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Effect of mg_2si along with bismuth on the microstructure andmechanical properties of mg-al/ mg_2si composite

G. Manjunath[1]*, D. Shivalingappa[1], R. Kishore Kumar[1], D. E. Umesha[2]

Department of Mechanical Engineering,
[1]Adhiyamaan College of Engineering, (Autonomous) Hosur, Tamil Nadu, India
[2]Bapuji Institute of Engineering and Technology, Davangere, Karnataka, India

Abstract : Recent studies show that magnesium based composites can be considered as a viable option for weight reduction in automobiles. The influence of Mg_2Si formed by the addition of silicon on the microstructure and mechanical properties of Mg-Al/Mg_2Si composite has been investigated in the present work. Convectional composite processing techniques produce large sized Mg_2Si particles, which are highly brittle in nature and eventually will deteriorate the mechanical properties. Hence, formation of large sized Mg_2Si particles is eliminated by adopting in-situ casting technique and as well as adding modifier, Bismuth for refining Mg_2Si thereby improving mechanical properties. It is revealed from hardness tests that Mg_2Si increases the hardness values of the composite, however its variation is in limited range only. The tensile test results revealed that the tensile strength of the composite decreases slightly with increase in silicon percentage in the composite. Compressive strength has been improved with increase in silicon percentage.
Keywords : Mg-Al/ Mg_2Si, in-situ composite, mechanical properties.

Introduction

Due to their light weight, magnesium and its alloys have found numerous applications in automotive and aeronautical industry. They are capable of even replacing some of the convectional metals in the manufacturing industry. Magnesium alloys are also having good damping capacity, excellent castability and superior machinability[1]. The presence of porosity and non-uniform grain refinement is seen to be a constant problem in magnesium metal matrix composites[2]. Mg alloys containing magnesium silicide (Mg_2Si) particles have high potential because it exhibits lower density and high hardness. Magnesium silicide reinforced magnesium metal matrix composites have wide opportunities, in automotive and aerospace industries[3]. Convectional casting method produces large sized Mg_2Si particles that are hard and brittle, which in turn will reduce the mechanical and tribological properties.

This can be overcome by in-situ stir casting processing[4]. Modification is a simple and effective technique for refining the microstructure and improving the mechanical, as well as tribological properties of the composites[5]. Recently Y, Gd, Na, La, B, Sr have found to be better in modifying Mg_2Si in the aluminum and magnesium metal matrix composites for obtaining fine microstructure and improved mechanical properties[6,9].The primary aim of the present study was to investigate the effect of Mg_2Si along with Bismuth on the Microstructure and Mechanical properties of Mg-Al/Mg_2Si Composite. Based on these results, the microstructure, hardness, tensile and compressive properties of the composite with different amounts of Bi were investigated.

Experimental procedures

Materials and processing

Commercially pure Mg ingot (99.3% purity), Al ingot (99.2% purity) and Si powder (99.95% purity) were used as the starting materials to prepare the MgAl/Mg_2Si composites. The melting process was carried out in a mild steel crucible located in a 2 kW electric resistance furnace. The furnace contains bottom pouring arrangement and is also provided with an inert gas atmosphere arrangement due to the inflammable property of magnesium with oxygen, the processing of magnesium metal matrix composites was carried out in an inert gas atmosphere. The processing of composites was carried out in two stages by stir casting technique. In the first stage, cast aluminum-silicon master alloy was synthesized by dispersing silicon particles into the molten aluminum.

In the second stage, cast Al-Si master alloy was dissolved in the molten magnesium to the extent to achieve about 8 wt% Al in Mg-Al matrix alloy and 1 wt% Mg_2Si reinforcement. The melt was held at 800°C for 10 min and stirred about 7 min at a speed of 600 rpm for the complete dissolution of silicon. After that, different amounts of bismuth powder (0 wt. %, 0.5 wt. % and 1 wt. %, 1.5 wt. %) preheated at 200 °C wrapped in aluminum foil was added to the composite melt, and stirred for about 5 min. Preheating of Bi particles were done at 100 °C to remove moisture and gases from the surface of the particulates. Finally, the composite melt was poured into a steel mould (size of 3 mm × 5 mm × 120 mm) preheated at 400 °C.

Materialcharacterization and phase analysis

Microstructure and phase analysis provide important information about the composite such as the position of the reinforcement, the orientation of reinforcements, porosity etc.The cast Mg-Al/Mg_2Si Composites were cut into 10 × 10 ×10 mm^3 size and surfaces of which were prepared for microstructure analysis. The samples were polished through standard procedure and etched with 10 ml picral + 100 ml ethanol for 10 seconds at room temperature.

