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Research Article

Fabrication and Hardness Estimation of Aluminium metal matrix alloy with Silicon Carbide

Pradeep Kundu[#*], Sandeep Kundu[$], Ashok Mishra[#]

[#]B.R.C.M. College of Engineering & Technology, Bahal, Bhiwani, Haryana, India
[$] AMSSS, Ghirai, Hisar , Haryana, India

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Abstract

Fabrication of high strength and good corrosion resistance properties aluminum alloys is still a challenge. In the same direction, different composite materials were fabricated with different grades of Al alloy 6063, 6066, and 6351 reinforced with silicon carbide particulates. The SiC particles were added in different percentage and resulting composite cast were tested for the hardness. The fracture mode of the cast was found to be ductile in nature and the hardness of aluminum alloys with addition of SiC increases. In addition, during fabrication Mg was added between Al and SiC particles to improve the wettability and reduces the formation of SiO_2 layer on the surface of SiC.

Keywords: *Aluminum alloys, silicon carbide, matrix composites, hardness*

1. Introduction

For composite fabrication, the continuous or matrix phase, i.e., metal and discontinuous or reinforcement phase, i.e., carbide in the form of fibers, whiskers or particles combined together. High strength to weight ratio makes Al alloy as a promising material in the metal category. Al MMC has the wide range of application such as in bicycle, aircraft, and car body structure etc (Chennakesava Reddy, 2003).

During Al MMC fabrication, Mg is added to enhance the wettability and reduce the formation of SiO_2 layer on the surface of the SiC. The reinforcing particles are usually tends to non-uniformly disperse and in the MMC because of the high density of SiC compare to Al alloy (Zlaticanin et al, 2004). The SiC particles always try to collect at the outer surface of the cast. During mixing, manual stirring is done in this work for achieving the uniform mixing. In cast conditions, the matrix phases are in multiphase and form the intermetallic which is brittle in nature. This phenomenon is observed in this work also, which was observed during microstructural analysis. But, the microstructural analysis is not the part of this work and will be presented in future. The matrix materials used in the present work are Al 6063, Al 6066 and Al 6351 alloys. The reinforcement materials are silicon carbide (SiC) particulates.

Present paper is organized as follows: the fabrication process of the composite is given in section 2. Section 3 gives the theory of the Vickers hardness test. Results are discussed in section 4 and section 5 concludes the paper.

*Corresponding author: Pradeep Kundu

2. Fabrication Process

A coal-fired furnace is used for melting of the Al alloy. After the specific temperature of Al melt (around 780°C); the powdered form SiC particulates were added in the melt. For homogeneous mixing of the molten phase and reinforcement phase manual stir casting method was used as shown in Fig. 1. The chemical composition for the different grades of the alloy is given in Table 1.

Table 1 Typical chemical composition for Aluminium alloys

Alloy	6063	6066	6351
Si	0.2 – 0.6	0.9-1.8	0.7-1.3
Fe	0.35	0.5	0.5
Cu	0.1	0.7-1.2	0.1
Mn	0.1	0.6-1.1	0.4-0.8
Mg	.45-0.9	0.8-1.4	0.4-0.8
Zn	0.1	0.25	0.2
Ti	0.1	0.2	0.2
Cr	0.1	0.4	-
Al	Balance	Balance	Balance

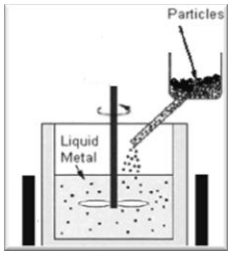

Fig.1. Charge preparation in the stir casting process (Reddy *et al*, 2010)

The SIC particles were added in the melted alloy at different percentage as shown in Table 2. The purpose of adding the SiC particles at the different percentage is to investigate how the mechanical properties of the Al vary with the % of SiC.

Table 2 Weight table of Al alloys & SiC

Material	5% Sic	7% Sic	9% Sic
Al 6063 (800 gm)	40 gm	56 gm	72 gm
Al 6066 (800 gm)	40 gm	56 gm	72 gm
Al 6351 (800 gm)	40 gm	56 gm	72 gm

After deciding the percentage of the SiC particles in Al; the mould was prepared by following the casting principle. The mould is set for the dry for one day; because wet mould can interact with the melt and can cause porosity in the composite. During experimentation, it was also found that with wet mould the perfect circular geometry will not be obtained because of sudden shrinkage. Fig. 2 shows the picture of the mould used for pouring the melting material. Now metal is melt until the temperature is reached around the 650º C-700ºC (Fig. 3). Now, SiC particulates were added inside the melt material (in % as mentioned in Table 2) and manually stirring was done for at least for half an hour until the uniform mixing of the Al melt and Sic particulates were achieved.

