EVALUATION OF TENSILE PROPERTIES OF MAGNESIUM ALLOY REINFORCED WITH CHOPPED BASALT FIBER

[1]SYED JUNAID ALI, [2]BABU REDDY, [3]AMBADAS
[1]M.Tech. Student, Department of Machine Design Centre for Post Graduate Studies, VTU, Kalaburagi
[2&3]Assistant Professor, Department of Machine Design Centre for Post Graduate Studies, VTU, Kalaburagi

Abstract*-Magnesium Alloy is the lightest of all light metal combinations and therefore is an outstanding choice for engineering applications when weight is a significant design consideration. Magnesium can be alloyed with other metals, making them more advantageous. The use of pure magnesium is very difficult due to its explosive nature at elevated temperatures and it is very corrosive in wet atmosphere. Basalt is a characteristic material that is found in volcanic rocks started from solidified magma, with a liquefying temperature of 1500°C to 1700°C. The basalt fibers allow one to produce composite materials which are non-combustible and fire resistant. The main aim of the work is to examine the tensile properties of the Magnesium Alloy reinforced with chopped basalt fibers of length 3mm in varying volume fractions of 2%, 4%, 6%, 8% and10%. The alloy and the fibers are casted by the stir casting method. The casted ingots are of 170mm length and 20mm in diameter. The specimen is machined as per the American Society of Testing and Materials (ASTM) E8 standard. After machining the specimen, the specimen is tested on the Universal Testing Machine (UTM). The test gives the graph of Load (KN) v/s Displacement (mm) and Stress (N/mm^2) v/s Strain (%) from which the Young's Modulus i.e. Modulus of Elasticity is obtained. The obtained results show that there is an increase in the tensile properties of the composite material when compared with the base Metal Alloy. Increase in volume fractions also increases the ultimate tensile strength. The said properties are maximum for the 10% fiber reinforcement.

***Keywords*- Chopped Basalt Fiber, Magnesium Alloy, Tensile Properties, Ultimate Tensile Strength, Young's Modulus, Stir Casting Method.**

I. INTRODUCTION

Composite is a material of combination of two or more materials that are mixed at a macroscopic level and are not soluble in each other. The first material is called Reinforcement while the second material is called Matrix. Metal Composite includes metal as matrix medium such as Aluminium, Magnesium, Titanium and it includes reinforcing medium as fibers such as Carbon, Basalt, Glass or mild fibers like Silicon Carbide, Tungsten Carbide etc.If Metal Matrix Composites contain three materials in one composite it will be called as Hybrid composite material. Metal Matrix Composites gives more benefits from the normal metals like Aluminium, Magnesium, Steel, Titanium etc.Metal Matrix Composites provide benefits like high melting point, high specific strength, high specific modulus, less coefficient of thermal expansion (α), less moisture effects and good wear and fatigue resistance.[2]

II. LITERATURE SURVEY

Basalt fibers are mineral fibers, which offer a few better properties in correlation with glass fibers.[4] Composites made of basalt fibers like polymer and metallic show great properties. Basalt is a characteristic material that is found in volcanic rocks started from solidified magma, with a liquefying temperature of 1500°C to 1700°C. Perhaps 80% of basalts are made up by two basic minerals i.e. plagiocene and pyroxene. Investigating the chemical arrangement it is feasible to watch that SiO2 is the fundamental constituent and Al2O3 is the second one. [4]

The study of basalt fiber reinforcement on the mechanical properties of cast aluminium compound 7075 composites containing short basalt fiber of substance going from 2.5 to 10 % by weight in steps of 2.5 % and manufactured utilizing compo-casting method. The aim of study was to examine the method possibility and resulting about material properties, for example, Young's Modulus, hardness, ductility. The properties acquired are compared with those of as-cast that were made with similar manufacturing conditions. The consequences of this examination shows that, as the short basalt fiber substance was expanded, there were critical increments in a young's modulus, ultimate tensile strength and hardness, joined by a diminishment in its ductility.[5]