Mechanical properties

Hardness, tensile and compressive properties were determined for the cast Mg-Al/Mg_2Si Composite. For hardness test, the specimens were indented with a 5 mm diameter hardened steel ball subjected to a load of 150N applied for 10 seconds. The diameter of the indentation left in the test material was measured with a low powered microscope. The specimen for tensile stress was made based on ASTM E8M -15a standard. The test process involves placing the test specimen in the testing machine and slowly extending it until it fractures. The specimen for compression test was made based on ASTM E9 standards.

Results and discussion

Microstructure analysis

Figure 1 shows the SEM images of Mg-Al/Mg_2Si composite containing 3% silicon for different magnifications (100 x, 200 x, 500 xand 800 x). The dark grey plate like shape phase and some white particlesare visible, distributed in the continuous α- Mg matrix phase. Dark grey plate like shape phase is Mg_2Si particles and white particles are MgO or Al_2O_3 oxides or combination of these two. The white patches surrounding the Mg_2Si phase and other locations is $Al_{12}Mg_{17}$ phase. The phase identification analysis has been carried out through XRD and SEM with EDAX elsewhere [10].The modification effect of bismuth can be clearly observed in the SEM images. It can be observed that the Mg_2Si particles become smaller with the addition of bismuth. It can also be seen that the particles had been properly distributed due to the good stirring mechanism. As the percentage of bismuth increased, the Mg_2Si particles become divided, finally resulting in a unique particle distribution. Due to the controlled atmosphere a very little oxide only be seen on the SEM images.

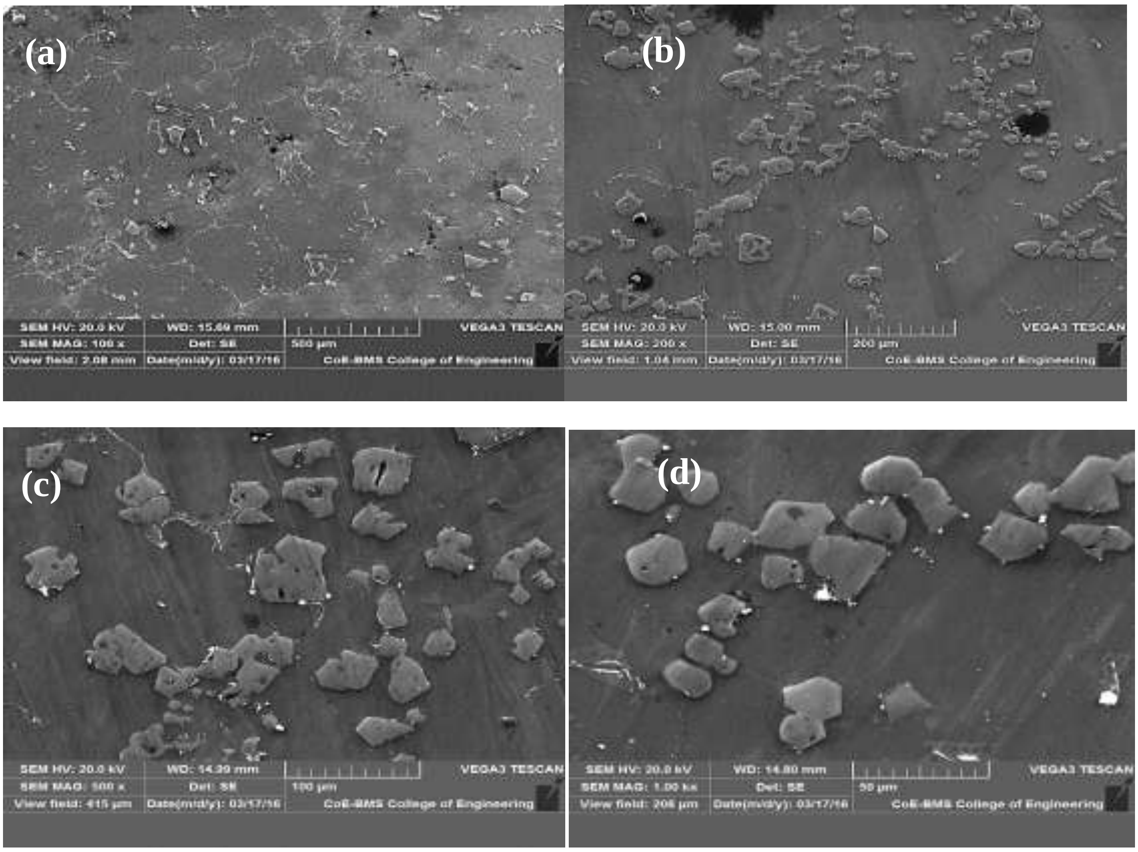

Figure 1 SEM images of Mg-Al/Mg_2Si composite with 3% Si under different magnifications:(a) 100 x, (b) 200 x, (c) 500 x and (d) 1000 x

