Effect of stirring speed on mechanical properties of aluminium 6082/SiC/carbon black metal matrix

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Received 02.04.2019 received in revised form 30.09.2019, accepted 04.10.2019

Abstract: Metal matrix composites are widely used engineering materials which are replacing the conventional metallic alloys in aerospace and automobile, marine and sports industries. Among the all metal matrix composites (MMCs), aluminium based MMCs are extensively used in manufacturing fields due to its excellent properties like high strength to weight ratio and resistance to corrosion. The objective of this paper is to examine the effect of stirring speed on mechanical properties of aluminium 6082/ SiC/carbon black MMCs. The samples have been made through stirring casting process. The tensile strength, flexural strength, impact strength and hardness have been tested at various stirring speed. It has been revealed from the analysis that MMC fabricated at 800 rpm stirring speed shows optimal values of hardness (73.2 HRC), tensile strength (340 MPa), flexural strength (169.5 MPa) and impact strength (46 KJ/m^2).

Keywords: MMC, Stirring speed, SiC, Carbon black

1. INTRODUCTION

Today's manufacturing industries focus on the production of quality products at minimum cost which fulfill the need of customers. Due to global competitions, automotive and aerospace industries demand new material which fulfill all the desired properties like light weight, good strength, corrosion resistive and high wear resistance. The fabrications of Al2O3 reinforce aluminium MMC to study the impact of wt. percentage of Al2O3. Therefore, recently develop advanced materials like polymers, composites and ceramics are replacing the general metallic materials like copper, cast iron, brass etc. to increase the quality of the products. The fabrication of aluminium based MMCs using stir casting methods to examine the impact of reinforcement particulates on mechanical properties of MMCs. These can be classified into four groups: (1) metals, (2) polymers, (3) composites, and (4) ceramics. Aluminum alloys are the most widely used materials in manufacturing fields due to its excellent properties like high strength to weight ratio and resistance in corrosion. Although, aluminium alloys have some limitations to achieve combinations of desire properties according to requirement. The combination of desire properties can be achieved using MMCs. The aluminium based MMCs offer such tailored property. The properties of MMCs depend on volume fraction, shape, size, and orientation of reinforcements in metal matrix. Hence this area of interest of the researcher's increases with increasing utilization of aluminium based MMCs. A lot of research has been carried out to enhance the properties of MMCs by addition of different reinforcement [1].

2. LITERATURE REVIEW

Kaur and Pandey (2010) used spray forming technique for the development of Al/Si-Zircon reinforced composites. The result indicates that spray formed composites has been found more wear resistant as compare to Al-Si base alloy and the wear coefficient of MMCs has been found lower than the base alloy [2].

Kumar et al. [3] fabricated Al6061-SiC and Al7075- Al2O3 MMCs using liquid metallurgy technique to investigate the effect of percentage weight of SiC and Al2O3 particles on hardness, tensile strength and wear resistance properties. The addition of SiC and Al2O3 particle increases the mechanical and wears properties of MMCs [3].

Kumar et al. [4] fabricated A380/fly ash metal matrix composites using stair casting method to study the impact of fly ash on wear of MMCs. The MMCs with large fly ash particles exhibited superior wear resistance as compare to fine fly ash particulates [4].

Yusoff and Jamaludin [5] used powder metallurgy technique for the manufacturing of aluminum MMCs with slag powder having various particle sizes. The different slag particle size and compaction pressure significantly influence the surface hardness of aluminum composites [5].

Sujan et al. [6] fabricated Al/ SiC and Al/ Al_2O_3 as reinforce materials to examine the thermo mechanical properties of developed MMCs. The MMCs shows superior physical and mechanical properties as compare to base material [6].

Shirvanimoghaddam et al. [7] investigated the effect of processing temperature and inclusion of micron-sized B_4C, TiB_2 and $ZrSiO_4$ on the mechanical performance of aluminum based MMCs. The hardness and tensile strength of MMCs have been found to be higher than monolithic aluminum [7].

