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Preparation and Microstructural Characterization of ZrO_2 Reinforced Al 6061 Metal Matrix Composites

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***Abstract*— Aluminum Metal Matrix Composites have optimized mechanical properties like good resistance to wear, high strength to weight ratio etc. and hence plays a great role in the fields of automotive, aerospace and marine applications. In the present work an attempt is made to synthesize MMCs using 6061 Al as base metal matrix reinforced with Zirconia (ZrO_2) using liquid metallurgy through stir casting method. The reinforcement addition level is varied from a range of 1 to 5 wt. % in levels of 2 wt. %. Reinforcement particles for each respective composite were preheated to about 150 ^{0}C and then dispersed into molten Al6061. Scanning Electron Microscope is used to obtain micrographs for analysis of the composition and microstructural characterization. EDAX is used to find out composition of obtained test sample and phase analysis is carried out using XRD analysis.**

Keywords*— *MMC's; ZrO_2 particulates; Al6061; Stir-casting

I. INTRODUCTION

Metal matrix composites (MMCs) are a kind of material in which reinforcements particles are dispersed in alloy matrix. MMCs have desirable properties such as greater wear resistance, greater elevated temperature; and also good resistance to abrasion [1-3]. Hence MMCs are used in all major application such as space shuttles, automobile and aerospace [4]. The high cost of fabrication of MMCs leads to the limitations of their actual application. Past research says that titanium, magnesium and aluminum are popular materials for the present applications. Aluminum, magnesium and titanium are popular matrix materials of current interest since they have low density properties [5].

Automotive industries are interested in manufacturing parts which are good in tribological properties and also light in weight. Hence Aluminum can be used for the fabrication of composites materials as a base metal matrix element. Aluminum Matrix Composites (AMCs) finds its major applications in aerospace, automobile, aircraft and other fields [6] due to the lightness, greater thermal conductivity, good tensile strength, large coefficient of linear expansion, good machining property, etc.

In order to enhance MMC's mechanical properties, a lot of research was carried for the selection of reinforcement particles for metal matrices. Different particles such as Al_2O_3, SiC, B_4C, TiC, TiB_2 and ZrO_2 have been identified as efficient reinforcements for metal, as the dispersion improves the modulus of elasticity, tensile strength at different temperatures, hardness and wear resistance of the alloys [7].

Zirconia (ZrO_2) is used majorly for dental ceramic application compared to other because of its different nature and versatility. The low magnitude of thermal conductivity, greater coefficient of thermal expansion, greater strength and high thermal shock resistance are the important properties making ZrO_2 a promising material [8-12].Aluminium Metal Matrix Composites have been used in almost all the emerging fields of engineering [13].

II. EXPERIMENTAL DETAILS

In the present work, Al 6061 is used as a base metal matrix material. The composition of the matrix metal is tabulated below in Table 1. ZrO_2 reinforcement particles having size of 50 µm and the variation amount of 1, 3, & 5 wt. % are used in preparation of composites. MMCs are prepared by stir casting technique. A determined quantity of Al6061 alloy placed inside the crucible and then heated to a temperature range of 840 ^{0}C. Preheating of ZrO_2 particles were done at temperature of 150 ^{0}C in order to remove the gases. After degassing process, preheated ZrO_2 particles poured into the molten alloy. Zirconia coated steel impeller is used to create vertex. The exact quantity of reinforcement needed was determined and then decanted into molten alloy thrice instead of pouring everything at single time. Stirring process is done mechanically for approximately 10 minutes after every stage of introduction of reinforcement particles. The stirrer was kept at a depth of approximately 2/3 height during the process at 150 rpm speed. The mixture of composite is then decanted into mild steel (Figure 1) mould having length of 150 mm and diameter of 18 mm at a pouring temperature of 850 ^{0}C. The cast work piece having diameter and thickness of 10 mm and 15 mm respectively were machined to study microstructural studies. Micrograph pictures were taken with the help of Scanning Electron Microscope along with EDAX test. For XRD, specimen of diameter 10mm and thickness 3 mm was machined form the casting.

