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PROCESSING OF ZA-27 BASED MMC REINFORCED WITH Al_2O_3 BY CENTRIFUGAL CASTING

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***Abstract*— In the present work, ZA-27 metal matrix composites reinforced with Al_2O_3 are prepared by Centrifugal casting process. Pre-treated ceramic particles are reinforced into the molten ZA 27 in different weight proportions as 5,10,15,20 & 25 % wt. at rotational speed of the mould as 400rpm. Mechanical properties of these different types of composites are compared in the present analysis. It is observed that with 20 % Wt. of Al_2O_3, hardness, tensile and compression strength values are improved, but at the cost of ductility**

Keywords— ZA-27 metal alloy, MMC, Al_2O_3 ceramic particles

I. Introduction

Zinc- aluminum based alloys are finding wide applications in Automobile Industries and are most commonly used bearing materials due to their excellent fluidity, high wear resistant properties and low cost[1] and due to ecological reasons[2]. Zn-Al alloys with variation in aluminum percentage have emerged as important material for tribological applications under high load and low speed applications [3, 4]Among these alloys, ZA-27 alloy has high strength to density ratio, excellent tribological properties and replaces other alloys like copper, aluminum and cast iron [5]. ZA 27 alloys exhibit excellent mechanical and wear properties only at room temperature and at higher temperature its properties are found to be unsatisfactory [6-10]. This limitation restricts the applications of these alloys at high temperature. Recent investigation have focused in developing ZA 27 based MMCs by reinforcing these alloys with ceramic particles. to form Metal Matrix Composite materials and other possible way for their improvement is by heat treatment [7-9]. ZA-27 alloy when reinforced with graphite particles improve its wear resistance with slight decrease in hardness [11-12]. When Alumina fiber is reinforced with ZA-27 alloy it was observed that, at elevated temperature tensile strength, compressive yield strength and wear resistance was increased [13].

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Much work has been carried out on ZA-27 alloy reinforced with various ceramic particles by varying the percentage and size of the particles fabricated by stir casting [14], Compo casting [2] and Squeeze casting [15,16].

In the present work, an effort has been to fabricate ZA-27 reinforced with Al_2O_3 through Centrifugal casting process with rotational speed of the mould set at 400rpm and by varying the percentage of Al_2O_3 particle from5,10,15,20 & 25 % wt.For each cast tube produced, Mechanical properties like hardness, tensile strength, compression strength, and ductility are studied and compared.

II. Experimental Procedure

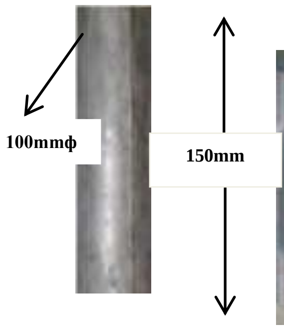
Specimen Preparation

In the present study, ZA-27 alloy having the chemical composition (ASTM B669-82) ingot specification is used as the basic matrix alloy and Al_2O_3particles of 20µm as reinforcement in the MMCs.. Al_2O_3 particles with mean size of 20µm with varying percentage of 5,10,15,20 and 25 were used as reinforcement. The alloy was melted with 200 °C super heat during teeming for all the cast tubes. Horizontal type centrifugal casting machine is employed to cast ZA-27 alloys samples in this investigation as shown in the Fig.1. Centrifugal casting is carried out with the pre heated mould rotating at 400rpm. The dimension of the cylinder is 100 mm outer diameter and 150 mm length to obtain the cast shown in Fig.2 (a).

Fig.1 Horizontal Centrifugal Casting Machine

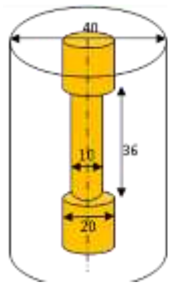
Testing of Specimen

All tests were conducted in accordance with ASTM standards. The compression tests were conducted in accordance with ASTM E9.Specimen dimensions are 12mm diameter and 20 mm length as shown in fig.2 (b). The compressive loads were applied gradually and corresponding strains were measured until failure of the specimen occurred. Tensile tests were conducted at room temperature using Universal Testing Machine (UTM) in accordance with ASTM E8-82.The tensile specimens of diameter 8.9mm and gauge length 76mm were machined from the cast composites as seen in the Fig.2 (c).The hardness tests were conducted in accordance with ASTM E10 standard using standard Brinell hardness testing machine with a ball indentor of diameter 2.5mm and load of 31.25 kg applied for 30 seconds.



