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Investigating Mechanical Properties of Composites of ADC12 alloy with Sic and Flyash As Filler Materials

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Abstract *- The coal industry produces a significant amount of Fly-ash, which poses a crucial environmental concern. Reusing is the best solution to tackle such industrial by-products. In this study, composites of ADC12 alloy with Sic and Fly-ash as the filler material are made by the squeeze casting method. Mechanical properties of the composites varied with composition, the pressure applied to squeeze, alloy melting temperature, and temperature maintained on the die are studied. This work proposes a route to reduce the industrial by-product without much compromise in the mechanical property of the composite.*

Keywords - *ADC12 alloy, Fly-ash, Silicon Carbide, Squeeze casting.*

I. INTRODUCTION

Composite materials have an ever-increasing demand in the fields like aerospace and automobile industries [1-5]. These materials were used where very specific stiffness, specific strength, and wear resistance [6-9] were important. The properties obtained in the product composites vary with composite constituents and their properties intrinsic them and the shape .size, weight, orientation, and distribution [10, 11]. The demand for this kind of material in the aerospace and automotive industries necessitates the development of Aluminum Matrix Composite (AMCs).

Several methods were used by the industries to manufacture the products, and each casting method has its own pros and cons. In conventional casting processes like pressure casting, defects such as pore formation due to gas, shrinkage porosities are pertinent, and these defects decrease the mechanical properties and integrity of the end product.

To overcome such defects, a comparatively new technique, squeeze casting, can be implemented [12-17]. This method applies very high pressure to the melt. Pressure during solidification may vary the melting point; the rate of solidification can also cause structural change in some cases [18-22].

In composite materials, fillers have a key role in determining the cost and weight of the product while improving or maintaining the desired properties of the end product. Thus, in many situations, the addition of fillers is a trade-off between cost reduction and the mechanical properties of the end product. It is found that fly-ash, a major by-product in a coal-based power plant, can be successfully dispersed into aluminum alloys to make aluminum-fly-ash composites [23-25]. Such composites are found to have low density and suitable properties for several automobile applications.

In this work, to estimate properties of composites of ADC12 alloy using silicon carbide and fly-ash made by squeeze casting have been tried. Mechanical behaviors of product materials using various process parameters were estimated, and the optimal composition for better properties was identified. As the process parameters in preparation of the sample increase, the number of experimental trials also get increases. To overcome this complexity, the Taguchi method is implemented, which screens various parameters to achieve a better quality result without increasing the experimental trial numbers and the cost of the experiment [26-28]. The process parameters attained from the Taguchi method were depended on the environmental conditions and various noise factors. To establish the optimum process conditions and the effect of processing parameters on properties, the Taguchi L9 method is used.

II. EXPERIMENTAL

A. Sample Preparation

Melt ADC12to780°C in graphite crucible using an induction furnace. Simultaneously, sic and Fly ash was preheated to 600 °C using a muffle furnace. These preheated Sic particles were added with the melted ADC12 and stirred well, and rotating was maintained at 500-600 rpm. To achieve uniformity during stirring, the baffle is used along the sides of the crucible. Heavy turbulence developed induces excellent mixing of the Sic and alloy melt. Preheated fly ash was then added when a vortex was formed. After the complete addition of filler materials, stirrer speed was reduced to 200- 400 rpm, then stirring lasted to 3-5 minutes. The temperature of mixed materials come to 680°C, and vibration was applied, mix it properly.

B. Sample details

ADC12 alloys were the matrix material. Table1 shows the material composition of ADC12 alloy estimated using the

Optical Emission Spectroscopy (OES) method. Silicon Carbide of average particle size 90 nm and fly ash of particle size 10 – 100 microns were used as reinforcement materials with different ratios. Samples were prepared using the squeeze casting method by varying process parameters melting temperature, squeeze pressure, and die temperature. In the present work, three-level and four process parameters were used, i.e., Sic/Fly-ash ratio, melting temperature, squeeze pressure, and die temperature were considered. Parameters and their selected levels are shown in Table2. In the case of four parameters and three levels, the experimental design would require 81 experiments. However, as per the design by Taguchi L9 orthogonal array, the experimental trials are reduced to 9. The experimental layout for the L9 orthogonal array is shown in Table3. This design involves 9 experiments with specified levels and parameters.