Table.1 shows Al-6061 composition details

Elements	Fe	Cu	Si	Pb	Ti
%	0.7	0.24	0.43	0.24	0.15

Elements	Mg	Mn	Ni	Zn	Sn
%	0.802	0.139	.005	0.25	0.001

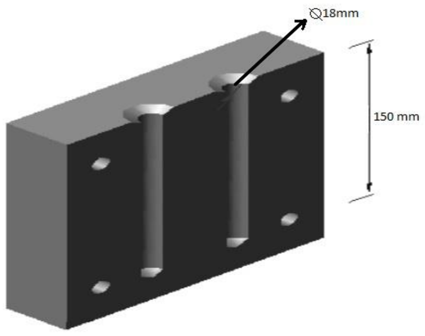

Fig 1. Steel Mould used for casting

III. RESULTS & DISCUSSIONS

A. Study of Al6061-ZrO_2 microstructure

Casting process is a hard process to fabricate ZrO_2 reinforced MMCs because ZrO_2 particulates have low property of agglomeration and wettability giving poor mechanical properties with non-uniform distribution. The present work explains the fabrication of Al6061-ZrO_2 composites by stir casting process with mixing of respective ZrO_2 quantity in 3 consecutive stages. The addition of ZrO_2 powders in the composites was 1, 3, 5 wt. %. Micrographs by SEM were captured as show in the figures 2[a-c] and explains the micrograph for Al6061 with varying wt. % of ZrO_2.

