg
AZ91	8.83	0.62	0.20	0.01	0.002	Bal.

Table 1.2Mechanical properties of Magnesium AZ91

Material	Alloy	Density (g/cm^3)	Melting point (°C)	Thermal conductivity (W/m K)	Tensile Strength (MPa)	Shear Strength (MPa)	Young's Modulus (GPa)
Magnesium	AZ 91	1.81	533	72.3	230	140	45

E-GLASS FIBER(REINFORCEMENT MATERIAL)

E-Glass was initially produced for covers of electrical wiring. Then it was found to have amazing fiber shaping abilities and is currently utilized solely as the strengthening stage in the material normally known as fiberglass. They occupy the maximum portion of the market of glass fibers as they are cheaper in cost. [10]

Fig 2 Chopped E-Glass Fiber

Table 1.3Properties of E-Glass Fiber

Properties of E-glass fibers	Units	Values
Density	g/cm^3	1.16
Specific gravity		2.68
Thermal conductivity	W/mK	1.30
Tensile Strength	Mpa	1700
Young's Modulus	GPa	72

IV. METHODOLOGY

METHODOLOGY DETAILS

The methodology of this thesis work can be summed into the following number steps:

- Procurement of materials
- Casting of specimens
- Machining of specimens
- Testing of specimens

PROCUREMENT OF MATERIALS

The reinforcement material that is chopped strands of E-Glass fiber of 3mm in length are purchased from Bangalore, Karnataka. The matrix material that is magnesium alloy AZ91 is purchased at the Hyderabad, Telangana.

CASTING OF SPECIMENS

- The Magnesium AZ91 alloy weighing about 2000gm is taken and added into the induction furnace. The induction furnace melts the magnesium alloy at temperature of about 800°C.

- When the magnesium alloy completely melts then the glass fiber are weighed to the desired volume fraction and are added into the induction furnace.
- The induction furnace rotates at speed of about 300rpm which facilitates the proper mixing of glass fibers with the magnesium alloy.
- Then the hot mixture of the magnesium alloy and the glass fiber is poured into the metal mould and allowed to solidify for half an hour.
- After half an hour the casted specimens are removed by opening the mold. Then again 2000gm of magnesium is taken and the casting procedure is repeated for the further volume fractions of glass fibers.

Fig3Composite mixture pouring into the mold

Fig 4 Casted specimen

Table 1.3 Compositions of Specimens

SL.NO.	CASTINGS	SPECIMEN NO.	E-GLASS FIBER (%)	MAGNESIUM ALLOY(%)
1	CASTINGS-1	0-T1	0	100
2		0-T2	0	100
3	CASTINGS-2	2- T1	2	98
4		2 - T2	2	98
5	CASTINGS-3	4- T1	4	96
6		4- T2	4	96
7	CASTINGS-4	6- T1	6	94
8		6- T2	6	94
9	CASTINGS-5	8- T1	8	92
10		8- T2	8	92
11	CASTINGS-6	10- T1	10	90
12		10- T2	10	90

MACHINING OF SPECIMENS TO ASTM E8

ASTM standard E8 provides the shape and dimensions of the tensile test specimen for the metallic materials. According to ASTM standard E8 the tensile test specimen should be round in cross-sectional area. The gauge length of the specimen should five times the diameter of the specimen. The below figure gives the details about the shape and dimension of the test specimen. [11]

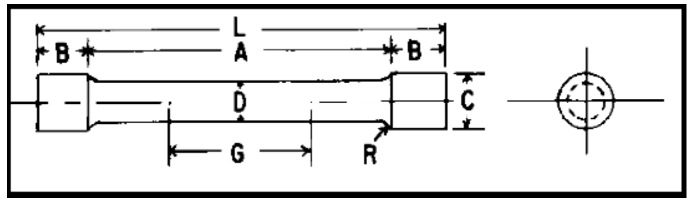


Fig 5 ASTM E8 Specimen

Table 1.4 ASTM E8 Dimensions

Particulars	Values (mm)
G-Gauge length	50
D-Diameter	12.5
R-Radius of fillet	10
L-Overall length	145
B-Length of end section	35
A- Length of reduced section	75

Testing of specimens

The apparatus required for performing the tension test on the prepared composite material specimens are Universal testing machine,Vernier caliper, Micrometer, Marker pen etc.

