Experimental Study on Mechanical and Tribological Properties of Aluminium Alloy 7075 Reinforced with Silicon Carbide and Fly-Ash, Hybrid Metal Matrix Composites Using Sem, Taguchi Method and Genetic Algorithm

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Abstract— *Aluminium based metal matrix composites (MMCS) are advanced materials having the properties of high specific strength and modulus, greater resistance, high elevated temperature and low thermal expansion co efficient. These composites are widely used in industries like aerospace, defense, automobile, biomaterials as well as sports etc. The mechanical and metallurgical properties of aluminum alloy 7075 metal matrix composite were investigated. The composite were prepared using the stir casting technique. The composite contains aluminium alloy 7075 reinforced with silicon carbide and flyash respectively. Composites are fabricated through 'Stir Casting Method'. Mechanical properties such as Tension, Hardness, and Wear test of the samples are measured and validated by using Taguchi and Genetic algorithm methods. The tested samples are examined using Scanning Electron microscope (SEM) for the characterization of microstructure on the surface of composites. The results of the research work shows that the proposed Hybrid composites are compared with Al based metal matrix composites at corresponding values of test parameters.*

Keywords— AA 7075, SiC, Fly ash, Metal matrix composites; stir casting; process parameter, Taguchi, SEM, Genetic algorithm

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1. INTRODUCTION (*HEADING 1*)

Automobile, Aeronautical industry or ship building industry are associated with continuous searching for materials with low density, low specific gravity, high stiffness and specific strength, materials which preserve tensile and compression strength at high temperature. Among aluminium alloy AA7075is a popular choice for matrix material. It is primarily due to it has good mechanical properties, weldability and formability characteristics. It contains magnesium and zinc as its major alloying elements.

AMC can be fabricated in various methods based on its end product use. Liquid-phase infiltration of MMCs is not straightforward, mainly because of difficulties with wetting the ceramic reinforcement by the molten metal.

2. MATERIAL SELECTION

Pure form of aluminium is soft in nature. Therefore the tensile strength, hardness strength is usually low. In order to have wide range of mechanical properties small amount of alloying element are added to the pure form of aluminium.

A. Al 7075

Aluminum alloy 7075 is an aluminum alloy with zinc as the primary alloying element. Aluminium alloy 7075 is a high strength alloy commonly referred to as an architectural alloy. It is normally used in intricate extrusions. It has a good surface finish; high corrosion resistance is readily suited to welding and can be easily anodized.

B. Silicon carbide

Silicon carbide has the density close to aluminum and is best for making composite having good strength and good heat conductivity. It occurs in nature as the extremely rare mineral moissonite. Silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plate in bulletproof vests.

C. Fly ash

Fly ash particles (usually of size 0-100micron) which are extracted from residues generated in the combustion of coal can be used as reinforcement material. As Fly ash has low density, chances of having good wetability between fly ash & matrix Al alloy. Particulate reinforced aluminium matrix composite are gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing. The high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight composites. Also production of Al may be significantly reduced by fly ash substitution.

3. FABRICATION OF MMC

The Al/SiC-Flyash metal matrix composite was manufactured by stir casting process. First, the Al matrix material was melted in resistance heated furnace in a graphite crucible and liquid metal heated to 800ºC. Next, SiC and Flyash are pre-heated to 400oC were added into molten aluminium material by means of argon gas flow with rate of 20 g/min.

Figure 1 Stir casting Setup

During the processes, the molten matrix and SiC-Flyash were stirred by a mixture with 750rev/min. When the temperature of the matrix material decreased to near the melting point, which makes the stirring process hard, the process was stopped, but the matrix material was heated again up to 800oC to ensure the homogeneity of the mixture.

4. RESULTS AND DISCUSSIONS

A. *Testing Mechanical Properties*

The Al/SiC-Flyash metal matrix composite was manufactured by stir casting process and the following test was conducted.

1 Tensile Test

2 Hardness Test

3 Wear Test.

1) Tensile Test: Tensile tests were used to assess the mechanical behavior of the composites and matrix alloy. By following the ASTM E8 standard tensile specimens with a diameter of 6 mm and gauge length of 30 mm are prepared Ultimate tensile strength (UTS), often shortened to tensile strength (TS) or ultimate strength, is the maximum stress that a material can withstand while being stretched or pulled before necking, which is when the specimen's cross-section.

