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Fabrication and Characterization of Az91e Hybrid Metal Matrix Composites

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***Abstract:** The current work expects to decide the attributes of compression of the (Magnesium composite) AZ 91E-Zro2-Fly Ash Hybrid Metal Matrix utilizing the conventional explanatory strategy and limited component technique. Fly ash and ZrO2 taken as equal weight proportions, composites are fabricated by means of a vortex method under the path of stir casting. The density and fracture toughness were found experimentally, the experimental density was decreased compare to the theoretical density, but the density is increased slightly for composites compare to the base material. The fracture toughness is decreased for composites compare to the base material; this is due to the improvement of the grains by adding strengthening molecules. The compressive strength was decreased by decreasing of the height of the deformation in percentage for base material and the composites of H/D 1.0 and 1.5. The compressive strength is high for the composites compare to the base material even the density of the composite is little bit high, hence suggested that composite system gives the better compressive strength results*

***Keywords:** Density, hybrid metal matrix, Materials, Z91E, Zro2/Fly Ash*

I. INTRODUCTION

Weight reduction has always been an important goal for air, land and space transportation. High resistance Steel, aluminum, and polymers are already used significant weight loss, but there may be additional reduction it is achieved using low density magnesium and its alloys. Pure magnesium is rarely used in structural applications, because of its weak mechanical properties [1-2].Add hard reinforcement particles to magnesium Alloy can greatly improve hardness and strength at ambient and high temperature [3-5]. The mechanical properties of AZ91D / SiC compounds increased as SiC particles increased and decreased as particle size increased. The distribution of particles and the broken surface was studied by SEM and the presence of the elements was detected by EDS study [6].

Three different methods of agitation are evaluated in the structure and properties of fine fly ash particles (average particle size 13 µm) of the reinforced Al-7Si-0.35Mg alloy compound. Between stirring metal casting, component casting (semi-solid treatment), modified component casting, and modified component casting followed by resident pressure casting methods, the latter resulted in dispersal of particle compounds from fly ash free from porosity, sparse, and relatively lumpy. Interactions between the fly ash molecule and the matrix that lead to the formation of spinel MgAl2O4 and iron between minerals are more in MFI compounds than in compound casting compounds [7]. U. S. Ramakanth et.al presents the research examined the influence of sic and fly ash on the wear behavior of Aluminum 7075/5 and weight percentage of hybrid complex. Aluminum alloy 7075 strengthened with sic-fly ash were examined [8-9]. Narayanasami and Pandey [9] studied the barreling effects of aluminum solid cylinder. Malayappan and Narayanasamy [10-12] performed experimental analysis of barrel phenomenon under different friction conditions with insertion on aluminium as a base material and fly ash as reinforcement.

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II. EXPERIMENTAL DETAILS

AZ91E alloy and its composites include with different weight percent of (ZrO2 Powder) and fly ash were used in the present study. Table1.1, Table 1.2 and Table 1.3 shows the chemical composition of AZ91E alloy, ZrO2 Powder and fly ash. Table 1.4 shows the composition of present hybrid composite.

Table 1.1 Chemical composition of AZ91E alloy

Chemical composition	Al	Zn	Mn	Cu	Si	Fe	Mg
Wt. %	8.93	0.86	0.28	< 0.001	0.13	< 0.001	Balance

Table 1.2 Chemical composition of fly ash (FA)

Chemical composition	SiO2	Al2O3	MgO	Fe2O3	CaO	TiO2	K2O	Na2O
Wt. %	58.29	32.75	1.2	2.9	0.5	1.27	1.29	0.25

Table 1.3 Chemical Composition of ZrO2 Powder

Chemical composition	ZrO2	SiO2	TiO2	Fe2O3	Other
Wt. %	99.5	0.1	0.007	0.002	0.39

a) FABRICATIONS OF COMPOSITES

ZrO2Powder stiffeners, fly ash, AZ91E stir casting and molten samples were

Table 1.4Composition of present hybrid composites

S.No	Sample no's	Composition of reinforcements	ZrO2Powder wt. %	Fly ash (FA) wt.%
1	Sample 1	AZ91E	0	0
2	Sample 2	AZ91E + 2.5% ZrO2 Powder + 2.5% Fly ash	2.5	2.5
3	Sample 3	AZ91E + 5% ZrO2Powder + 5% Fly ash	5	5

Shown in Fig 1.1: In the present work, a stir casting process is used to manufacture samples.

