Fabrication and Mechanical Characterization of Aluminium Metal Matrix Composites Using Stir Casting

Dr. O P Upadhyay

Department of Mechanical Engineering,
M.J.P Rohilkhand University, Bareilly, U.P., India
opu_bly@rediffmail.com

Abstract

Metal Matrix Composites (MMCs) have increased use in current applications because of their better strength-to-weight ratio and high temperature resistant behavior etc. They impart the combined benefits of metals and ceramics. For the construction of Aluminium MMCs using the stir casting technique, pure Aluminum was used as the matrix, and SiC and Flyash were chosen as reinforcement materials, respectively. Mechanical tests were carried out after the manufacture of MMC samples by altering the weight fractions of SiC and Flyash (5-25%) while keeping all other parameters constant. The maximum hardness value was obtained in the case of Al +21 percent SiC, while the least value was obtained in the case of Al +7 percent SiC. Impact strength improves as percent Wt reinforcements increase, and compression test results show the similar trend.

Keywords: Aluminum, SiC, Metal matrix composites, Stir casting, Mechanical Testing

1. INTRODUCTION

Traditional monolithic materials are limited in their ability to provide a desirable balance of strength, stiffness, toughness, and density. Composites are the most promising materials of current interest for overcoming these flaws and meeting the ever-increasing demand of modern technologies. Polymer matrix, metal-matrix, and ceramic composites are examples of composite materials characterized by the physical or chemical composition of the matrix phase. When compared to unreinforced alloys, MMC has dramatically improved features such as high specific strength, specific modulus, damping capacity, and wear resistance. Particulate reinforced aluminum matrix composites are gaining popularity these days due to their low cost and benefits such as isotropic characteristics and the ability to undergo secondary processing, allowing for the manufacture of additional components.

Fly ash is one of the most affordable and low density reinforcements available in significant amounts as a solid waste by-product of coal combustion in thermal power plants, among the several discontinuous dispersoids employed. As a result, composites reinforced with fly ash are anticipated to overcome the cost barrier for widespread use in automobile and small engine applications. It permits a traditional metal processing technique to be used, lowering the product's final cost. This liquid metallurgy method is the most popular and cost-effective approach for fabrication of different types of MMC used for domestic and commercial applications.

The primary issue with this technique is that the particle dispersion is not uniform due to poor wet ability and gravity-controlled segregation. The size, shape, and volume fraction of the reinforcement, the matrix material, and the response at the interface all influence the mechanical properties of composites. Many researchers have looked into these issues. In influencing the properties of MMCs, the interaction between the matrix and reinforcement is crucial. Load transfer across the interface is required for stiffening and strengthening. The crack deflection at the interface affects toughness, while the relaxation of peak stress near the contact affects ductility. Fly ash (which primarily comprises of refractory oxides such as silica, alumina, and iron oxide) and SiC are employed as reinforcing phases in this study. The composite was made with 7%, 14%, and 21% flyash as well as SiC as a reinforcing phase. Melted and cast commercially pure Al was also used. The composite's mechanical properties were examined and compared to commercially pure Al in terms of hardness, tensile and compressive strength, and impact strength.

2. FABRICATION METHOD

Pure Aluminum has been chosen as matrix and SiC (400 mesh size) and Flyash (Procured from Century Pulp and Paper, Lalkuan) as reinforcements for fabrication of MMC by stir casting process as shown in Figure 1. Different % Wt reinforcements (5-25% by weights) were used along with pure Al. In the present study, coal fired furnace has been used. The crucible material was Graphite. A blower has also been used for supplying the required quantity of air.

Fig. 2 Experimental set-up of Stir casting

Fig. 3 Flowchart of Stir casting process

(a) (b)

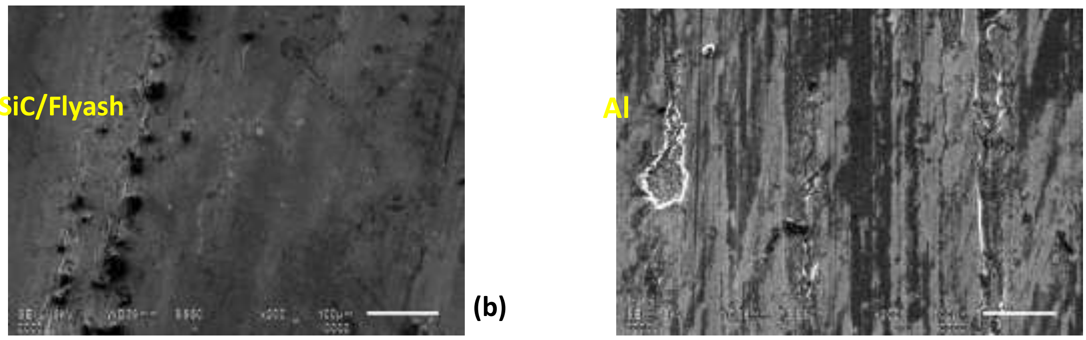

Fig. 4 (a) and (b) SEM images of MMC fabricated by stir casting process

3. MECHANICAL TESTING

Following tests were conducted to check the Mechanical behavior of fabricated Al MMC with different % weights of reinforcement (SiC and Flyash).