Ghasali et al. [8] fabricated Al/SiC/TiC MMCs with two type's aluminum powders (pure and 1056). The highest relative density, bending strength and micro-hardness have been obtained with Al 1056 sintered at 750°C [8].

Kandpal et al. [9] fabricated Al_2O_3 reinforce aluminium MMC to study the impact of wt. percentage of Al_2O_3 on mechanical properties and microstructure of fabricated MMCs. The Al_2O_3 particles distributed homogeneously in the aluminium matrix. Also, clusters of Al2O3 particles were found in few places [9].

Parswajinan et al. [10] fabricated Al/SiC/ Carbon Nanotubes based MMCs using stir casting method to investigate the impact of % weight of reinforcement on mechanical properties of MMCs. It has been revealed that addition of SiC particulates increases the hardness of the MMCs and hardness of MMCs increases with increase in % weight of SiC in MMC [10].

A number of studies have been conducted to investigate the effect of weight percentage of reinforced particles on mechanical properties. Very few studies have been found to investigate the effect of stirring speed on mechanical properties. The Al 6082 alloy is a structural alloy with excellent corrosion resistance. It has the highest strength of the 6000 series alloys. Due to higher strength, it replaced alloy 6061 in many applications. It is mostly employed for machining purpose, for the fabrication of highly stressed application, trusses, bridges, cranes, beer barrels etc. In the present work, an attempt has been made to investigate the effect of stirring speed on mechanical properties of Al 6082/SiC/Carbon black MMCs.

3. FABRICATION OF MMCs

This section discusses on the fabrication of Aluminium MMC using automatic stir casting. Here aluminium 6082 alloy is reinforced with 5% Silicon Carbide and 4% Carbon Black. Besides this, 1% magnesium is added in all MMCs. Magnesium increases wetting between the reinforcement and the matrix alloy during the fabrication of MMC. With addition of Carbon black in MMC, initially tensile strength, flexural strength, impact strength and hardness increase with increase in percentage weight of carbon black. This is due to the increase in bonding surface area between the matrix and reinforcement, which increases the ductile nature of the MMCs. Also, carbon black particulates control the transfer and distribution of load from one place to another place in the MMC, which further increase mechanical properties. In addition to this, the carbon black particulates behave as an obstacle for the stress transfer from one place to another which further increases the mechanical properties. The MMCs have been fabricated using same weight percentage of ingredients but at different stirring speeds. Three MMCs are fabricated with stirring speed of 600, 800 and 1000 respectively. Table 1 shows the fabricated MMCs Al 6082 5% SiC 4% Carbon Black at different rotational speed for the present work.

In literature [11] the chemical composition of Al 6082 alloy is shown in Table 2.

Table 1 : Design matrix for the fabrication of MMCs at different rotational speed

MMCs Designation	SiC(wt %)	Carbon Black (wt %)	Al 6082(wt %)	Magnesium(wt %)	Rotational speed (RPM)
Al/5SiC/4CB/600	5	4	90	1	600
Al/5SiC/4CB/800	5	4	90	1	800
Al/5SiC/4CB/1000	5	4	90	1	1000

Table 2 : Chemical composition of alloy Al 6082

Cu	Mg	Si	Fe	Zn	Ti	Cr
0.06	0.77	0.95	0.32	0.016	0.037	0.038

Fig. 1 shows the sample rod of Al 6082 alloy.

Figure 1: Sample rod of Al 6082 alloy

Figure 2 shows the setup of stirring casting machine for fabrication of MMCs.

Figure 2 : Setup of stirring casting machine for fabrication of MMCs

Figure 3: Rockwell cum Hardness tester

4. EQUIPMENTS USED FOR TESTING

The Rockwell hardness test for the measurement of hardness of all fabricated MMCs has been carried out according to ASTM: E-18 standard using Rockwell cum Brinell hardness tester machine (Fig. 3), manufactured by Engineering models and equipment, Roorkee, India.

