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PREPARATION AND PROPERTIES OF Al-6061/FLY-ASH/ZrO2 METAL MATRIX COMPOSITES (MMCs) PROCESSED BY STIR CASTING METHOD

Satish Kumar Sharma
Assistant Professor, Mechanical Engineering Department,
M B S College of Engineering and Technology, Jammu

Abstract: ***The present work has been carried out to investigate the improvement in mechanical properties of the composite by the addition of Zirconium oxide and Fly ash in Al-6061 to form a metal matrix composite. The composite has been produced by stir casting process. The volume fractions of both the reinforcing constituents have been varied. Tensile test have been performed on the prepared samples. The results are showing the improvement of properties of these constituents.***
Index Terms: Aluminium 6061, Fly-ash, Zirconium oxide, Metal Matrix Composite (MMCs), Stir casting.

I. INTRODUCTION

Composites are just a combination of materials in such a way that the resulting materials have desired properties. Now a day's composite materials are widely used for many number of applications like engineering structures, aerospace, marine application, sports and so on.[1] Composites are one of the most advanced and adaptable engineering materials. A fast progress in the field of material science and technology has given birth to these fascinating and wonderful materials. Composites are heterogeneous in nature. [5] Aluminum metal matrix composites (Al MMCs) are being considered as advanced materials for its light weight, high strength, high specific modulus, excellent wear resistance and low co-efficient of thermal expansion compared to conventional metals and alloys. [3] Beinias et al. used aluminium with fly-ash as reinforcement and concluded that with the addition of fly-ash brittleness and corrosion increases as it forms porosity. [2] Sudarshan and M. K. Surappa has synthesized A356 Al-fly-ash particle composites. They studied the mechanical properties and dry sliding wear and come into brief idea that the damping capacity of the composite increases with the increase in the volume fraction of fly-ash. [6] Malhotra et al. investigated the effect of reinforcement (Zirconia+ Fly-ash) on the mechanical properties of Al-6061 composites samples, processed by stir casting techniques. The composites were prepared with fixed percentage of Fly-ash (10%) & with varying percentages of Zirconia (5% & 10%) by weight fraction. The Hardness and ultimate tensile strength were improved, when compared with the unreinforced alloy whereas elongation decreased as compared to unreinforced aluminium. [5]

EXPERIMENTAL:-

In this work Al-6061 is used as a matrix and Fly-ash and Zirconium oxide as reinforcement.

Aluminium 6061: It is a precipitation of hardening aluminium alloy having a density of 2.70 g/cm3. Its major alloying elements are magnesium and silicon. It is the most commonly used alloy of aluminium. It exhibits good weldability and has good mechanical properties. [8]

Table 1: Chemical Composition of Al-6061[8]

Components	**Amount (% wt.)**
Silicon	0.4 – 0.8
Iron	0 – 0.7
Copper	0.15 – 0.40
Manganese	0 – 0.15
Magnesium	0.8 – 1.2
Chromium	0.04 – 0.35
Zinc	0 – 0.25
Titanium	0 – 0.15
Others	0.15 (No more than 0.05 % each)
Aluminium	95.85 – 98.56

Fly-ash: It is one of the residues generated during the combustion of coal in coal fired plants. Fly-ash is a waste by-product material which must be disposed off or recycled. [9]

Table 2: Chemical Composition of Fly-ash [9]

Components	**Amount (% wt.)**
SiO_2	67.2
Al_2O_3	29.6
Fe_2O_3	0.1
CaO	1.4
MgO	1.7

Zirconium Oxide: It is also called as zirconium dioxide or zirconia. It is a white colored crystalline oxide of zirconium. [7]

Table 3: Chemical Composition of Zirconium oxide [11]

Components	**Amount (% wt.)**
ZrO_2	99.6
SiO_2	≤ 0.3
CaO	0.2
MgO	< 0.1

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Fe_2O_3	< 0.1
Al_2O_3	< 0.1
TiO_2	< 0.1