2(a) Cast Specimen

2(b) Specimen used for testing Compression



2(c) Dimension of tensile specimen

III Results and Discussions

In the present study, Taguchi method was used with the objective of achieving maximum mechanical properties in ZA-27/Al_2O_3 composites. Five parameters identified as processing factors in centrifugal casting which affect the mechanical strength are melting temperature, rotational speed, wt. % of Al_2O_3, particle size and distance from the centre with five levels. To analyse the significance of each factor an L_{25} orthogonal array was chosen since it has 5 parameters and 5 levels. The factor and selected levels are shown in Table1. Although full factorial method consists of 5^5 (3125) experiments, the Taguchi method requires only 25 experiments

Table 1 Factors and their levels used in experiment

Factors	Symbols	Levels				
		01	02	03	04	05
Melting temperature, °C	A	450	500	550	600	650
Rotational Speed, rpm	B	400	500	600	700	800
Wt. % of Al_2O_3	C	5	10	15	20	25
Particle Size, µm	D	20	40	60	80	100
Distance, mm	E	0	10	20	30	40

As per the data in Table.1 the five main factors are assigned to columns 1- 5 in L25. The experimental values for different levels are given in the Table 2.

Table.2. Obtained Experiment Results

Sl. No.	A	B	C	D	E	Hardness, BHN	UTS, MPa	Comp strength MPa	Ductility, %
01	450	400	5	20	0	86.6	326.5	228.0	3.010
02	450	500	10	40	10	96.7	333.0	238.2	2.861
03	450	600	15	60	20	105.1	344.3	246.6	2.723
04	450	700	20	80	30	107.6	350.1	249.1	2.585
05	450	800	25	100	40	100.1	340.0	241.4	2.437
06	500	400	10	60	30	99.9	339.2	241.4	2.723
07	500	500	15	80	40	101.0	343.6	242.0	2.589
08	500	600	20	100	0	100.6	340.5	243.1	2.733
09	500	700	25	20	10	97.1	337.0	240.0	2.794
10	500	800	5	40	20	98.2	334.5	241.0	2.887
11	550	400	15	100	10	98.1	338.0	241.1	2.741
12	550	500	20	20	20	103.7	343.6	246.7	2.813
13	550	600	25	40	30	108.6	344.9	251.5	2.688
14	550	700	5	60	40	100.5	339.8	242.7	2.782
15	550	800	10	80	0	94.4	336.9	238.2	2.902
16	600	400	20	40	40	106.9	343.2	249.6	2.701
17	600	500	25	60	0	100.4	339.7	244.7	2.853
18	600	600	5	80	10	96.5	339.0	240.6	2.922
19	600	700	10	100	20	102.9	342.8	247.2	2.741
20	600	800	15	20	30	105.1	345.0	249.4	2.810
21	650	400	25	80	20	100.4	343.0	245.7	2.640
22	650	500	5	100	30	99.9	339.8	244.5	2.706
23	650	600	10	20	40	99.0	338.9	243.1	2.761
24	650	700	15	40	0	103.1	339.4	248.8	2.931
25	650	800	20	60	10	104.2	343.4	250.3	2.798

The present paper discuss only the effect of only one factor i.e. the wt. % of Al_2O_3which has been varied from 5 to 25 % with level 5 on ZA 27 based MMC at rotational speed of the mould as 400rpm only.

Hardness

Hardness is the measure of resistance of a material to its deformation**.**Fig.3 shows the variation in the hardness of the cast specimen containing varying percentage of Al_2O_3.As the wt. percentage of Al_2O_3increases from 5% to 20% in steps of 5%, the hardness of the cast tube increases from 86.6 BHN to 106.7 BHN owing to the influence of alumina particle strength in mechanical properties of these composites. But with further increase in wt. Percentage of Al_2O_3 to 25%, it is observed that hardness value decreases to 100.4 BHN

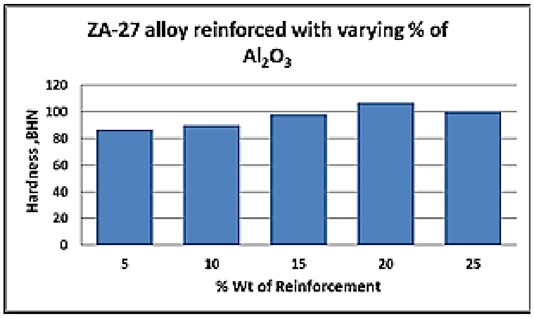


Fig. 3Variation of Hardness for Different Percentages Al_2O_3

Ultimate Tensile Strength

Fig.4 shows the effect of varying percentage of Al_2O_3 on UTS. It is observed that as Al_2O_3 content increases, the UTS of the Composite material also increases. Maximum value of UTS is obtained at 20% of Al_2O_3; this increase in UTS is due to dispersion-strength effect. The propagation of dislocations in the microstructure is restricted due to the presence of Reinforcement, as these are stronger and stiffer than the base metal ZA-27 alloy. Further increasing wt. percentage of Al_2O_3 to 25%, results in decrease of UTS.