Table 3 Tensile Tests Results

Materials	Aluminium 7075 + Silicon Carbide+ Flyash		
Specimen no	Flyash Mixture (%)	Sic Mixture (%)	Tensile strength (MPa)
1	**0**	**0**	**212.0**
2	1	0	146.2
3	1	0.5	200.0
4	1	1	192.5
5-	1	1.5	185.2
6	2	0	195.7
7	3	0	178.2
8	3	0.5	155.4
9	3	1	158.8
10	3	1.5	162.9
11	4	0	171.4
12	5	0	134.7
13	5	0.5	151.5
14	5	1	156.6
15	5	1.5	126.4
16	5	4	169.4
17	6	0	199.9
18	10	0	189.6
19	15	0	166.4

2) Hardness Test: The Micro-Vickers hardness values of the specimens were measured on using diamond cone indentor with a load of 100gms and 15 seconds as a holding time.

Table 4 Hardness Tests Results

Materials	Aluminium 7075 + Silicon Carbide+Flyash		
Specimen no	Flyash Mixture (%)	Sic Mixture (%)	Vickers Hardness (HV)
1	0	0	96
2	1	0	108
3	1	0.5	112
4	1	1	109
5	1	1.5	105
6	2	0	105
7	3	0	105
8	3	0.5	104
9	3	1	104
10	3	1.5	101
11	**4**	**0**	**113**
12	5	0	112
13	5	0.5	109
14	5	1	104
15	5	1.5	100
16	5	4	96
17	6	0	95
18	10	0	92
19	15	0	89

3) Wear Test: The wear specimens were manufactured with a diameter of 8 mm and a height of 30 mm. The ends of the specimens were sequentially polished with abrasive paper of grades 600, 800 and 1000 prior to the wear tests. Dry sliding wear tests were performed in accordance with the ASTM G99-05 test standards.

Table 4 Wear Rate for SiC composite

A	B	C	wear rate (μm)	SN-Ratio
30	**1.2**	**10**	**209**	**-46.4029**
30	1.4	12	442	-52.9084
30	1.6	14	959	-59.6364
50	1.2	12	180	-45.1055
50	1.4	14	1000	-60.0000
50	1.6	10	1191	-61.5182
60	1.2	14	956	-59.6092
60	1.4	10	615	-55.7775
60	1.6	12	440	-52.8691

Table 5 Friction Force for SiC composite

A	B	C	Friction Force	SN-Ratio
30	1.2	10	9.1	-19.1808
30	**1.4**	**12**	**9**	**-19.0849**
30	1.6	14	13.5	-22.6067
50	1.2	12	7.1	-17.0252
50	1.4	14	9.5	-19.5545
50	1.6	10	12.3	-21.7981
60	1.2	14	13	-22.2789
60	1.4	10	12.6	-22.0074
60	1.6	12	13.7	-22.7344

B. Genetic Algorithm

The Genetic Algorithm is based on the process of Darwin's Theory of Evolution. By starting with a set of potential solutions and changing them during several iterations the Genetic Algorithm hopes to converge on the most 'fit' solution. The process begins with a set of potential solutions or chromosomes (usually in the form of bit strings) that are randomly generated or selected. The entire set of these chromosomes comprises a population. The chromosomes evolve during several iterations or generations. New generations (offspring) are generated using the crossover and mutation technique. Crossover involves splitting two chromosomes and then combining one half of each chromosome with the other pair. Mutation involves flipping a single bit of a chromosome. The chromosomes are then evaluated using a certain fitness criteria and the best ones are kept while the others are discarded. This process repeats until one chromosome has the best fitness and thus is taken as the best solution of the problem

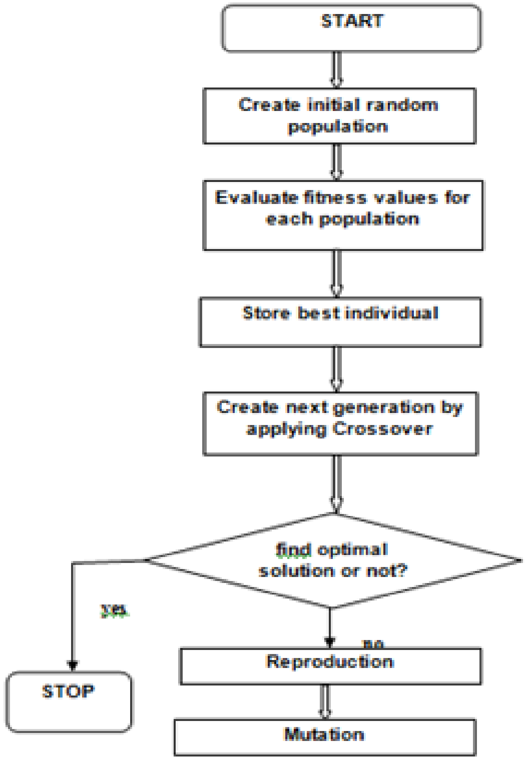

Figure 6 Flowchart of GA

Optimum Wear from GA

Load 30.0016N,Speed 1.20006m/s, Time 13.84093 Min, Optimum Wear: 457.7788

Optimum Friction force from GA

Load 30.00377N,Speed 1.200232m/s, Time 12.8091 Min, Optimum friction force: 9.925N