The study of Magnesium alloy (AZ91D) composites strengthened with silicon carbide molecule with various volume rateswere created by two stage mix throwing process. The impact of changes in molecule size and volume portion of SiC particles on physical and mechanical properties of composites were assessed under as cast and heat treated conditions. The experimental results were compared with the standard hypothetical models. The results expose that the mechanical properties of composites expanded with expanding SiC particles and reduces with expanding molecule size. [6]

Magnesium alloy AZ91 was reinforced with alumina short strands and silicon carbide particles utilizing the powder metallurgical or crush throwing procedures. The fracture toughness and tensile tests were conducted at raised and room temperature. The impact of reinforcement and manufacturing process on mechanical property of composites and alloy has been discussed. They have revealed that the reinforcement expanded the tensile related property and diminished the fracture toughness and ductility of the AZ91 alloy. The powder metallurgy alloy and composites showing substantially more tensile quality and less fracture toughness compared by the crush throwing procedures. [7]

III. MATERIALS USED FOR MANUFACTURING METAL MATRIX COMPOSITE

MAGNESIUM ALLOY AS MATRIX

Magnesium and its alloys have received incredible consideration on account of their better properties, for example, less density, more specific strength, good dimensional stability and electromagnetic protecting property, superior damping limit, high creep quality, good machinability and weldability, more impact protection and high thermal and electrical conductivities. They are utilized as a part of fields where weight reduction is basic or where specific specialized necessities are required, for example, car, aerodynamic and aviation including space station, satellite, space carry, electronic and military ventures, together with AVCC (Audio video-Computer-Communication) hardware, convenient instruments and so forth.

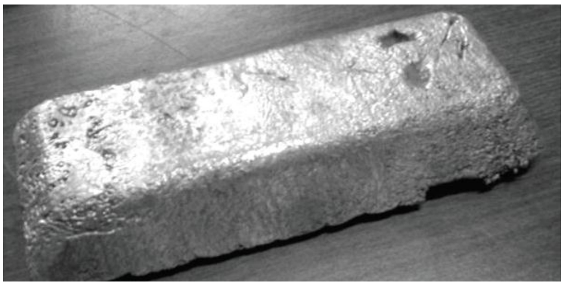


Fig. 1 Magnesium Alloy

Table 1.1 Mechanical Properties of Magnesium Alloy AZ91 [8]

Property	value
Ultimate Tensile Strength (UTS)	240 MPa
Compressive Yield Strength	160 MPa
Tensile Yield Strength	160 MPa
Elastic Modulus, Shear	17 GPa
Elastic Modulus, Tension	45 GPa
Liquidus Temperature	1110 °F
Brinell Hardness	70
Density	1.81 g/cc
Thermal Conductivity	51 W/k*m
Fracture Elongation	3%

BASALT FIBER AS REINFORCEMENT

Basalt fiber is purchased from Hydro Design Management Co. Pvt. Ltd. Delhi.The Basalt or Rock fiber is manufactured by crushing a rock of a special chemical structure by melting it in a furnace at high temperatures i.e. more than 1500 °C. This complex basalt fibers consists of 200 elementary filaments that are binded with special oiling liquid (sizing) and it is stretched out through a special device named feeder at the bottom of the furnace. Types of sizing process are selected depending on environmental conditions of Rock fiber. Ultimately, after the polymerization phase, it results in subsequent formation of rock chopped fiber or assembled continuous roving (which is used for Rock rebar manufacturing).

Fig. 2 Chopped Basalt Fiber

Table 1.2 Mechanical Properties of Basalt Fiber [9]

Property	Value
Density	2.63 g/cc
Elastic Modulus	89 GPa
Tensile Strength	3200 MPa
Thermal Conductivity	0.031 W/m.k

IV. METHODOLOGY

METHODOLOGY DETAILS

The methodology details are as follows

- Procurement of raw materials

- Casting the composite specimen
- Machinining the specimens
- Testing the specimens
- Calculation of properties

PROCUREMENT OF RAW MATERIALS

The Matrix material as Magnesium Alloy (AZ91) and the reinforcement material as chopped Basalt fiber of 3 mm length is procured and calculated as per the required volume fractions in terms of mass. The six volume fractions are carried out in steps of 2 units from zero units.