Fig 1.1 Stir Casting and casting samples

In this study, AZ91E was used as a matrix and ZrO2Powder, Fly Ash (FA) was used as reinforcements. The required amount of magnesium and AZ91E were melted according to the calculations in the furnace. Once the melting temperature reaches 800 ° C, argon gas is continuously supplied to the furnace due to the magnesium flammability at higher temperatures. The ZrO2Powder and fly ash (FA) particles were heated to remove moisture content and add soluble reinforcements.

Next, a stirrer spin at 400 rpm was placed on the molten metal to form a peak in the melting as well as to obtain an even distribution of the reinforcement with the mould. After thawing is finished, the slag part of the molten material is removed. Average time, the metal die was heated with a diameter of 22 mm and a length of 170 mm before pouring the molten compound. The natural convection method was used to solidify the molten metal. A varying percentage of ZrO2Powder and fly ash particles between 0% and 5% were added in steps of 2.5% to the molten metal to obtain the required foundry compounds.

b) DENSITY MEASUREMENT

Density of the AZ91E (1.81g/cc) and density of reinforcements (Fly Ash 1.0g/cc &ZrO2Powder 2.75 g/cc), composite sample was calculated using Rule of mixture formula theoretically and given by

$$P_{mmc} = V_r \rho_r + (1-V_r)\rho_m \quad (1.1)$$

Where ρ_{mmc} =Density of Composite sample, V_r = Weight ratio of Reinforcement, ρ_r=Density of Reinforcement, ρ_m =Density of Un reinforcement.

Archimedes Drainage method was used to determine the actual density of AZ91E and composites. First the cylindrical sample was weighed in air using electronic balance with an accuracy of 0.1 mg, then the sample was dipped in distilled water for sufficient time and again weighed in this condition. Density of the composite sample was calculated experimentally using Arches Median Principle as given by

$$\rho_{mmc} = (m/m-m_1) * \rho_{H2O} \quad (1.2)$$

ρ_{mmc} = Density of Composite sample, m=Mass of the Composite sample in air, m_1=Mass of the Composite sample in distilled water, and ρ_{H2O}=Density of water =0.998 g/cc (Standard Value). The results are shown in table 1.5.

Porosity (p)in percentage = $[1-(\rho_{actual}/\rho_{theoritical})]100$ (1.3)

Table 1.5 Density and porosity of base and Composites

S. No	Composition of reinforcements	Density (Rule of Mixture)	Density (Archimedes Drainage method)	Porosity (p) in percentage
1	AZ91E	1.81	1.8	0.55
2	AZ91E + 2.5% Zro2 + 2.5% Fly ash	1.88	1.76	6.38
3	AZ91E + 5% Zro2 + 5% Fly ash	1.96	1.74	11.22

c) IMPACT TEST

The samples were manufactured according to ASTM D256 standards and the Izod Impact Test Machine was used to find the fracture resistance of the AZ91E base alloys and composites. Three readings were considered on average to assess the fracture resistance of the composites. Fig 1.2 showed effect samples after the fracture, shown table 1.6.