The tensile strength and flexural strength of all fabricated MMCs have been measured using universal testing machine manufactured by Engineering Models and Equipment, Roorkee. The tensile tests have been conducted at constant crosshead speed of 1 mm/min. The flexural strength of the fabricated composites is computed using three-point bending method on UTM. The flexural tests have been also performed at constant crosshead speed of 1 mm/min. The applied load and cross-head displacements have been recorded for the measurement of flexural strength using equation 1. The testing setup is shown in Figure 4.

Figure 4: Universal testing machine

Figure 5: Impact testing machine

$$F.S = \frac{3PL}{2bt^2} \qquad (1)$$

where, P = Maximum load; b= Width of specimen; t= Thickness of the specimen; L = Span length of the sample.

The impact strength of all fabricated MMCs has been measured using Izod impact tester, manufacturer by Engineering models and equipment, Roorkee as shown in fig. 5.
The impact strength of the specimen is calculated as:

$$I = \frac{K}{A} \qquad (2)$$

where, I = Impact strength; K = Impact energy; A = cross section area.

5. EFFECT OF STIRRING SPEED ON MECHANICAL PROPERTIES

As mention earlier, initially, three MMCs have been fabricated using same weight percentage of ingredient but at different stirring speed. After that mechanical testing (hardness, tensile, flexural and impact strength) have been carried out on these specimens for the identification of best stirring speed for the fabrication of MMCs.

5.1 Rockwell hardness

The wear behavior of any material depends on its hardness. So, for the improvement of wear resistance of the material, it is required to improve the hardness of the material.

Table 3 : Hardness of MMCs at different stirring speed

Composite Designation	Sample 1(HRC)	Sample 2 (HRC)	Average (HRC)
Al/5SiC/4CB/600	71.4	71.8	71.6
Al/5SiC/4CB/800	73.6	72.8	73.2
Al/5SiC/4CB/1000	70.6	71.2	70.9

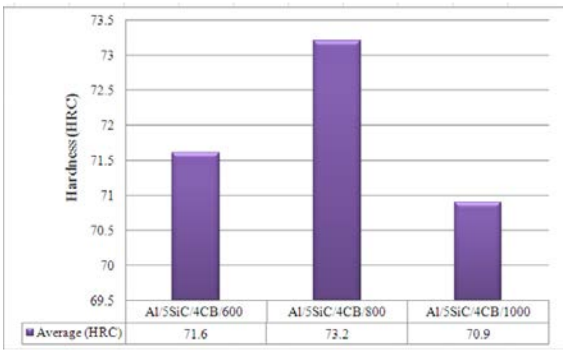

Figure 6 : Bar chart for hardness MMCs fabricated at different stirring speed

Fig. 6 revealed that hardness of the MMCs initially increases with increase in stirring speed from 600 rpm to 800 rpm. Further increases in stirring speed from 800 rpm to 1000 rpm, decreases the hardness of the MMC. This is due to the distribution of reinforce particulates in the matrix. The hardness of the MMCs increases with increase in homogeneous distribution of particulates in the MMCs. At low stirring speed, non-homogeneous distribution of reinforced particulates take place due to clustering of reinforced particulates in some localized region in the matrix. The inter-particle distance increases with increase in stirring speed. This increases the homogeneous distribution of reinforce particulates in the matrix. On the other hand, at very high stirring speed, reinforced particulates flow near the surface of the MMC due to circumferential force. This increases the clustering of particulates near the surface of MMC. Hence, non-uniform distribution of reinforce particulate increases with increase in stirring speed beyond a particular speed. The maximum hardness of MMCs has been obtained at 800 RPM.

5.2 Tensile strength

The tensile strength of any material depends on the resistance offer by material to withstand a load in tension and the resistance offer by MMCs under tensile loading is directly proportional to the bonding between the reinforcement and the matrix. The bonding between the matrix and reinforcement particulates depends on the homogeneous distribution of reinforcement particulates in the matrix.