CASTING THE COMPOSITE SPECIMEN

- Initially the matrix material i.e. Magnesium Alloy is melted in the furnace. The melting point of the magnesium alloy is 1110°F
- Once the Magnesium Alloy is melted the chopped Basalt fiber of length 3mm is added as per the volume fraction calculations into the crucible (container). The stir casting technique is applied so that the reinforcement medium should completely mix with the matrix medium.
- The red hot mixture of liquid is now ready to be poured into the mould i.e. die mould of mild steel. The hot mixture is poured into the mould of required dimensions i.e. 170 mm×20 mm.
- The poured mixture is left undisturbed as per the ASTM freezing time.
- After freezing the mould, the specimens are separated from the mould and are processed for the machining.
-

Fig. 3 Pouring Hot Mixture in Mould

Fig. 4 Casted Ingots

Table 1.3 Compositions of Specimens

Sl No	Casting	Sample No.	Basalt Fiber(%)	Magnesium Alloy(%)
1	Specimen Type 1	0-T1	0	100
2		0-T2	0	100
3		0-T3	0	100
4	Specimen Type 2	2-T1	2	98
5		2-T2	2	98
6		2-T3	2	98
7	Specimen Type 3	4-T1	4	96
8		4-T2	4	96
9		4-T3	4	96
10	Specimen Type 4	6-T1	6	94
11		6-T2	6	94
12		6-T3	6	94
13	Specimen Type 5	8-T1	8	92
14		8-T2	8	92
15		8-T3	8	92
16	Specimen Type 6	10-T1	10	90
17		10-T2	10	90
18		10-T3	10	90

MACHINING THE SPECIMENS

The above prepared specimen by casting is now machined on the lathe as per the ASTM E8 procedure. The lathe uses the HSS (High Speed Steel) tool for the machining process. The ASTM E8/E8M specimen is as shown in figure below. [10]

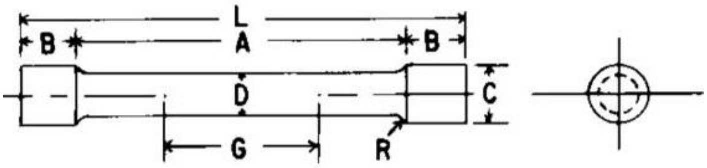


Fig. 5 ASTM E8 Specimen [10]

Table 1.4 ASTM E8 Dimensions [10]

Symbol	Dimension (mm)	Description
G	50±0.1	Gage Length
D	12.5±0.2	Diameter
B	20	Length of End Section
A	100	Length of Reduced Section
R	2	Radius of Fillet
L	155	Overall Length
C	20	Diameter of End Section

TESTING THE SPECIMENS

After the completion of machining process the specimens are now tested for the Tensile Strength. The testing of the specimens are carried out on the Universal Testing Machine (UTM). The testing was done as per the American Society of Testing and Materials (ASTM) standards. The Universal Testing Machine includes maximum load of 100 KN and Hydraulic pump of motor 2 HP. Uniaxial tensile is the basic test on the Universal Testing Machine for finding the Material Strength, percentage elongation of specimens, similarly we get the young's modulus from the Stress v/s Strain curve and we can also obtain the reduced area of cross-section.

METHOD OF TESTING SPECIMENS

- The American Society of Testing and Materials (ASTM) E8 standard specimens of round cross-sections are chosen for the testing.
- The specimens prepared as per ASTM E8 of round cross-section are having the dimensions as 50 mm in gage length and initial diameter is 12.5 mm and fillet radius is of 2 mm and length of the reduced section is 100 mm.
- The length of the end section should be more such that the specimen holds good in the gripped section during the application of load.
- Now the load is applied to the specimen in increasing order from zero and simultaneously it is monitored.
- The maximum load that a specimen resist, yield load and the breaking load is tabulated.
- The strength of tensile and the elongation of the specimens in percentage are also tabulated.
- Simultaneously the load (KN) v/s displacement (mm) and stress (N/mm^2) v/s percentage of Strain graphs are obtained from the digital Universal Testing Machine.