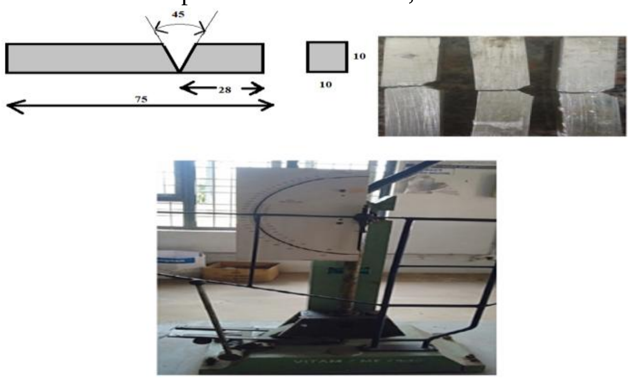

Fig 1.2 showed effect samples after the fracture.

Table 1.6 Fracture toughness of base and composites.

S.No	Composition of reinforcements	Fracture toughness
1	AZ91E	1.98
2	AZ91E + 2.5% ZrO2Powder + 2.5% Fly ash	1.85
3	AZ91E + 5% ZrO2Powder + 5% Fly ash	1.74

d) Compression Test On UTM

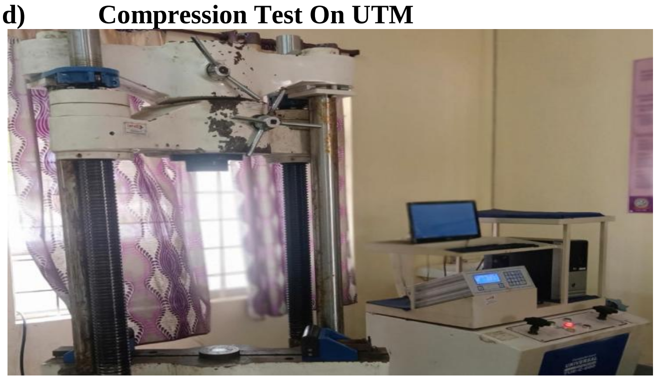

Fig 1.3 UTM for compression test

Fig 1.4 Compression Samples of H/D 1.0 and 1.5

The UTM was used for conducting the experiments as shown in Fig 1.3 on prepared samples made of AZ 91E and AZ 91E/ZrO2Powder/Fly Ash materials. The experiments were conducted for H/D ratio 1.0 & 1.5 for the two different materials like AZ 91E and AZ 91E/ZrO2Powder/Fly Ash as shown in Fig 1.4. The test was carried out up to broken of the specimens. The compression test was carried out on UTM, for total 36 samples are prepared of H/D ratio 1.0 and 1.5. The axial load was applied on the specimen up to the height was reduced to 50 to 0 percentage of deformation. For each deformation (reduction of height) the compressive strength was found.

III. RESULTS AND DISCUSSIONS

Density test results showed that with increasing ZrO2Powder and fly ash content, the density of the compound is slightly increased compare to base material, this may be due to the addition of high-density reinforcements (i.e. ZrO2Powder) in the matrix material [12-13]. The experimental values are low to the theoretical values calculated using the rule of mixture formula as shown in Fig 1.5.This demonstrates that the combined procedure for manufacturing composite materials is most appropriate. Porosity is a measure of the empty spaces in matter. High porosity indicates that casting is ineffective. It is identified that porosity enhances with weight percentage of reinforcement. The same phenomenon was observed in [14]. Fracture resistance is the material's ability to resist fracture

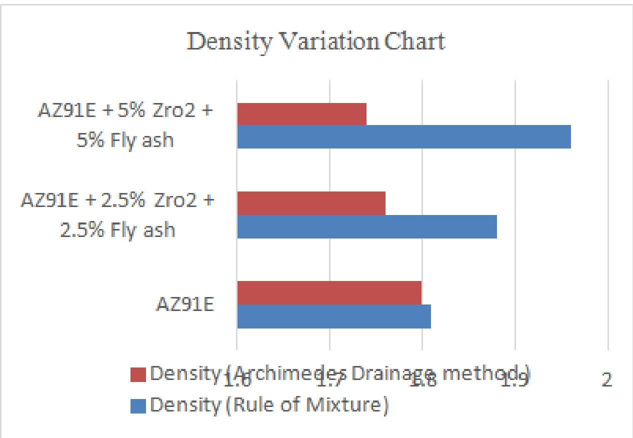

Fig 1.5 Density variation chart

and is a very important property in design applications. The difference of fracture resistance with variable reinforcement of different ratios of ZrO2Powder and fly ash is shown in Fig 1.6. From Fig 1.6, it is noted that the fracture resistance of the supported samples decreases with an increase in the ratio of reinforcement. This is due to the improvement of the grains by adding strengthening molecules. We knew that the coarse granular structure had a higher rigidity in fracture compared to the fine granular structural material. The same phenomenon was noted in [15].