Fig.2. Mould prepared for pouring the melting material

Fig.3. Melting of material in crucible by hard coke

After uniform mixing, the melted material is poured into the mould (Fig. 4) and rests it for solidifying for one day. After solidification, the mould was broken and the material was put out from the mould. Fig. 5 shows the solidified piece after extracted from the mould. It can be seen from the Fig. 5 that the solidified piece are not circular at the end of the rod may be because of the not proper shrinking. But that is not an issue and can be removed during machining.

Fig.4. Pouring of melted material in the mould

Fig.5. Solidified piece

3. Vickers Hardness Test

To characterize the mechanical properties of the composite; Vickers hardness test was performed in the present work. Rest other test will be performed in the future work. The term hardness means 'Resistance to penetration'. Fig.6 shows the pictures of the sample used for the Vickers hardness test.

Fig.6. Pictorial view of sample for hardness test

For determining the hardness of metals; the penetrator was used in the form of a right pyramid with a square base. The penetrator has the specified angle between opposite faces at the vertex and forced into the metal under the application of Load 'F'. Fig. 7 shows the schematic of the Vickers hardness testing machine and Fig. 8 shows the photograph of the machine used to perform hardness testing. After removal of the load, the diagonal 'd' of the indentation left on the surface of the test place was measured. The Vickers hardness number (HV) is obtained by dividing the test load 'F' by the sloping area of indentation. The sloping area of the indentation can be obtained as:

$$A = \frac{d^2}{2\sin(136°/2)} \quad (1)$$

Vicker hardness can be determined as:

$$HV = \frac{F}{A} \approx \frac{1.8544F}{d^2} \quad (2)$$

where d is the average length of the diagonal left by the indenter in millimeters and F is in kgf

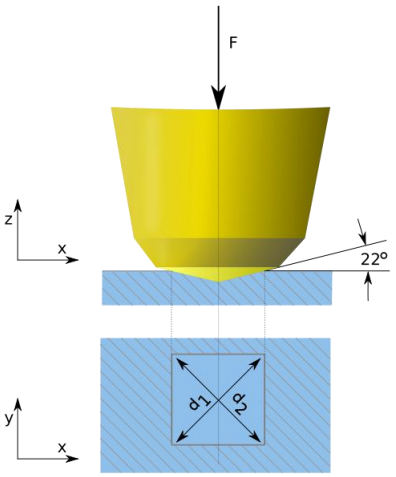

Fig.7. Vickers Test Scheme [4]

Fig.8. Vickers Hardness Testing Machine

4. Results & Discussion

Finally, when the specimen are ready with different weight percentage of the SIC; for the purpose of the design criteria the harness test was done. Generally, ingot Al 6063 hardness is 44-48 HV, ingot Al 6351 hardness is 45-49 HV and ingot Al 6066 hardness is 46-52 HV. Table 3 shows the obtained hardness value at different weight percentage of SiC. It can be seen that the reinforcement of SiC with Al ingot increase its hardness.

Table 3 Vicker Hardness table for Al metal matrix composite (HV)

Material	5% Sic	7% Sic	9% Sic
Al 6063	53.5	58.5	59.5
Al 6351	67.5	74.5	74.5
Al 6066	69.5	77.5	80.5

Table 4 represents the percentage increase in the hardness value of the composite with SiC. From the percentage hardness table, it was observed that there is the significant increment in the hardness value from 5% to 7 % in comparison of 7% to 9%. That will require further investigation and can be explained from the microstructure analysis which will be part of the future work.

Table 4 Percentage (%) increase in hardness

Material	5% Sic	7% Sic	9% Sic
Al 6063	16.3	27.17	29.34
Al 6351	44.79	52.04	52.04
Al 6066	43.61	64.89	71.27

Conclusion and Scope for Future Work

The present work explained the steps involved in the fabrication process of the Al metal matrix composite. The SiC particulates were used as a composite material for the increase in the mechanical properties of the Al. The SiC particulates were added at different weight percentage in the Al melt. From the Vickers hardness test, the hardness of the Al was found to be increased with the increment in the percentage of the SiC. The other mechanical properties also need to be investigated for the purpose of the design criteria that will be part of the future work. In addition, there is the significant amount of increment in hardness was found from 5% to 7% weight percentage of SiC in comparison of 7% to 9%. This may be because of the non-uniform mixing of the particulates inside the Al melt. This need to be further investigated and can be validated from the microstructure analysis which will be part of future work.

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