C. Characterization

The surface morphology of samples was analyzed with a Hitachi S-3400N machine. Tensile test specimens were machined and polished to their standardized sample cross-section. Tensile test was carried out using Universal Testing Machine by adopting the standard ASTM A370:2014with with a crosshead speed of 5 mm/min. The sample specimen dimensions are shown in Figure1a. The photograph of tensile test samples before the test is shown in Figure1b and then shown in Figure1c. The hardness of the material was estimated using Rockwell Hardness Test machine model MSM from Meta test Instrument Pvt. Ltd., India. The Rockwell Hardness was measured on a B scale with a minor load of 10 kg for 20 seconds. The standard ASTM E18:2014 was used for the hardness test.

III. RESULTS AND DISCUSSIONS

The surface morphology of squeeze cast samples was analyzed using a scanning electron microscope. The non-crystalline Fly-ash particles are visible in Figure2a as smooth oval-shaped particles, while the crystalline Sic particles of sharp edges are seen in Figure2b. The tensile strength of the composite varies with composition, squeeze pressure, melting temperature, and die temperature[29, 30]. Variation of tensile strength with these parameters was studied. The Stress-Strain graph of the composites with different composition is shown in the Figure3a, and the ultimate tensile strength of those are given in the Figure3b. Sic does not improve tensile strength, whereas Fly-ash improves the tensile property significantly. It is found that there is a minimum squeeze pressure required to obtain optimum tensile strength. Squeeze pressure is equivalent to 25 tons and at 30 tons show similar tensile strength, whereas 20 tons show low tensile strength (Figure3c and 3d). Thus, the tensile property is found to saturate after a typical squeeze pressure. Another important property that influences the characteristics of composite material is the melting temperature. The composite preparation was carried out at three different melting temperatures 600 °C, 625 °C, and 650 °C. Sample with a melting temperature of 650 °C shows improvement in tensile strength (Figure3e and 3f) as compared with the other two samples prepared under lower temperatures. The melting of the ADC12 alloy could not be completed below 650 °C. This may be the reason for the better tensile strength of the sample with a melting temperature of 650 °C. Another parameter that may affect the properties of composite material is the die temperature. Three different die temperatures, 100 °C, 150 °C, and 200 °C, and tensile strength of the samples were studied (Figure3g and 3h). The die temperature does not seem to affect the material properties to a significant extend.

Rockwell Harness test is performed on the samples, and the variation of hardness with composition, squeeze pressure, melting temperature, and die temperature is given in Figure4. It can be observed from Figure4a that the percentage of Sic increases from 2.5% to 7.5%, Rockwell Hardness values increases from 37 to 40. Thus Sic is more preferable to improve the hardness of the composites, but at the same time, Fly-ash does not deteriorate the property much. Hence, the amount of Fly-ash should be optimized depending on the requirement of end product properties. As a result of the high pressure of solidification of the melt, porosities due to gas and shrinkage are eliminated or prevented. Hence as the squeeze pressure increases, the compactness of the composite is likely to increase. This expected nature in hardness is observed in Figure4b. As the squeeze pressure from 20 tons to 30 tons is increased, the Rockwell Hardness value is increased from 30 to 38. The molten ADC12 is mixed with Sic and Fly-ash by the mechanical stirring process. As the melting temperature increases, the phase change of ADC12 occurs completely, and thereby uniform mixing with Sic and Fly-ash is expected to be accomplished. The Rockwell Hardness value increases from 34 to 40 as the melting temperature varies from 600 °C to 650 °C (Figure4c). As expressed in Figure4d, the Rockwell Hardness value increases from 28 to 40 since the die temperature increases from 100 °C to 200 °C. Thus slow cooling of the melt is more preferable to achieve a better hardness of the composite.

IV. TABLE I

MATERIAL COMPOSITIONS OF ADC12 ALLOY (OES METHOD).