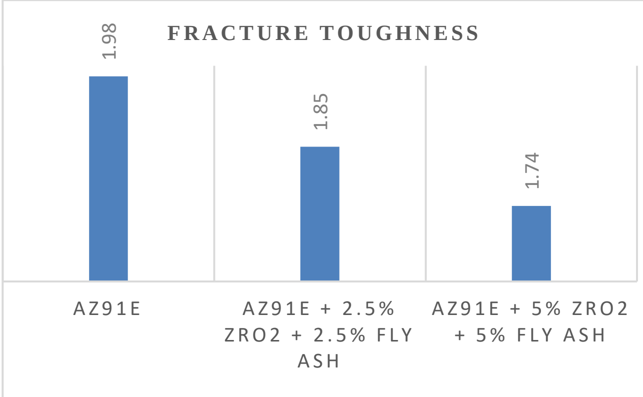

Fig 1.6 Variation of Fracture toughness

The plastic behavior of H/D ratio 1.0 and 1.5 samples made of AZ 91E and AZ 91E/ZrO2Powder/Fly Ash materials were analysed using plasticity theory. The Fig 1.7 to 1.10 shows the load and displacement curves of (0-50% of deformation) base and their composites.

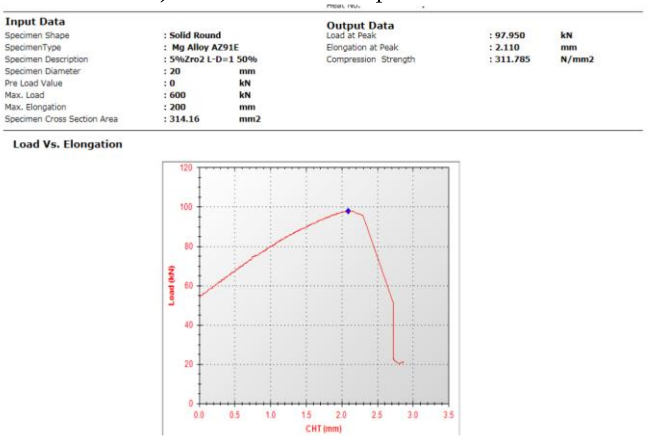

Fig 1.7 the load and displacement curves of 5% composite (H/D1.0)

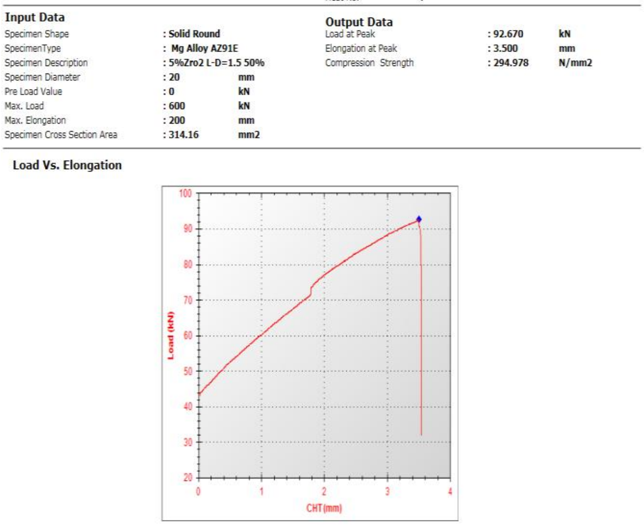

Fig 1.8 the load and displacement curves of 5% composite (H/D1.5)