Regression Equations:

(i) For Tungsten carbide:

Wear Rate = 389 + 6.9 * x(1)- 222 * x(2) + 3.38 * x(3);

Friction factor = 11.2 + 0.630 * x(1)- 9.13 * x(2)+ 0.1008 * x(3);

(ii) For Silicon Carbide:

Wear Rate = -341 + 9.3 * x(1)+ 467 * x(2) - 2.92 * x(3);

Friction factor = -6.05 + 0.167 * x(1)+ 8.58 * x(2)+ 0.0669 * x(3);

C. Testing Metallurgical Properties

The Al/SiC-Flyash metal matrix composite was manufactured by stir casting process and the following test was conducted.

1) Scanning Electron Microscope : SEM morphology of the worn out surfaces formed during dry sliding wear in the steady state regime gives an important tool for accurate determination of the wear behaviour of the composites.

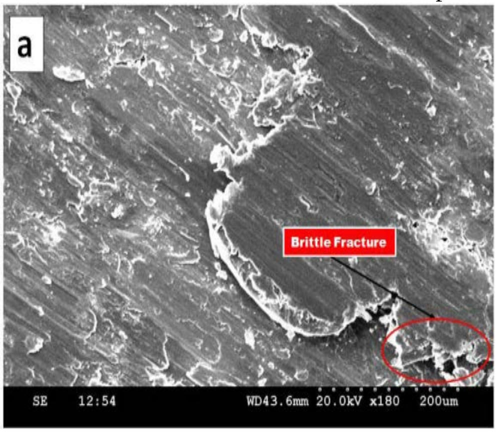

Figure 2 SEM morphologies of the worn surface of AA 7075 matrix at applied load of 20 N. (a) Low-magnification micrograph

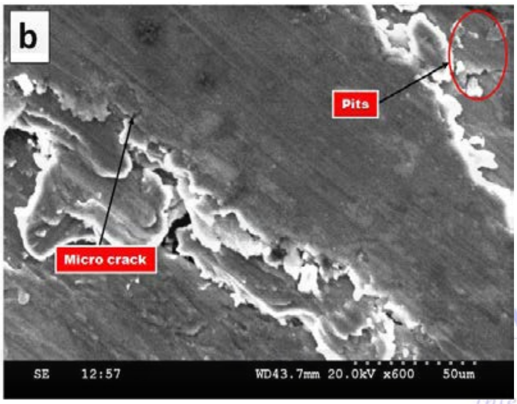

Figure 3 SEM morphologies of the worn surface of AA 7075 matrix at applied load of 20 N. (b) high-magnification micro graph

5. CONCLUSION

The conclusions drawn from this study are summarized as follows:

- AA 7075, Al-SiC, Al-Flyash, Al-SiC-Flyash composites using micro level powders have been successfully developed by Stir casting technique.
- As the weight percent of the flyash increased the hardness of the hybrid composite dropped down drastically with 3% weight and increased gradually on the addition of 5% weight of flyash.
- Similarly, the hardness of the hybrid composite with silicon carbide as reinforcement tends to increase with the addition of 1% weight of flyash and a consistent drop was observed as the weight percent of flyash increases.
- Contrarily, as the weight percent of flyash is increased with 3 and 5 percents, the tensile strength tends to decrease gradually.
- On the other hand, with the addition of Silicon carbide as reinforcement along with flyash, the tensile strength of the hybrid composite drops initially with 1% weight of flyash and as the weight percent of the flyash is increased with the different proportions of silicon carbide the tensile strength tends to increase gradually.
- Contrarily, with the increase in the addition of fly ash along with Silicon carbide, there is a slight improvement in the tensile strength of the composite material.
- The Taguchi analysis for wear rate in SiC composite based on smaller the better combination shows that the speed that is taken majorly contributes and causes increase in wear rate. The wear rate contribution of SiC composite is clearly evident from the output graph.
- The Taguchi analysis for friction force in SiC composite based on smaller the better combination shows that again the speed that is taken majorly contributes and causes increase in friction force. The friction force contribution of SiC composite is clearly evident from the output graph.

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