Table 4 shows the tensile strength of two specimens along with the average value of tensile strength of fabricated MMC. The tensile test has been conducted at constant crosshead speed of 1 mm/min.

Table 4 : Tensile strength of MMCs at different stirring speed

Composite Designation	Sample 1 ultimate tensile strength (MPa)	Sample 2 ultimate tensile strength (MPa)	Mean of ultimate tensile strength(MPa)
Al/5SiC/4CB/600	326	321	323.5
Al/5SiC/4CB/800	338	342	340
Al/5SiC/4CB/1000	315	311	313

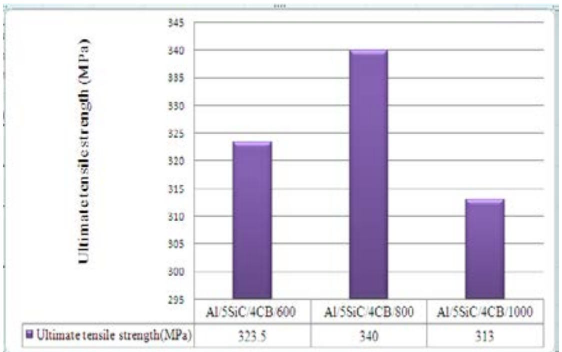

Figure 7:Bar chart for tensile strength MMCs fabricated at different stirring speed

The Figure 7 shows the bar chart for the average value of tensile strength of fabricated MMCs.

From the figure, it has been revealed that initially tensile strength of MMCs increases with increase in stirring speed from 600 rpm to 800 rpm, due to the distribution of particulates in partial homogeneous way after that it decreases with further increase in stirring speed from 800 rpm to 1000 rpm This is mainly due to the formation of clusters due to the collision of the particulates because of the higher speed.

5.3 Flexural strength

The flexural test is used for the identification of the bending strength of the material. The flexural strength of the fabricated composites is computed using three-point bending method on UTM. The flexural tests have been conducted at constant crosshead speed of 1 mm/min.

The flexural test has been conducted on two samples of each MMC. Finally, the mean of two values of flexural strength is considered as flexural strength for that MMC. The Table 5 shows the flexural strength of fabricated MMCs along with the average value of flexural strength for each MMC, while Figure 8 shows the graphical representation of average value of flexural strength for fabricated MMCs. Form the figure it has been revealed that flexural strength of the MMCs initial increases with increase in stirring speed from 600 rpm to 800 rpm, further increase in stirring speed from 800 rpm to 1000 rpm decreases the flexural strength.

Table 5 : Flexural strength of MMCs at different stirring speed

Composite Designation	Flexural strength (MPa) Sample 1	Flexural strength (MPa) Sample 2	Average Flexural strength (MPa)
Al/5SiC/4CB/600	152	164	158
Al/5SiC/4CB/800	171	168	169.5
Al/5SiC/4CB/1000	157	166	161.5

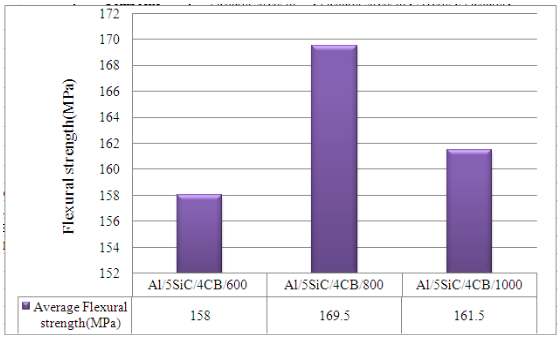

Figure 8 : Bar chart for flexural strength MMCs fabricated at different stirring speed

The flexural strength depends on the bonding between the matrix and reinforcement. The bonding increases with increase in homogeneous distribution of reinforcement particulates in the matrix. At low stirring speed, weak bonding has been exhibited due to clustering of reinforced particulates in some localized region in the matrix. The bonding between the matrix and reinforcement particulates increases with increase in stirring speed up to the optimum speed. It is due to increase in inter-particle distance. This increases the homogeneous distribution of reinforce particulates in the matrix. Further increase in stirring speed decreases the bonding. It is due to flow of reinforced particulates near the surface of the MMC because of the circumferential force. This increases the clustering of particulates near the surface of MMC. Hence, non-uniform distribution of reinforce particulate increases with increase in stirring speed beyond the particular speed.

