EFFECT OF ZrO_2 ADDITION ON MECHANICAL PROPERTIES AND MICROSTRUCTURE OF LM 4 ALLOY COMPOSITE MATERIAL

Vandana J. Rao, D. R. Lodhari, Vishal Kalia
Metallurgical and Materials Engineering Department, M.S. University of Baroda, Vadodara, Gujarat, India.

ABSTRACT

Cast particulate composite containing ZrO_2 as reinforcing particles have been develop by using low cost, liquid stir cast method with the help of bottom pouring furnace. Magnesium is added to the melt in order to help wetting of ZrO_2 particles by molten aluminium and to retain the particles inside the melt. Stirring is performed under nitrogen gas environment to avoid oxidation and porosities. The present work aims to understand the influence of amount of ZrO_2 particles added on the microstructure and mechanical properties of the resulting cast composites. The microstructure of the produced composite is examined by optical microscope and scanning electron microscope. Brinell hardness test and universal tensile test is performed on the composite specimen. Microstructural observation of several cast composite showed the uniform distribution of ZrO_2 particles into the LM4 matrix material. Hardness value can be increased in the range of 50 to 65% than original material .

Key Words : Bottom pouring furnace, Stirring, ZrO_2 Mechanical properties

INTRODUCTION

Cast metal matrix particulates composites (CMMPCs) are attractive because it is easy to fabricate the engineering components at competitive price. LM 4 alloy is attractive where abrasion and wear rate is prime important, but still better control on properties is achieved after longer duration of heat treatment. In order to have better performance during applications, addition of ZrO_2 has been evaluated. In the areas of CMMPCs reaction between molten aluminium and metal oxides such as TiO_2(1), $2SiO_2$(2), B_2O_3(3), Fe_2O_3(4) have been reported. The present work is intended to investigate the microstructure and mechanical properties of cast composite obtained by dispersing different amount (1wt%, 3wt%, 5wt%) of ZrO_2 with fixed amount of K_2TiF_6(1wt%) flux into the molten LM 4 metal.(5) Magnesium addition(5wt%) after the addition of ZrO_2 improves the wettability of oxides particles(Al_2O_3) by molten metal.(6) Sequence of addition of magnesium metal and oxide particles is important to control the mechanical properties and microstructure of the resulting composite.

EXPERIMENTAL PROCEDURE

CMMPCs can be generated by addition of 1wt%, 3wt% and 5wt%of ZrO_2 particles with fixed 1wt% of K_2TiF_6 flux into molten LM 4 alloys. The resulting slurry is cast into a permanent steel mold by bottom pouring furnace. The Schematic diagram of the investigation is shown in figure No1

Magnesium (5wt% fixed) is added to the melt. The temperature of the melt is measured by using a digital temperature indicator connected to a chromel-alumel thermocouple placed inside the melt. Pouring is done in a temperature around 695-700^{0}C. Stirring is done at around 300rpm speed for 3 minute. Slurry can poured into a preheated steel mould. Degassing of the slurry is carried out at the final stage of pouring.

The Binell hardness test is carried out at a load of 62.5kg using a steel ball indenter of 2.5mm diameter. The tensile testing of 11.28mm gauge diameter and 56mm gauge length has been tested under tension at a very slow strain rate. Specimens for metallographic studies have been prepared by standard metallographic procedure. Before etching the final composites are examined by Scanning Electron Microscope under BES mode. The typical distribution of various microstructural features of the composite has been recorded by EDS facilities of SEM 5610 LV model.

RESULTS AND DISCUSSION

The average particle size of ZrO_2 is 5-10µm. A few of them are even at around 1µm in size. Chemical analysis of ZrO_2 represent 63.40 W% of Zr and 36.60 W % of oxygen (Fig. 2 and Fig.3).

The chemical analysis of Raw LM 4 alloy indicate presence of Cu 2.3%, Si 5.0%, Fe- 0.5% balance 95.5% Al. Following EDS analysis of final composite at different location like on white silicon needle, on aluminium grain, even at eutectic location and overall analysis indicate presence of ZrO_2 particle (Figs. 4-11).

Thus we conclude that uniform distribution of zirconium oxide particles into the matrix material, is possible by addition of K_2TiF_6 flux and with 5 W% of magnesium metal. Recovery of magnesium is obtained around 60-70% into the matrix. The variation in Brinell hardness number and tensile properties with different percentage of ZrO_2 addition is presented in Table No. 1.

The hardness increases with the addition of 1wt% ZrO_2 particles but in case of 3wt% ZrO_2 and 5wt% ZrO_2 hardness value becomes almost constant. It may be due to fixed addition of K_2TiF_6 Flux with variation of ZrO_2 particles.(5) Hardness of heat treated sample is reduced due to precipitation of $AlCu_2Mg$ which have needle like morphology and are semi coherent with the matrix(7) but tensile properties improves. As cast sample tensile properties are quite lower than standard value because of ZrO_2 additions. Porosity and interfacial gap has a significant influence on tensile properties of cast composite.(8, 9, 10) Porosity increases significantly with increase of processing temperature and processing time. Increasing amount of ZrO_2 addition generates more porosity and gas porosities are stabilized by reinforcing particles.(6) Percentage elongation also decrease with variation of w% of ZrO_2 particles.

Failure analysis of tensile test sample results indicate the presence of ZrO_2 particles and there bonding with matrix. Magnesium presence indicates role of wettability of oxide particles with matrix. Actually wetting between oxide particles (Al_2O_3) and matrix is better than Carbide (SiC) particles.[11] Following EDS analysis presents the above discussion. The SEM microscopic examination of fractured surfaces of broken tensile bar indicates the presence of Zr Oxide particles and also exhibits a predominantly brittle cleavage fracture mechanism (Fig. 12-13).

CONCLUSIONS

From this study following points can be concluded.

- It is possible to produce composite with the addition of ZrO_2 using K_2 TiF_6 flux and Magnesium metal.
- With balance wt% of ZrO_2 and K_2 TiF_6 flux the average Brinell hardness of the composite increases drastically from value of 56 to 110 HB. At higher wt% of ZrO_2, there is no effect on hardness value but it remains almost constant.
- Addition of ZrO_2 particulate in LM4 results in lower tensile properties ie UTS and % El than the base alloy. It may be due to brittle behaviour of cast composite material. With heat treatment there is significant improvement of tensile strength and ductility of the aluminum composite containing different amount of ZrO_2 particulate.

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