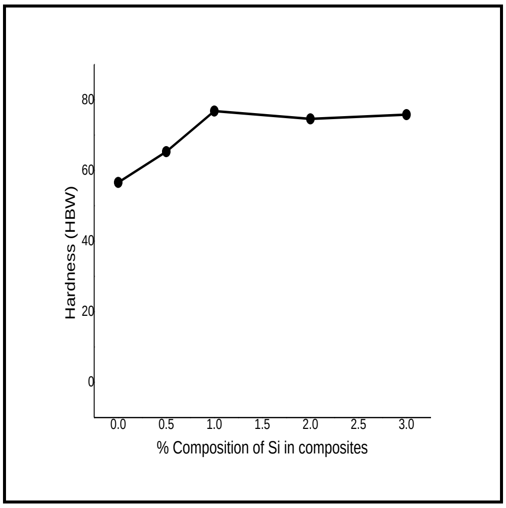

Figure 2 Variation of hardness of Mg- Al/Mg_2Si composite with varying Si content

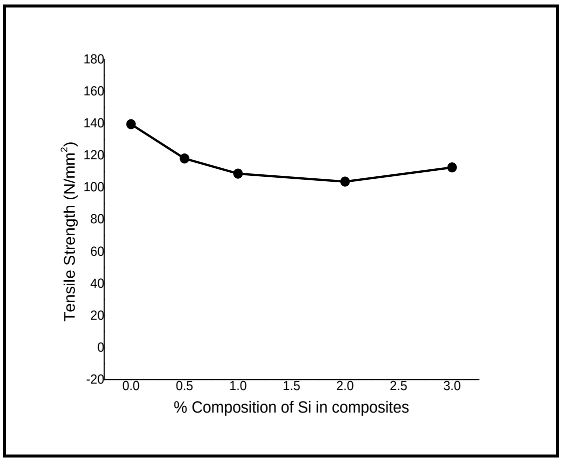

Figure 3 Variation of tensile strength of Mg-Al/Mg_2Si composite with varying Si content

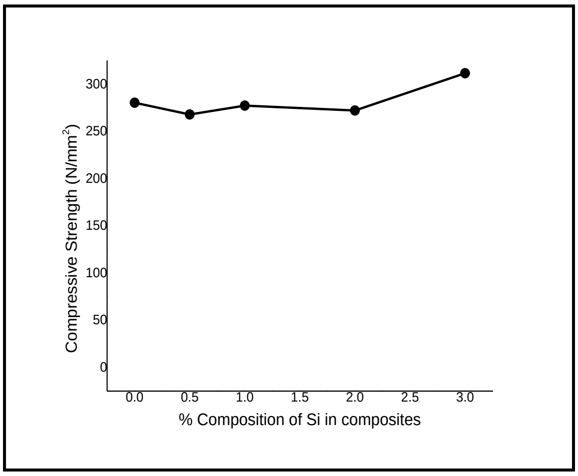

Figure 4 Variation of compressive strength of Mg-Al/Mg_2Si composite with varying Si content

Mechanical properties

The hardness graph of the composite (Mg-Al/Mg_2Si) with varying bismuth content is shown in the figure 2. It is revealed from hardness tests that Mg_2Si increases the hardness values of the composite, however its variation is in limited range only. The Mg-Al/Mg_2Si composite with 1% Si shows good hardness property than the other composites. The tensile graph of the composite (Mg-Al/Mg_2Si) with varying bismuth content in terms of N/$mm^2$is shown in the figure 3.It was revealed from tensile test that Mg_2Si decreases the tensile strength of the composites.

A slight zigzag variation can be seen in the graph shown, however when compared to the base matrix, the tensile strength seems to be slightly.

The compressive graph of the composite (Mg-Al/Mg_2Si) with varying bismuth content in terms of N/$mm^2$is shown in the figure 4.It was revealed from compression test that Mg_2Si increases the compressive strength of the composites. It can be seen from the graph that composite with 3% silicon content shows good compressive strength when compared to compositeand base matrix, on comparison with base matrix, the compressive strength seems to be increased for composite with 3% silicon content.

Conclusion

From the research work, it can be clearly seen thatMg_2Si particles influences the mechanical properties as well as the microstructure of the composite.Mg_2Si particlesincreased the hardness as well as the compressive strength of the composite, however its variation is in limited range only. Increase in silicon percentage caused a decrease in the tensile properties of the composite. Based on the results obtained and due to the increase in hardness, the processed composites can be used in automobile structures because of its light weight and it can be preferred for brake disk, Gear box, Steeringrod and valve insert.

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