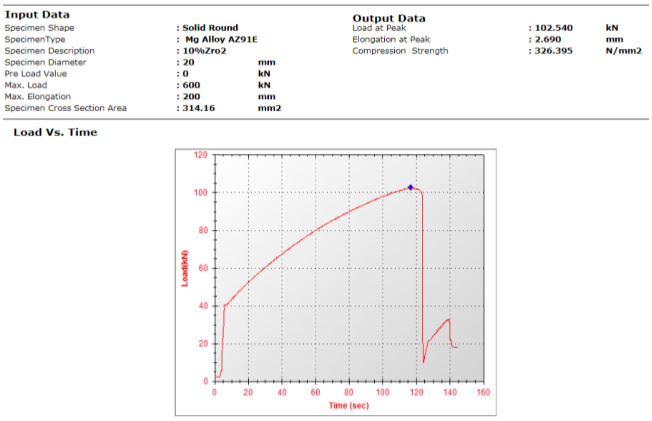

Fig 1.9the load and displacement curves of 10% composite (H/D1.0)

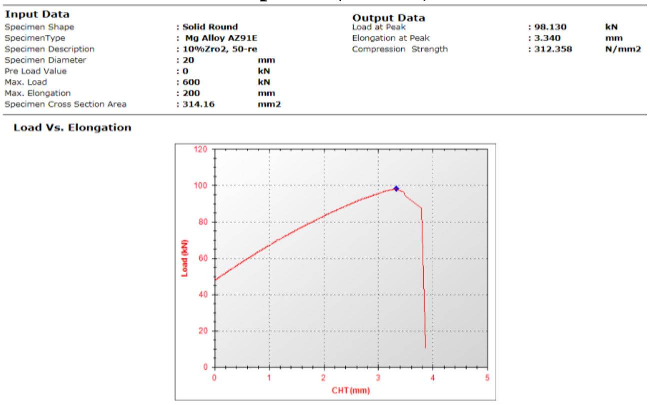

Fig 1.10the load and displacement curves of 10% composite (H/D1.5)

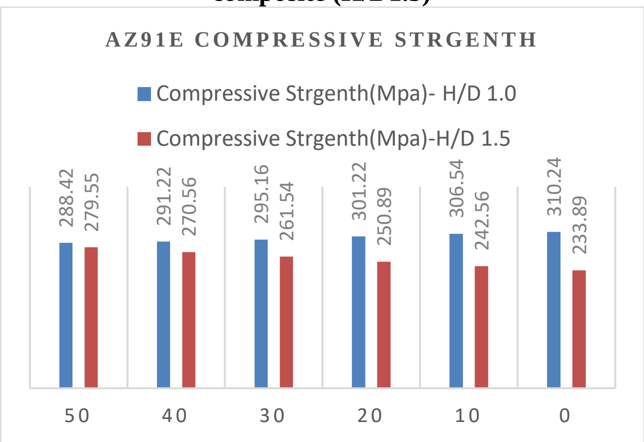

Fig 1.11 Compressive strength versus % of reduction in height of AZ91 E

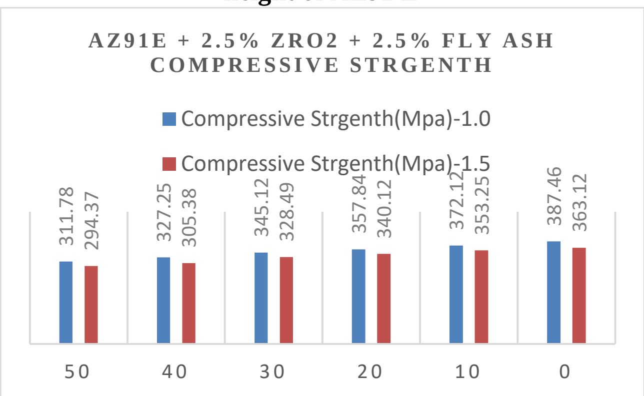

Fig 1.12 Compressive strength versus % of reduction in height of 5% of composites