Fig. 6 Specimens before Testing

Fig. 7 Specimen Loaded in UTM

Fig. 8 Specimens after Testing

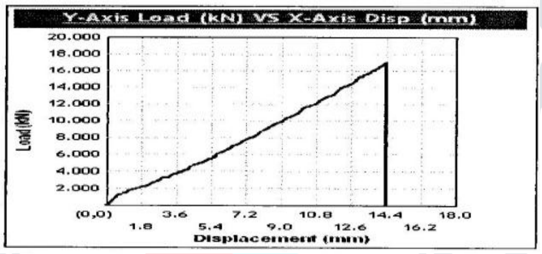
V. RESULTS AND DISCUSSION

In this study work tensile test was carried out. Every test was done with six volume fractions and three specimens in every volume fraction. Total eighteen numbers of specimens was tested for tensile. For every specimen Load versus Displacement graph is shown for each volume fraction. Simultaneously the Stress (N/mm^2) versus Strain percentage graph is also obtained for every specimen. From the Stress (N/mm^2) versus Strain percentage graph Young's Modulus is calculated with the help of the slope. The Young's Modulus versus number of specimens is plotted and also the Ultimate Tensile Strength versus number of specimens is plotted.

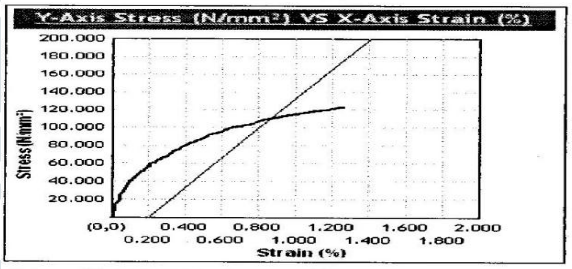
EXPERIMENTAL RESULTS

The experimental results of the specimens are calculated as per the below graphs

Specimen Type 1 Sample 0-T1



Graph 1 Load (KN) v/s Displacement (mm) for Specimen Type 1 sample 0-T1

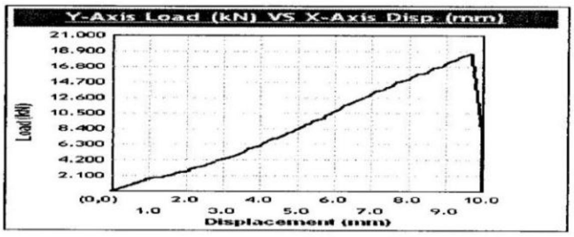


Graph 2 Stress (N/mm^2) v/s Strain (%) for Specimen Type 1 sample 0-T1

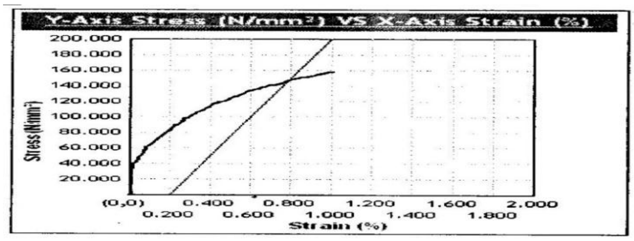
From the above graph the young's modulus will be,

$$E = \frac{\Delta y}{\Delta x} = \frac{80 - 40}{\frac{0.4-0.1}{100}} = 13.33\ GPa$$