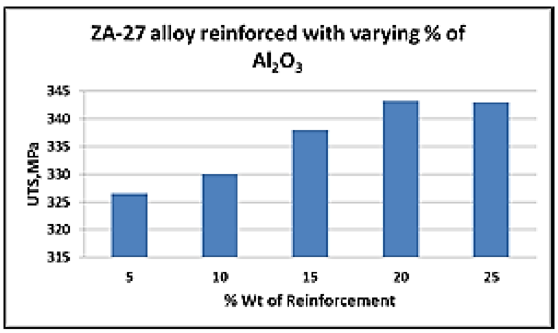


Fig. 4 Variation of Ultimate Tensile Strength for Different Percentages Al_2O_3

Compression Strength

Fig. 5 shows the effect of increase in wt. percentage of Al_2O_3 particles in ZA-27 alloy on uniaxial compression. With 5% of Al_2O_3particles, compression strength is observed to be as 228 MPa, further increase in Al_2O_3particles enhances the compression strength of the composite. But at 25% wt. of Al_2O_3, the compression strength is reduced. This is because of applied compressive stress, the matrix material ZA-27 alloy around Al_2O_3particle,move away from the particle in a direction perpendicular to the compressive stress applied. Cavity is formed at the interface of Al_2O_3 particles and matrix. This cavity formation decreases the composite strength because of the decrease in load transfer from matrix to particles.

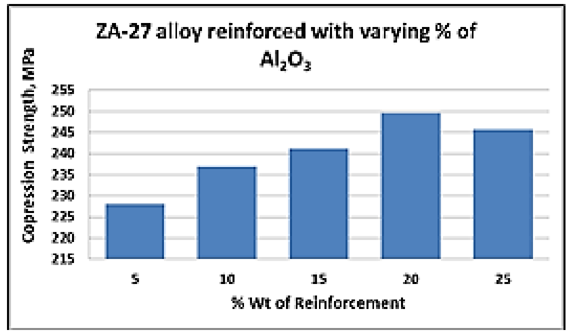


Fig. 5 Variation of Compression strength for Different Percentages Al_2O_3

From Fig.3, 4, and 5, it can be observed that Hardness, Ultimate Tensile Strength and Compression strength of the ZA 27/Al_2O_3 Composites increases till 20% Wt. of Al_2O_3 but at 25% the values of hardness and strength are decreased and this may be due to the mismatch of the coefficients of thermal expansion between the ZA 27 matrix and Al_2O_3 reinforcements causing a residual stress. When the residual stress becomes larger than a certain value, dislocations are punched out into the matrix to relax the stress. Due to dislocations produced Al_2O_3 particulates flow in a direction perpendicular to the load applied, reducing load transfer from matrix to reinforcement. Thus Dislocations left in the plastic domains after punching strongly affect the mechanical properties of composites

Ductility

Ductility of composites containing varying amount of Al_2O_3 is shown in Fig.6. It can be seen that as the Al_2O_3 content is increased, the percentage elongation of the composite material decreases. With 5% Wt. of Al_2O_3 as reinforcement, ductility is 3% further increase in wt. percentage of Al_2O_3 to 10%,15%,20% and 25%,the specimen results decrease in percentage elongation. The stiffer reinforcements resist dislocation motion, causing increased local stress concentration sites. This can also be due to increase in porosity of the composite which acts as stress concentration zones, promoting crack initiation and resulting in reduction of ductility.

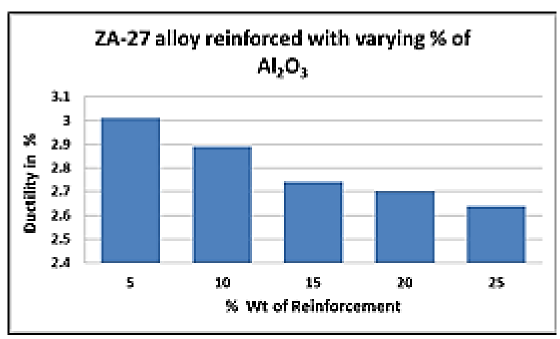


Fig. 6 Variation of Ductility for Different Percentages Al2O3

Conclusions

Based on the experimental results obtained in the present research, the following conclusions can be made.

ZA-27based MMC processed by centrifugal casting have better mechanical properties with addition of Al_2O_3 particles. With increase in the wt. percentage of Al_2O_3 particle, properties like Compression strength, Hardness, and Ultimate Tensile strength increases, with decrease in Ductility. This is due to higher strength and stiffness of Al_2O_3 than ZA-27 alloy matrix material. But as the yield point is reached at 20 wt. percentage of A_2O_3 particles, mechanical properties of ZA-27based MMC gets decreased with increase in wt. percentage of Al_2O_3particles.

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