Procedure of performing tenion test

- First the specimen is taken and gauge length of 50mm is marked on the 12.5mm diameter part of the specimen with help of a permanent marker.
- The extensometer is fixed to the specimen around the marked gauge length.
- Now first fix the specimen in the upper end grips of the machine and then fix the lower end grip.
- Now first fix the specimen in the upper end grips of the machine and then fix the lower end grip.
- Ensure that the specimen is properly gripped so that no slip occurs during the test.
- Now with the help of computer constantly apply the load and also hold the gripping lever for preventing any slips.
- The extensometer records the strain rate over the gauge length.
- Gradually increase the load until the specimen breaks.

The load at which the specimen breaks gives the tensile strength of the specimen and then Computer generates the plot of Load vs Displacement and Stress vs Strain.

Fig. 6 Universal Testing Machine

Fig. 7 Specimens after Testing

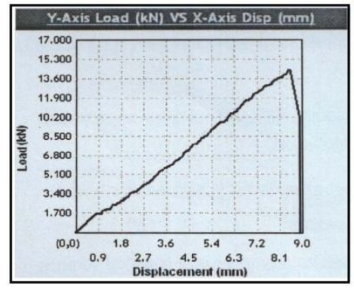
V. RESULTS AND DISCUSSION

In this research work tension test on the composite material of Magnesium alloy AZ91 and E-Glass fibers has been performed. Tension test is performed on six different volume fraction of the composite composition. Total twelve specimens were made i.e. two specimen of each volume fraction. The plots of stress vs strain, load vs displacement has been obtained for each specimen after testing. The graph of tensile strength varying with volume fraction of reinforcement is plotted. The graph of Young's Modulus varying with the volume fraction of glass fibers is also plotted.

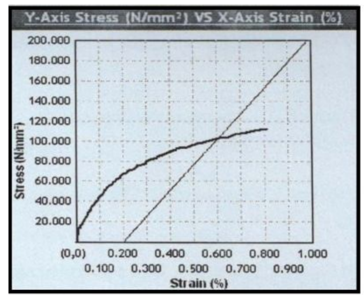
EXPERIMENTAL RESULTS

The graphs of obtained after testing of each specimen are given below:

1. For pure magnesium alloy AZ91 i.e. casting No. 1: Specimen No.-0T1



Graph 1: load in KN against displacement in mm for Specimen No. 0-T1



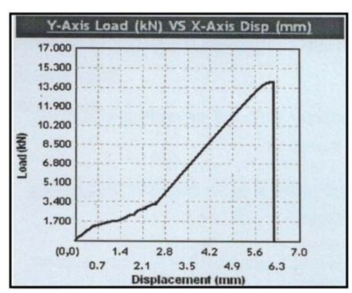
Graph 2: stress in N/mm² against strain in % for Specimen No. 4-T1

The Young's modulus is calculated from the above graph as

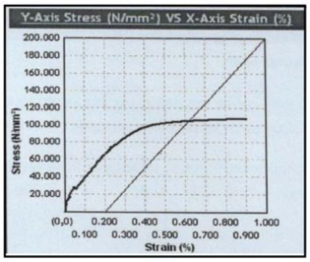
$$E = \frac{dy}{dx} = \frac{80 - 40}{\frac{0.4 - 0.12}{100}}$$