Figure 1: Fly-ash

Figure 2: Zirconium oxide

II. EXPERIMENTAL PROCEDURE

The Metal matrix composite samples are prepared by stir casting method. A measured quantity of Al-6061 is taken in the graphite crucible and put in the casting furnace for melting. When the temperature of the furnace reaches 830 oC, measured quantity of preheated reinforcement in the melt is added. The reinforcement is preheated at a temperature of 200 oC for 2 hrs. The melt is then stirred at a stirrer speed of 400 rpm at 750 oC for 4 minutes. The molten mixture is further heated upto a temperature of 830 oC and then poured into the prepared green sand mould of required shape. The melt is then allowed to solidify.

Table 4: Composition of Metal Matrix Composites (% wt.)

Sample Name	Al-6061 (% wt.)	Zirconium Oxide (% wt.)	Fly-ash (% wt.)
S1	100	0	0
SF1	95	0	5
SF2	90	0	10
SZ1	95	5	0
SFZ5	90	5	5
SZF	85	5	10
SZ2	90	10	0
SFZ	85	10	5
SFZ10	80	10	10

TESTING OF PROPERTIES:-

The testing of the prepared samples is performed in Thapar University, Patiala. The following tests were conducted on the metal matrix composite.

Tensile Test

The specimen for tensile test is prepared as per ASTM E8-04 standard.

Figure 3: Tensile Test Specimen before and after the Test.

III. RESULTS AND DISCUSSION

The results of tensile test are shown in the table.

Table 5: Results of Tensile Test

Samples	Yield Strength (MPa)	UTS (MPa)	% Elongation
S1	32	42	7.19
SF1	44	64	3.69
SF2	40	45	4.97
SZ1	32	40	8.93
SFZ5	45	56	3.63
SZF	59	68	3.92
SZ2	47	58	8.42
SFZ	51	64	4.35
SFZ10	83	92	3.12

COMPARISON OF YIELD STRENGTH (YS)

Effect of Fly-ash on Yield Strength

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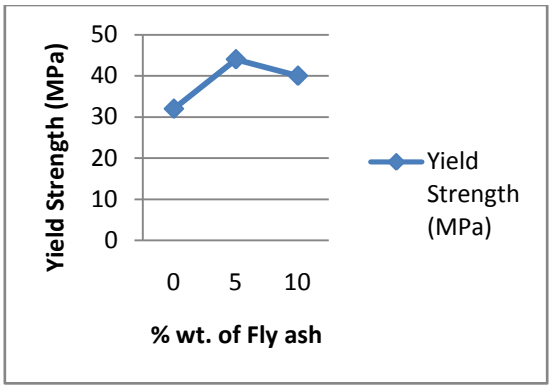

Figure 4: Variation of Yield Strength with variation in the vol. fraction of Fly-ash

With the addition of Fly-ash content in Al-6061 from 0 to 5 % vol., the yield strength increases significantly but it decreases slightly with further increase in the Fly-ash from 5 to 10 % vol. The increase noticed in the yield strength is 12 MPa with increase in Fly-ash from 0 to 5 % vol. and decrease noticed is 4 MPa with further increase in Fly-ash from 5 to 10 % vol.

Effect of Zirconium oxide on Yield Strength

Zirconium oxide has also been added to the Al-6061 and its effect on yield strength is discussed in this section.

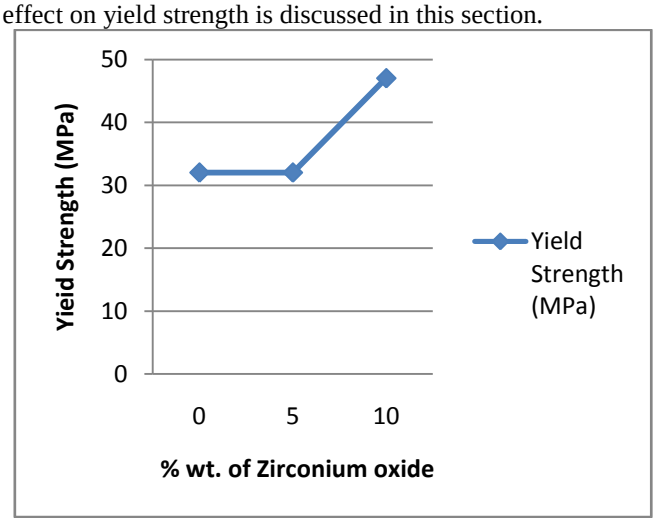

Figure 5: Variation of Yield Strength with variation in the vol. fraction of Zirconium oxide