ELEMENT	WEIGHT %
Al	86.7
Si	9.89
Fe	0.66
Cu	1.61
Mg	0.18
Cr	0.03
Ni	0.07
Zn	0.55
Ti	0.05
Pb	0.11
Ca	0.01
Zr	0.01
Mn	0.14

TABLE II

PROCESS PARAMETERS AND LEVELS USED IN THE PRESENT EXPERIMENTAL DESIGN

PARAMETERS	LEVEL1	LEVEL2	LEVEL 3
Reinforcements	7.5% Fly-ash 2.5% Sic	5% Fly-ash 5% Sic	2.5% Fly-ash 7.5% Sic
Melting temperature (°C)	600	625	650
Squeeze pressure (tons)	20	25	30
Die temperature(°C)	100	150	200

TABLE 3
TAGUCHI L9 ORTHOGONAL ARRAY USED FOR THE SYSTEM DESIGN

TRIALS	PARAMETERS REINFORCEMENTS	MELTING TEMPERATURE(°C)	SQUEEZE PRESSURE (TONS)	DIE TEMPERATURE(°C)
1	7.5% Fly-ash 2.5% Sic	600	20	100
2	7.5% Fly-ash 2.5% Sic	625	25	150
3	7.5% Fly-ash 2.5% Sic	650	30	200
4	5% Fly-ash 5% Sic	600	25	200
5	5% Fly-ash 5% Sic	625	30	100
6	5% Fly-ash 5% Sic	650	20	150
7	2.5% Fly-ash 7.5% Sic	600	30	150
8	2.5% Fly-ash 7.5% Sic	625	20	200
9	2.5% Fly-ash 7.5% Sic	650	25	100

Figure 1
THE DIMENSIONS OF THE TENSILE SAMPLE AND THE PHOTOGRAPHS OF SAMPLES BEFORE AND AFTER THE TENSILE TEST.