Specimen Type 6 Sample 10-T1



Graph 3 Load (KN) v/s Displacement(mm) for Specimen Type 6 sample 10-T1



Graph 4 Stress (N/mm^2) v/s Strain (%) for Specimen Type 6 sample 10-T1

From the above graph the young's modulus will be,

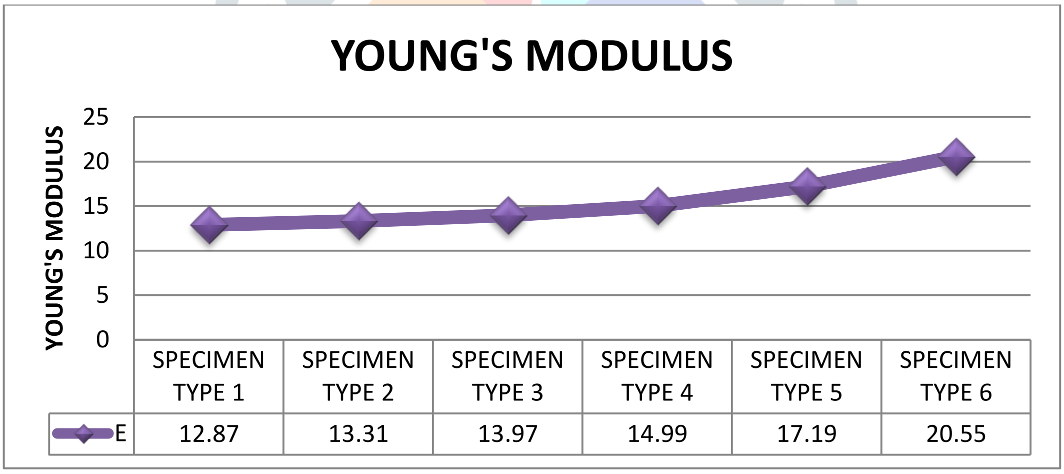
$$E = \frac{\Delta y}{\Delta x} = \frac{120 - 40}{\frac{0.42-0.05}{100}} = 21.6\ GPa$$

TENSILE TEST RESULTS

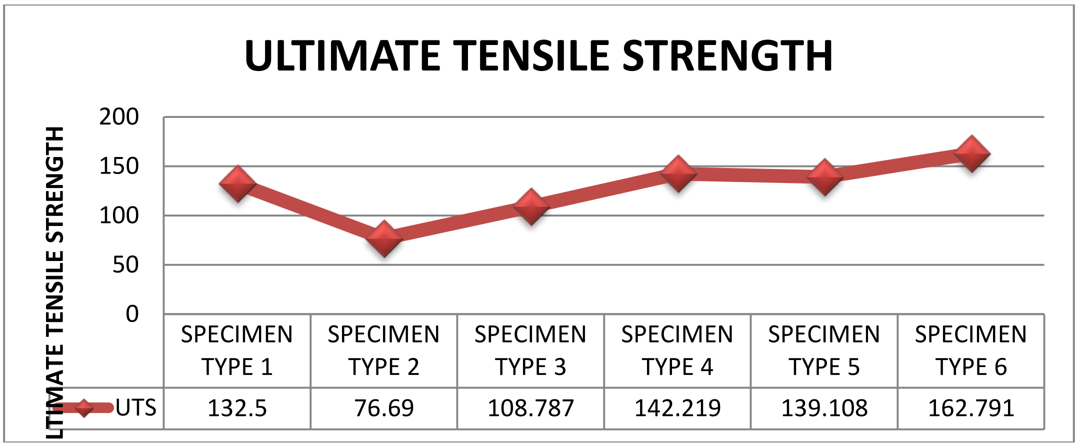
Experimental Results of the specimens are tabulated below. From the graphs the corresponding values of tensile test are calculated and tabulated.

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

Sl. No.	Casting	Sample No.	Ultimate Load (KN)	Ultimate Tensile Strength (N/mm²)	Average Ultimate Tensile Strength (N/mm²)	Young's Modulus (GPa)	Average Young's Modulus (GPa)
1	Specimen Type-1	0-T1	17.36	135.965	132.500	13.33	12.87
2		0-T2	14.04	114.407		12.00	
3		0-T3	18.20	147.130		13.30	
4	Specimen Type-2	2-T1	11.64	95.152	76.690	12.13	13.31
5		2-T2	5.12	41.324		14.10	
6		2-T3	11.56	93.596		13.70	
7	Specimen Type-3	4-T1	8.28	69.909	108.787	14.10	13.97
8		4-T2	15.84	128.864		14.50	
9		4-T3	15.960	127.588		13.33	
10	Specimen Type-4	6-T1	20.04	157.696	142.219	15.00	14.99
11		6-T2	19.00	148.810		13.33	
12		6-T3	14.840	120.152		16.66	
13	Specimen Type-5	8-T1	14.44	121.528	139.108	20.00	17.19
14		8-T2	20.12	158.325		13.33	
15		8-T3	17.360	137.472		18.26	
16	Specimen Type-6	10-T1	18.80	159.511	162.791	21.66	20.55
17		10-T2	22.28	177.558		20.00	
18		10-T3	17.92	151.304		20.00	