With the addition of Zirconium oxide content in Al-6061 from 0 to 5 % vol. fraction, the yield strength remains constant but it increases with further increase in the Zirconium oxide from 5 to 10 % vol. The increase noticed in the Yield strength is 15 MPa with increase in Zirconium oxide from 5 to 10 % vol.

Effect of Fly-ash & Zirconium oxide on Yield Strength

Now the combined effect of both the constituents have also been studied and discussed as under:

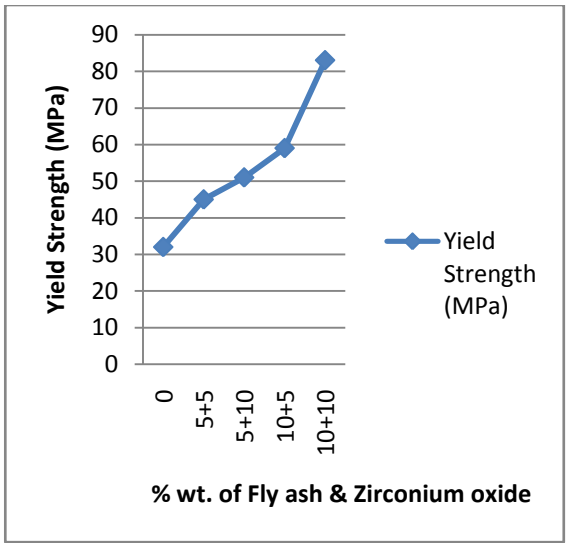

Figure 6: Variation of Yield Strength with variation in the vol. fraction of Fly-ash & Zirconium oxide

There has been a largely increase in the yield strength of the material with proportion to the increase in both constituents by 5 % each. With every increase in these constituents, yield strength increases. The total increase noticed in yield strength is 51 MPa when both the constituents are 10 % each in Al-6061.

COMPARISON OF ULTIMATE TENSILE STRENGTH (UTS)

Effect of Fly-ash on Ultimate Tensile Strength

With the addition of Fly-ash in small amount in Al-6061, the tensile strength increases but at higher amount of fly-ash it decreases.

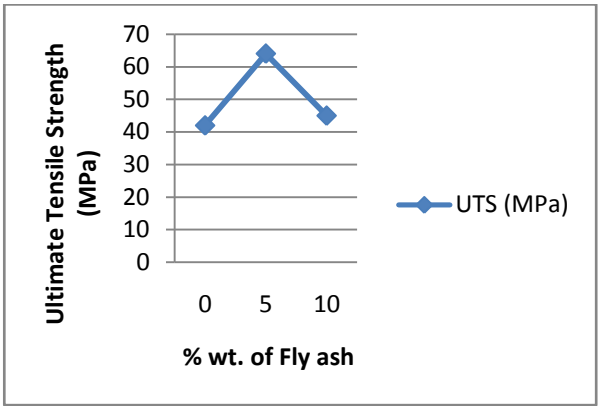

Figure 7: Variation of Ultimate Tensile Strength with variation in the vol. fraction of Fly-ash

The increase noticed in the Ultimate Tensile strength is 22 MPa with increase in Fly-ash from 0 to 5 % vol. fraction and decrease noticed is 19 MPa with further increase in Fly-ash from 5 to 10 % vol. fraction.

Effect of Zirconium oxide on Ultimate Tensile Strength

With the addition of Zirconium oxide in Al-6061, the tensile strength decreases slightly but at higher amount of zirconium oxide it increases significantly.