E = 14.28 GPa

2. For composite specimen with fiber volume of 10% i.e. casting No. 6
Specimen No.10T1



Graph 3: load in KN against displacement in mm for Specimen No. 10-T1



Graph 4: stress in N/mm² against strain in % for Specimen No. 10-T1

The Young's modulus is calculated from the above graph as

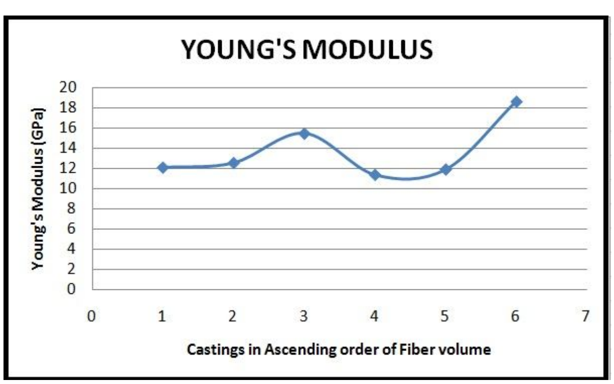
$$E = \frac{dy}{dx} = \frac{100 - 40}{\frac{0.4 - .12}{100}} = 20.70\ GPa$$

TENSION TEST RESULTS

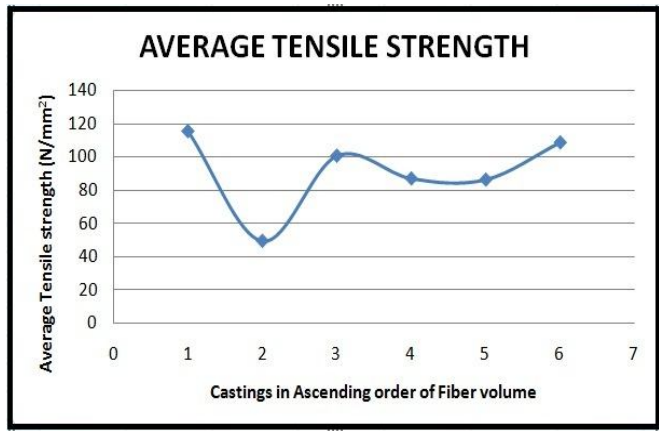
The young's modulus of the all specimens calculated from their respective stress-strain graph is tabulated below:

Table 1.5 Young's Modulus and UTS from Graph for Specimen Types

Sl. No.	Casting	Specimen No.	Ultimate Load (KN)	Ultimate Tensile Strength (N/mm²)	Average Tensile Strength (N/mm²)	Young's Modulus (GPa)	Average Young's Modulus (GPa)
1	Casting-1	0T1	14.36	115.53	115.16	12.90	12.07
2		0T2	14.52	114.79		11.25	
3	Casting-2	2T1	5.96	49.51	49.37	6.66	12.53
4		2T2	6.84	49.23		18.40	
5	Casting-3	4T1	12.84	104.62	100.43	14.28	15.45
6		4T2	11.85	96.25		16.66	
7	Casting-4	6T1	12.72	101.37	86.80	12.00	11.35
8		6T2	8.88	72.24		10.71	
9	Casting-5	8T1	11.80	93.58	86.13	13.33	11.88
10		8T2	9.32	78.69		10.43	
11	Casting-6	10T1	14.08	118.87	108.43	20.70	18.63
12		10T2	11.72	97.99		16.57	



Graph 5: Young's modulus in GPa vs Volume fractions



Graph6: Ultimate Tensile strength (N/mm²) vs Volume fractions

VI. CONCLUSIONS

SUMMARY AND CONCLUSION

The aim of this work is to study the tensile properties of composite material made of magnesium alloy AZ91 and E-glass fiber. For this tensile specimen of magnesium alloy AZ91 reinforced with varying weight fraction of E-glass fiber are successfully prepared. The specimens are casted by stir casting method. Total 12 specimens of 6 different volume fractions of reinforcement i.e. 0%, 2%, 4%, 6%, 8% and 10% are prepared which will be equal to 2 specimens for each volume fraction. ASTM standard E8M is followed during the preparation and machining of the specimen. The specimens are then tested on a universal testing machine and following conclusions are drawn:

- Tension test specimens of Magnesium alloy AZ91 reinforced with E-glass fiber are casted by stir casting method.
- The holding time between matrix and reinforcement is found to be a significant factor for processing of composite.
- ASTM standards are helpful for getting better results.
- It is found that fraction of fiber volume has a crucial effect on tensile properties.
- With the increase in the fiber volume, increase in the young's modulus of composite is seen.
- The increase in the young's modulus is a result of increase in the area of contact in the fibers with the matrix material.
- An increase of 142.50% is found in young's modulus of the composite material with 10% of fiber volume in comparison with the pure matrix material.

Work which can be carried out in future

- The matrix material magnesium alloy AZ91 can be reinforced with some other fibers such as carbon fiber or with some particulates.
- Effect of various length of E-glass fibers on the tensile properties of the matrix can be studied.
- Different method of casting can be adopted and results can be matched for comparison with those of stir casting method.
- Apart from tension test other test such as compression test, hardness test can also be performed.

REFERENCES

[1] Anup Goel, "Elements of Mechanical Engineering", Technical Publications, An Upthrust for Knowledge.

[2] Bhaskar Chandra Khandpal and Jatinder Kumar, "Production Technologies of Metal Matrix Composite: A Review", International Journal of Research in Mechanical Engineering and Technology (IJRMET), T Vol. 4, Issue 2, Spl - 2 May - October 2014.

[3] Halpin, J. C., "Stiffness and Expansion Estimates for Oriented Short Fiber Composites", Journal of Composite Materials, vol. 3, 1969, p.732-734.

[4] Karl Ulrich Kainer, "Basics of Metal Matrix Composites", Researchgate publications Chapter June 2006.

[5] Abhijit Dey and Krishna Murari Pandey, "Magnesium Metal Matrix Composites-A Review", Institute of Problems of Mechanical Engineering, Russia,Rev.Adv.Mater. Sci. 42 (2015) 58-67.

[6] Nikhil gupta, Dung D. Luong 1 and Kyu Cho, "Magnesium Matrix Composite Foams-Desnity, Mechanical properties and applictions", Metals- Open Access Metallurgy Journal.

[7] Siddharth Patel, "Study on mechanical properties of environment friendly Aluminium E-waste Composite with Fly ash and E-glass fiber", ScienceDirect Materials Today: Proceedings 4 (2017) 3441–3450.

[8] G. G. Sozhamannan, "Effect of Processing Paramters on Metal Matrix Composites: Stir Casting Process, Journal of Surface Engineered Materials and Advanced Technology", Journal of Surface Engineered Materials and Advanced Technology, 2012.

[9] "Magnesium Alloys", The American Society Technical Department, 2006 Casting Source Directory, Schaumburg, Illiniois.

[10] Fredrick T, Wallenberger, James C Watson and Hong Li, "Glass Fibers", PPG Industries Inc.

[11] "Standard Test Methods for Tension Testing of Metallic Materials", American Association State Highway and Transportation Officials Standard, AASHTO No.-T68, An American National Standard.

[12] Pan N, "The elastic constants of randomly oriented fiber composite: A new approach to Prediction", Science and Engineering of composite materials, Vol. 5, No. 96 2, pp.63-72, 1996.

[13] Md Abid Alam, "Experimental Study on Properties of Glass Fibre Reinforced Concrete", International Journal of Engineering Trends and Technology, Volume 24, Number 6-June 2015.

[14] Robert M Jones, "Mechanics of Composite materials", Taylor and Francis Inc.

[15] Preetam Kulkarni, "Evaluation of Mechanical Properties of AL 2024 Based Hybrid Metal Composites", IOSR Journal of Mechanical and Civil Engineering, Volume 12, Issue 5 Ver. IV (Sep. - Oct. 2015), PP 108-122.