Graph 5 Average Young's Modulus v/s Specimen Types



Graph 6 Average Ultimate Tensile Strength v/s Specimen Types

VI. CONCLUSIONS

CONCLUSION AND SUMMARY

The main aim of this research work is to know the effect of tensile properties of Magnesium Alloy reinforced with chopped Basalt fibers of length 3mm with different volume fractions of 2%, 4%, 6%, 8% and 10% of chopped Basalt fibers. The tensile test was conducted by ASTM procedures and loaded in Universal Testing Machine of capacity 100 KN with the scope of study for the following important conclusions

- Magnesium Alloy (AZ91) reinforced with chopped Basalt fibers have manufactured by Stir Casting Method.
- In this research work total 18 specimens are tested for every volume fraction of 3 specimens. The average values of Young's Modulus are calculated from the Stress (N/mm^2) v/s Strain (%) graphs.
- Weight proportions have critical impact on tensile properties.
- The Ultimate Tensile Strength increases as the percentage of fiber increases from 2 percent to 10 percent in the increasing order i.e. 2%< 4%< 6%< 8%< 10%. The maximum Ultimate Strength is obtained for 10% fiber reinforcement in matrix.
- As the Ultimate Tensile Strength increases there will be increase in Modulus of Elasticity of the Magnesium Alloy composite matrix.
- The maximum load on the specimens obtained is in increasing order as the volume fractions of fiber increases from 2% to 10%.
- Both Young's Modulus and Ultimate Tensile Strength increases with the increase in volume fraction of fiber in matrix medium.

FUTURE SCOPE

- Apart from the tensile properties different mechanical properties can be studied on this composite.
- Similar metal matrix composites can be prepared by using different techniques of manufacturing like powder metallurgy method etc. and compare it with these results.
- Studies can be made by changing the diameter and length of the fiber.
- Studies can be done by using milled Basalt fibers in place of fiber form and can be compared.
- Studies can be made by further varying the volume fractions of the fibers.

REFERENCES

[1]. P.C. Mallik, Marcel Decker, "Fibre Reinforced Composites", 1993.

[2]. Autar K. Kaw, "Mechanics of Composite materials", CRC Press, 2nd Ed, 2005.

[3]. Rober M. Jones, "Mechanics of Composite Materials", Taylor & Francis, 1998.

[4]. Fiore V, Scalici T, Di Bella G, Valenza A, "A review on basalt fibre and its composites", *Composites Part B* (2015), doi: 10.1016/j.compositesb.2014.12.034.

[5]. S. Ezhil Vannan, S. Paul Vizhian "Microstructure and Mechanical Properties of as Cast Aluminium Alloy 7075/Basalt Dispersed Metal Matrix Composites" Journal of Minerals and Materials Characterization and Engineering, 2014, 2, 182-193.

[6]. S. Aravindan, P.V. Rao, K. Ponappa "Evaluation of Physical and Mechanical Properties of AZ91D/Sic Composites", Journal of Magnesium and Alloys 3 (2015) 52e62 www.elsevier.com/journals/journal-of-magnesium-and-alloys/2213-9567.

[7]. K Purazrang and P. Abachi "Mechanical Behaviour of Magnesium Alloy MMCs Produced By Squeeze Casting and Powder Metallurgical Techniques",Composites Engineering, Vol. 3. No 6 pp 489-505, 1993. Printed in Great Britain.

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

[9]. Jian-jun Li, Zhi-ming Zhao, "Study on Mechanical Properties of Basalt Fiber Reinforced Concrete", 5th International Conference on Environment, Materials, Chemistry and Power Electronics (EMCPE 2016).

[10]. "ASTM E8/E8m-16a Standard Test Methods for Tension Testing of Metallic Materials American Standard Testing and Materials", Annual book of ASTM Standards.