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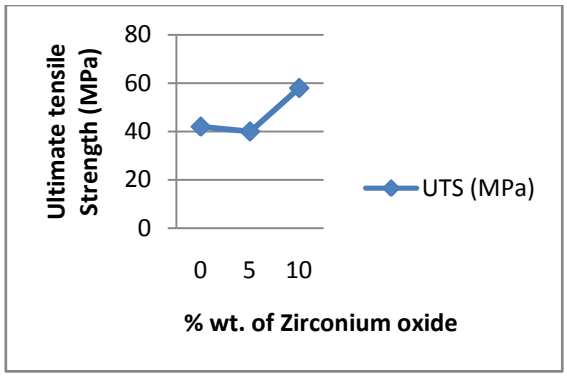

Figure 8: Variation of Ultimate Tensile Strength with variation in the vol. fraction of Zirconium oxide

The decrease noticed in the Ultimate Tensile strength is 2 MPa with increase in Zirconium oxide from 0 to 5 % vol. and increase noticed is 16 MPa with increase in Zirconium oxide from 0 to 10 % vol.

Effect of Fly-ash & Zirconium oxide on Ultimate Tensile Strength

The combined effect of both the constituents have also been studied and discussed as under:

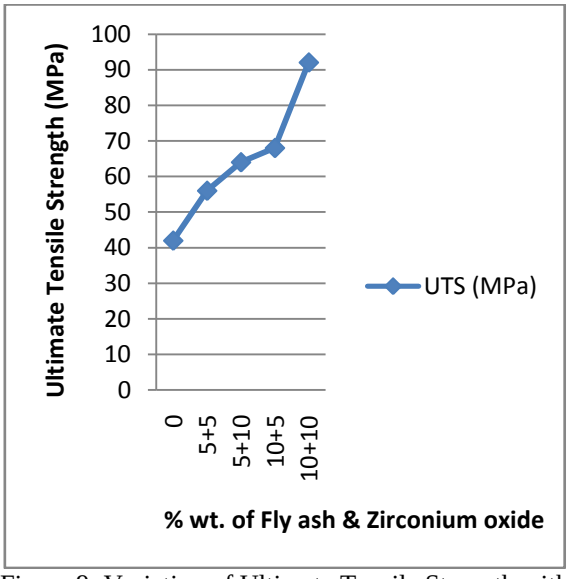

Figure 9: Variation of Ultimate Tensile Strength with variation in the vol. fraction of Fly-ash & Zirconium oxide

A large amount of increase in the Ultimate tensile strength of the material is observed with increase in the proportion of both the constituents in steps of 5 % each. With every increase in these constituents, ultimate tensile strength increases. The total increase in the ultimate tensile strength is 50 MPa when the amounts of both the constituents are 10 % each.

COMPARISON OF % ELONGATION

Effect of Fly-ash on % Elongation

With increase in the amount of Fly-ash content in Al-6061 from 0 to 5 % vol. fraction the % Elongation decreases significantly but it increases slightly with further increase in the Fly-ash from 5 to 10 % vol.

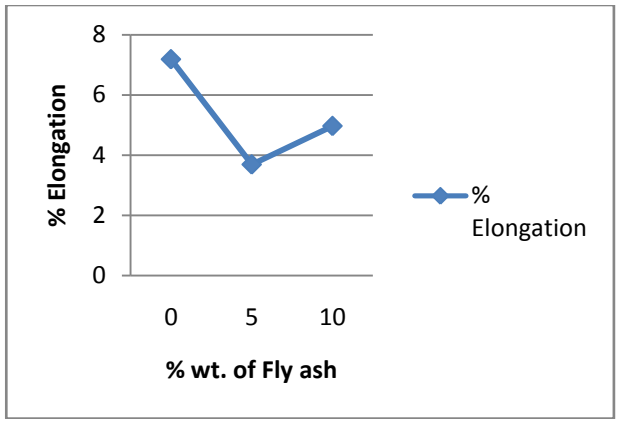

Figure 10: Variation of % Elongation with variation in the vol. fraction of Fly-ash

The decrease noticed in the % Elongation is 3.5 with increase in the amount of Fly-ash from 0 to 5 % vol. and increase noticed is 1.28 with further increase in the amount of Fly-ash from 5 to 10 % vol.