5.4 Impact strength

The energy absorbed per unit area by the material before fracture under sudden and dynamic application of the load is called Impact strength. It gives the value of toughness of the material that is capability of a material to absorb energy before rupture. Table 6 shows the impact strength of fabricated MMCs along with the average values of impact strength of MMCs. The figure 4shows the graphical representation of average impact strength of fabricated MMCs. Form the analysis of figure, it has been revealed that impact strength of the MMCs initial increases with increase in stirring speed from 600 rpm to 800 rpm, further increase in stirring speed from 800 rpm to 1000 rpm decreases the impact strength.

Table 6 : Impact strength of MMCs at different stirring speed

Composite Designation	Impact strength (kJ/m^2) Sample 1	Impact strength (kJ/m^2) Sample 1	Mean of Impact strength (kJ/m^2)
Al/5SiC/4CB/600	44	42	43
Al/5SiC/4CB/800	45	47	46
Al/5SiC/4CB/1000	38	42	40

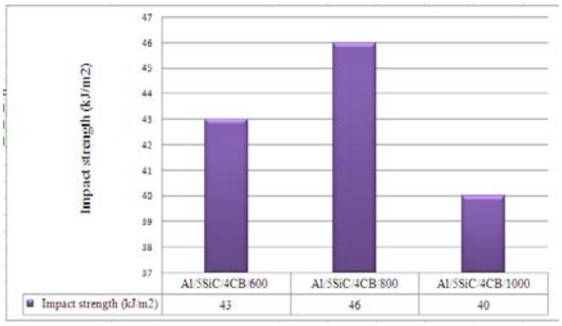

Figure 9:Bar chart for impact strength MMCs fabricated at different stirring speed

From the analysis of mechanical properties of fabricated MMCs, it has been revealed that MMC fabricated at 800 rpm exhibits superior mechanical properties.

The bonding between the matrix and reinforcement particulates increases with increase in stirring speed up to the optimum speed. It is due to increase in inter-particle distance. This increases the homogeneous distribution of reinforce particulates in the matrix.

Further increase in stirring speed decreases the bonding between matrix and reinforcement particulates. It is due to flow of reinforced particulates near the surface of the MMC because of the circumferential force. This increases the clustering of particulates near the surface of MMC. Hence, non-uniform distribution of reinforce particulate increases with increase in stirring speed beyond the particular speed.

Al/5SiC/4CB/800 shows the excellent mechanical properties (hardness, tensile strength, flexural strength and impact strength). The results obtained are in line with the existing studies on Aluminium MMCs [9] and [10].

4. CONCLUSION

The Al 6082 alloy is a structural alloy with excellent corrosion resistance. It is mostly employed for machining purpose, for the fabrication of highly stressed application, trusses, bridges, cranes, beer barrels etc. Therefore, study on this aluminium alloy will be quite useful. Accordingly, the main objective of this study is to examine the effect of stirring speed, on mechanical properties of aluminium 6082/ SiC/carbon black MMCs. It can be concluded that Al/5SiC/4CB/800 shows the excellent mechanical properties (hardness, tensile strength, flexural strength and impact strength) among the fabricated Al/5SiC/4CB/600, Al/5SiC/4CB/800 and Al/5SiC/4CB/1000 MMCs, which indicates that MMC fabricated at 800 rpm stirring speed shows excellent mechanical properties. Distribution of the reinforcement is so homogeneous that leads to exhibit a total improvement in both tensile strength and hardness of the composite.

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