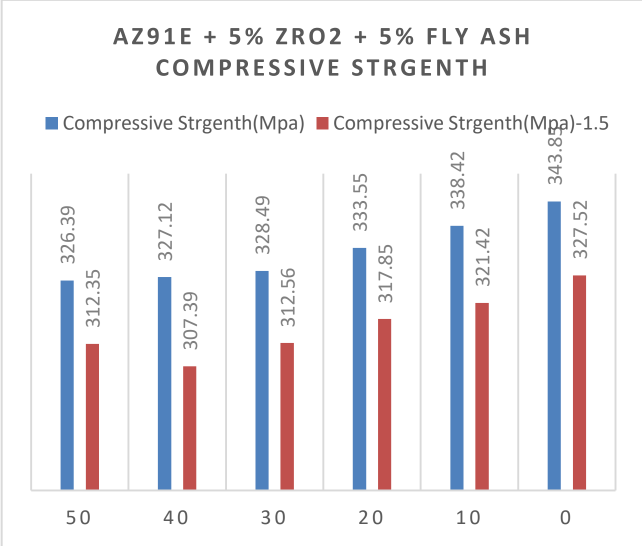

Fig 1.13 Compressive strength versus % of reduction in height of 10% of composites

Table 1.7 Compressive strength of base and composites

Type of Material	% of Deformation	Compressive Strength (MPa)- H/D 1.0	Compressive Strength (MPa)-H/D 1.5
AZ91E	50	288.42	279.55
	40	291.22	270.56
	30	295.16	261.54
	20	301.22	250.89
	10	306.54	242.56
	0	310.24	233.89
	% of Deformation	**Compressive Strength (MPa)- H/D 1.0**	**Compressive Strength (MPa)-H/D 1.5**
AZ91E + 2.5% zro2 + 2.5% Fly ash	50	311.78	294.37
	40	327.25	305.38
	30	345.12	328.49
	20	357.84	340.12
	10	372.12	353.25
	0	387.46	363.12
	% of Deformation	**Compressive Strength (MPa)- H/D 1.0**	**Compressive Strength (MPa)-H/D 1.5**
AZ91E + 5% zro2 + 5% Fly ash	50	326.39	312.35
	40	327.12	307.39
	30	328.49	312.56
	20	333.55	317.85
	10	338.42	321.42
	0	343.85	327.52

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The compressive strength was decreased by decreasing of the height of the deformation in percentage for base material and the composites of H/D 1.0 and 1.5.
The compressive strength is high for the composites compare to the base material,
the lower aspect ratios the compressive strength is high compare to higher aspect ratio as shown in Fig 1.11 to 1.13, the reason is the axial force is greater needed for the lower aspect ratio for the same amount of deformation.

IV. CONCLUSIONS

The following conclusion can be reached based on the present investigation.

1. AZ 91E alloy prepared in the laboratory was in tune with the commercial alloy.
2. Metal-metal composites of AZ 91E reinforced withZrO2Powder and fly ash alloy particulate have been successfully fabricated using stir casting method under vertex route.
3. Composite with reinforcements have shown improved mechanical properties in terms of density and fracture toughness.
4. But whereas the density was increased slightly for composites compare to the base AZ91E however the compressive strength of the composites is greatly high compare to the base material.
5. Compare to lower aspect ratio the higher aspect ratio compressive strength is almost equal and somewhat high for all the composites and base material.
6. 50 % of deformation to the zero percentage of deformation the compressive strength is increased.

V. SCOPE FOR FUTURE WORK.

In this project use only hard ceramics ZrO2Powder and Fly Ash for analyzing the plastic behaviour of the magnesium alloy AZ91E in the stir casting method. For better improvement of results to maintain proper varying stirring speed, casting for better plastic behaviour results use any other reinforcements like nano B4C, SiC etc.

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