Effect of Zirconium oxide on % Elongation

With the increase in the amount of Zirconium oxide in Al-6061, the % elongation increases but at higher amount of zirconium oxide it decreases slightly.

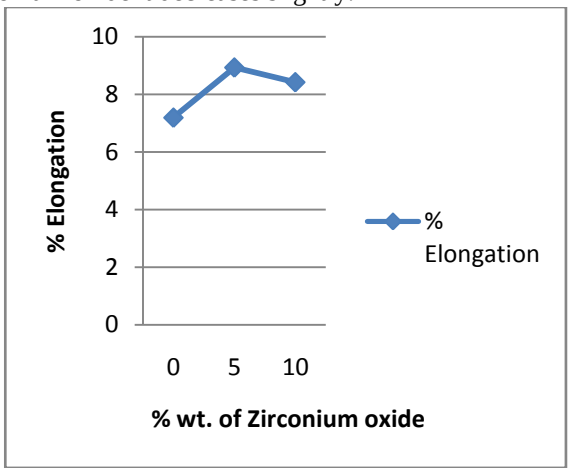

Figure 11: Variation of % Elongation with variation in the vol. fraction of Zirconium oxide

The increase noticed in the % Elongation is 1.74 with increase in the amount of Zirconium oxide from 0 to 5 % vol. and decrease noticed is 0.51 with further increase in the amount of Zirconium oxide from 5 to 10 % vol.

Effect of Fly-ash & Zirconium oxide on % Elongation

With the increase in the amount of both Fly-ash and Zirconium oxide the % Elongation decreases.

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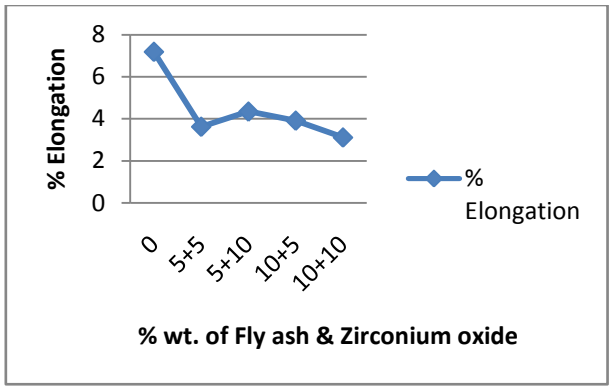

Figure 12: Variation of % Elongation with variation in the vol. fraction of Fly-ash & Zirconium oxide

The % Elongation firstly decreases with increase in the amount of both Fly-ash and Zirconium oxide from 0 to 5 %. Then it slightly increases with further increase in Zirconium oxide from 5 to 10 % vol. and also with further increase in Fly-ash from 5 to 10 % vol. but it again slightly decreases with the increase in the amount of both Fly-ash and Zirconium oxide from 5 to 10 %. The decrease noticed is 4.07 with increase in the amount of both Fly-ash and Zirconium oxide from 0 to 10 %.

IV. CONCLUSIONS

The conclusions drawn from the present investigation are as follows:

- The Al-6061/Fly-ash/Zirconium oxide MMCs have been successfully fabricated by stir casting method.
- Both Yield strength and Ultimate Tensile Strength of the MMCs increases with the increase in the % wt. of reinforcement particles.

The results confirmed that the Al-6061/Fly-ash/ZrO_2 reinforced composite is superior to the base alloy Al-6061 in comparison of tensile strength.

SCOPE OF FUTURE WORK:

- This work can be further extended by varying the volume fraction of the reinforcement added.
- By using different method of production of MMC's like squeeze casting, powder processing etc.

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