1. Tensile strength test
2. Compressive strength test
3. Hardness (Vicker's) test

Fig. 5 Specimen configuration for tensile strength test

Fig. 6 Specimen configuration and size for compressive strength test

4. RESULTS AND DISCUSSION

4.1 TENSILE TEST ANALYSIS

Initially for commercial aluminum, tensile strength was measured as 139.40 MPa which is 4.2% less than Al-5% SiC composite. When the percentage of SiC addition in the composite increases from 5% to 10% SiC, the corresponding increase in tensile strength of composite (i.e. Al-10%SiC) is 10.07%, with further increase in the percentage of SiC (5%), increase in tensile strength of composite (i.e. Al-15% SiC) is 7.9%. If the SiC percentage (5%) is increased further in the composite then there is reduction of tensile strength to the extent of 11.8% and 11.5% respectively. Hence, it is clear from Fig. 7 that the composite sample with 15% SiC gives the maximum tensile strength i.e. 172.54 MPa.

4.2 COMPRESSION TEST ANALYSIS

Compression test of the entire prepared specimens were also carried out on UTM. Standard compression test specimen was used which was having a diameter of 16 mm. The initial cross section (A_0) calculated was 201.06 mm^2. This cross sectional area was used to calculate compressive strength. Similar to tension test, applied load in kg_f was read on load indicator scale of UTM. The applied load was converted in Newton to calculate compressive strength. For every composition of SiC in Al, two compression test specimen were prepared and an average value was taken. Table 1 shows the results of compression test for all specimens. Maximum compressive strength value was found to be 322.85 MPa for Al-15% SiC composite material. The results of compression test are shown in Fig. 8. Similar trend has been observed in compression test results; however, the percentage increase in compressive strength is more as compared to tensile strength of sample. The percentage decrease in compressive strength is also more in compression test when the values are compared with the tensile strength of sample. From the Fig. 8, it is clear that the optimum combination of Al and SiC composite is Al-15% SiC. When the weight fraction of SiC in commercial aluminum is increased to 5%, 10% and 15%, the increase in compressive strength of composite obtained were 5.46 %, 15.3 % and 14.4 % respectively. 21.19% and 11.11% decrement in compressive strength was observed when the percentage of SiC was increased to 20% and 25% respectively.

4.3 HARDNESS TEST ANALYSIS

Hardness test was carried out on Brinell Hardness Tester. On each sample specimen, four impressions were made by steel indentor ball and diameter of each impression was predicted by Brinell microscope. Average value was taken to calculate the Hardness value in BHN. Table 1 and Fig. 9 show the results of hardness test obtained during experimentation.

Table 1. Vicker's hardness test results for different Weight % reinforcement

% wt	Load (kg)	Dia (mm)	TS	CS	Hardness
Pure Al	50, 100	0.5, 0.7	139.4	232.01	50.15
Al +5%SiC	50, 100	0.5, 0.7	145.24	244.68	68.2
Al +10%SiC	50, 100	0.4, 0.6	159.87	282.2	72.88
Al +15%SiC	50, 100	0.35, 0.4	172.54	322.85	87.1
Al +20%SiC	50, 100	0.35, 0.4	152.07	254.43	56.63
Al +25%SiC	50, 100	0.35, 0.4	134.52	226.17	42.23

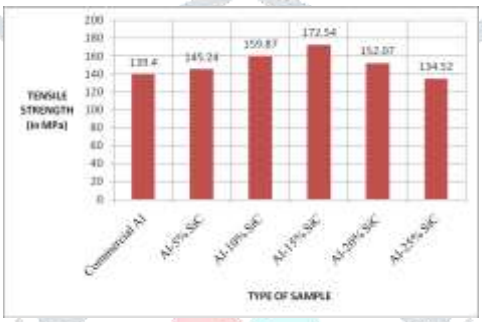

Figure 7. Tensile strength test results for different Wt% reinforcement

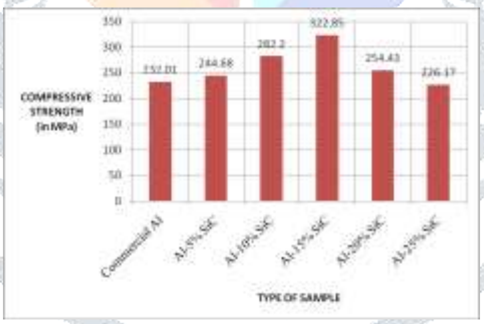

Fig. 8 Compressive strength test results for different Wt% reinforcement

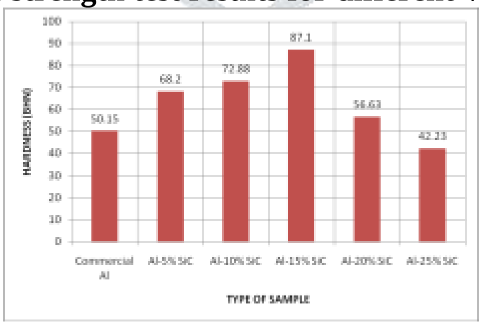

Fig. 9 Hardness test results for different Wt% reinforcement

5. CONCLUSIONS

The following conclusions can be drawn from the present work:

1. The MMC samples fabricated by stir casting shows better mechanical behavior as compared to pure Al.
2. The ultimate tensile strength increases with increase in weight percentage of SiC and Flyash in the matrix.

3. The Hardness increases after addition of SiC and Flyash particles in the matrix.
4. Impact strength increases by addition of SiC and Flyash.
5. Fly ash can be effectively used for fabrication of such types of metal matrix composites which eliminates the problem of its disposal and will reduce the problem of air pollution in the future.

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