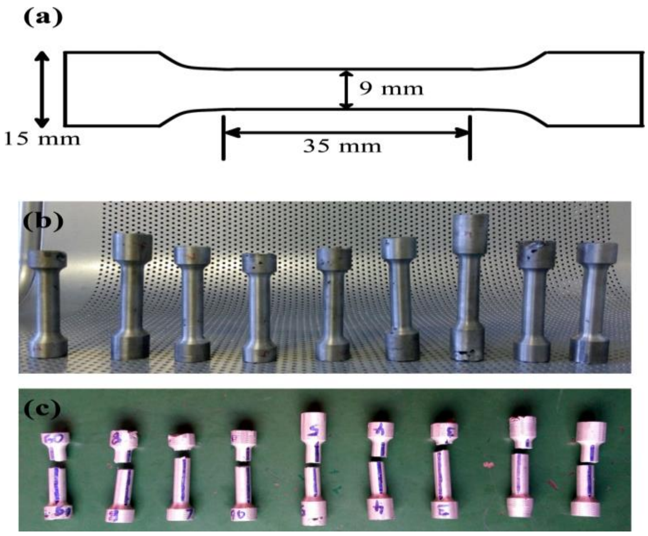


Figure 2
SCANNING ELECTRON MICROGRAPHS OF ADC12/SIC/FLY-ASH COMPOSITE

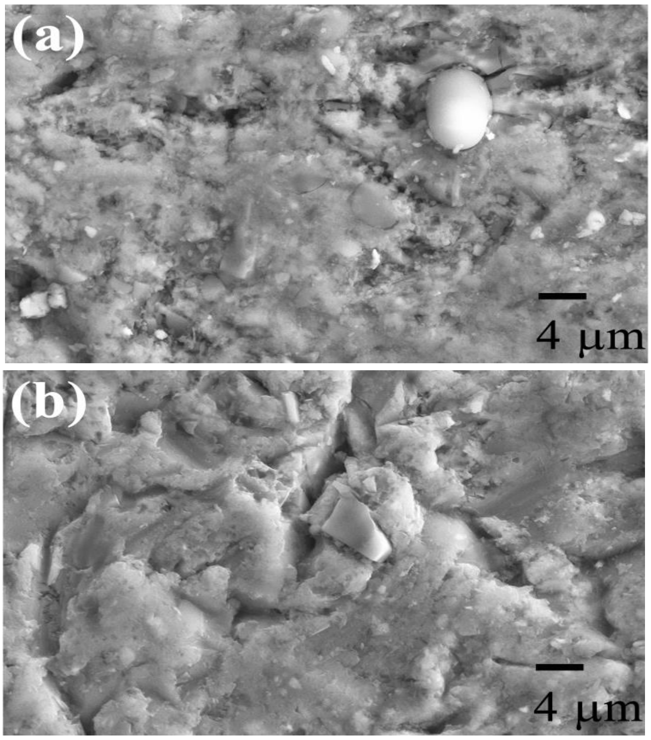


Figure 3
THE VARIATION OF TENSILE STRENGTH WITH COMPOSITION, SQUEEZE PRESSURE, MELTING TEMPERATURE, AND DIE TEMPERATURE.

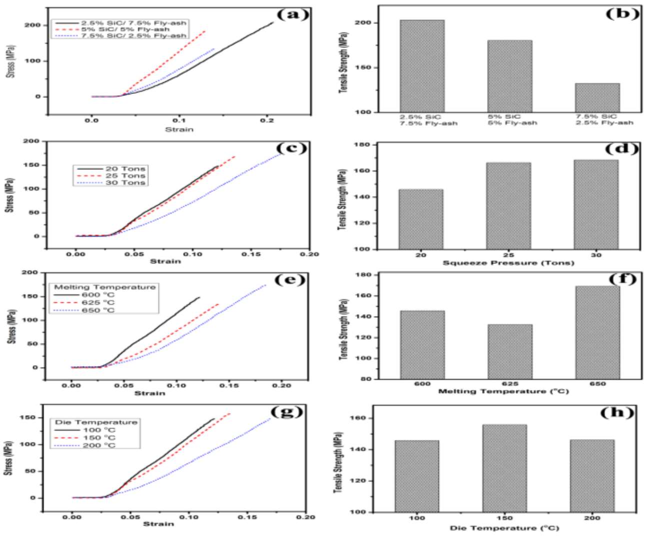
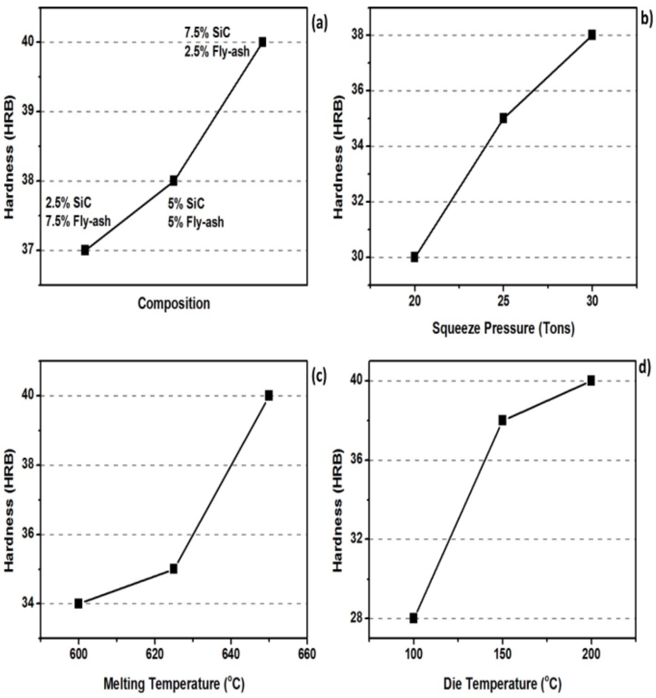


Figure 4
VARIATION OF ROCKWELL HARDNESS WITH COMPOSITION, SQUEEZE PRESSURE, MELTING TEMPERATURE, AND DIE TEMPERATURE.



VI. CONCLUSIONS

The squeeze casting method is employed to prepare ADC12 composites with Sic and Fly-ash as filler material. Properties of the product were studied by varying the composition of composite, squeeze pressure, melting temperature, and die temperature. Fly-ash is found to be a very good filler that can cut the cost of the end product without compromising on mechanical property. The optimum values for squeeze pressure and melting temperatures are determined. Also, it is found that slow cooling of the melt, achieved by increasing the die temperature, is required to enhance composite properties.

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