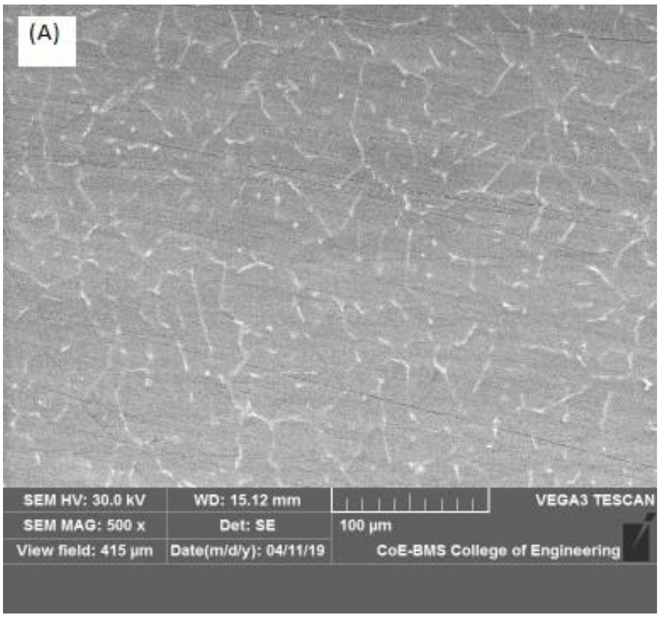

Fig.2.a. Micrograph of Al6061-ZrO_2 particulates with 1wt. % of ZrO_2

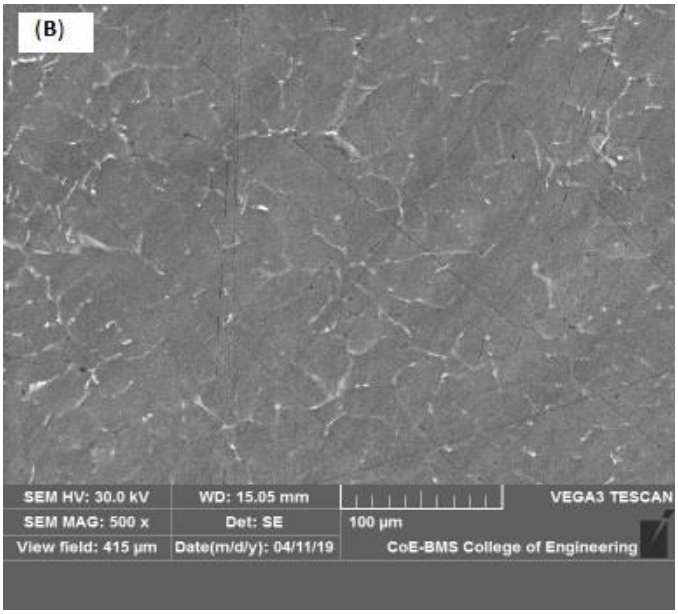

Fig.2.b. Micrograph of Al6061-ZrO_2 particulates with 3wt. % of ZrO_2

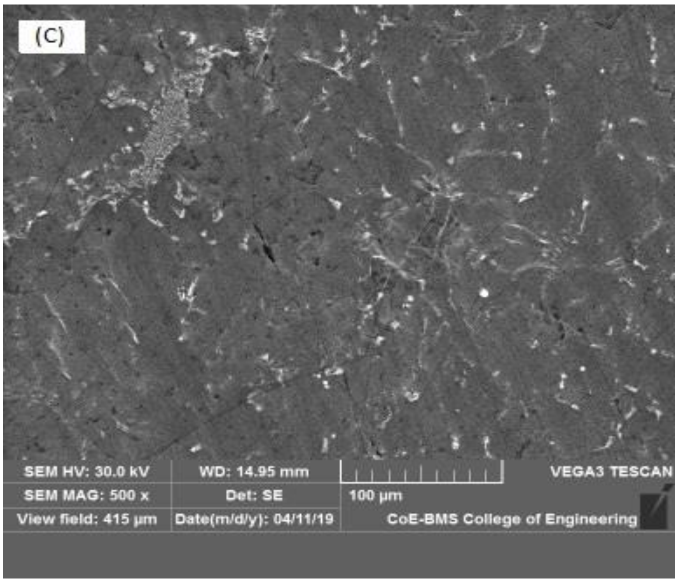

Fig.2.c. Micrograph of Al6061-ZrO_2 particulates with 5wt. % of ZrO_2

B. XRD RESULTS

Figure 3 (a-b) represents XRD graph carried on Al6061-ZrO_2 composite. The test has been carried out to identify the presence of ZrO_2 for 3wt. % and 5wt. % of ZrO_2. Fig.3.a represents the XRD pattern for Al 6061 alloy with 3 wt. % ZrO_2 MMCs. In the pattern, totally five peaks are noticed ranging from 20^0 - 90^0 span and the respective values are 2 theta for 38.36^0, 44.580^0, 64.97^0 and 78.08^0 with respect to Al and 2 theta at 82.29^0 belongs to ZrO_2.

Figure 3b shows the XRD patterns of Al 6061 alloy with 5wt. % ZrO_2 with five peaks varies between 20^0-90^0 span. The 2 theta of 38.33^0, 44.55^0, 64.96^0 and 78.1^0 peaks value were obtained with respect to Al and 2 theta of 82.30^0 belongs to ZrO_2.

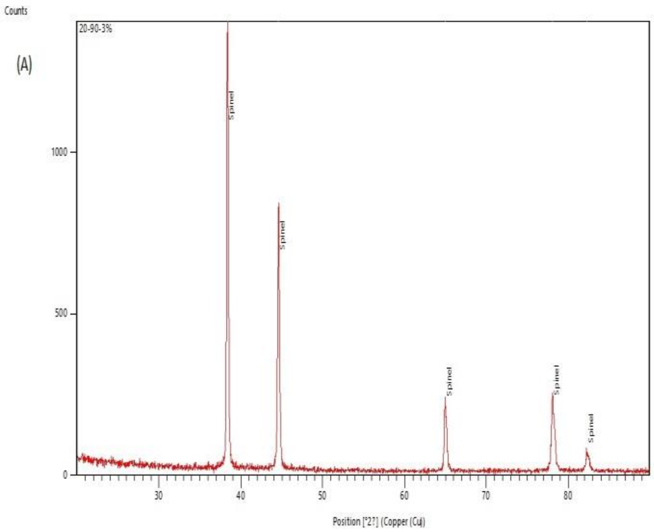

Figure 3.a. XRD pattern for Al6061-ZrO_2 with 3 wt. % ZrO_2.

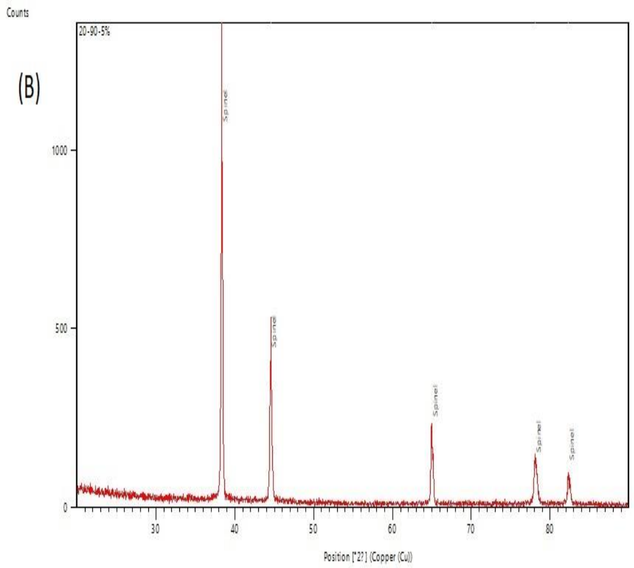

Figure 3.b. XRD pattern for Al6061-ZrO_2 with 5 wt. % ZrO_2.

IV. CONCLUSIONS

The fabrication of Al 6061 reinforced ZrO_2 metal matrix composites by stir casting and studies on the composition of the processed composite with microstructural characterization has led to following conclusions

1. The composites of Al6061-ZrO_2 with different proportions i.e. 1, 3 and 5 wt. % of ZrO_2 are successfully fabricated and synthesized by stir casting process.

2. The uniform distribution of ZrO_2 particles in Al6061 metal matrix were analyzed by SEM micrographs.

The XRD analysis clearly shows the formation of ZrO_2 phase in the processed composite

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