Research on wear Behavior of LM-25 hybrid Metal Matrix Composite

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Abstract-*In current industrial scenario composite material has lot of Scope due to its Mechanical properties like hardness, toughness, Compressive strength& tensile strength and Wear properties. Conventional monolithic materials have limitations with respect to Composite material. Development of hybrid metal matrix composites has become an important area of research interest in Material Science. Aluminum alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys. The aim of the present Case study investigation is provide the detailed review on effect of hybrid reinforcement on wear behavior of aluminum matrix composite.*

The Case study deals with the fabrication of aluminum based hybrid metal matrix composite and then characterized wear properties. To achieve this objective stir casting technique has been adopted. The overview indicates that the developed method is quite successful in the value of wear strength with increase in weight percentage of reinforcement.

Keywords-Metal Matrix composites, Aluminium alloy, wear strength, reinforcement, etc.

I. INTRODUCTION

In current industrial scenario composite material has lot of Scope due to its Mechanical properties like hardness, toughness, Compressive strength& tensile strength. Conventional monolithic materials have limitations with respect to Composite material. Development of hybrid metal matrix composites has become an important area of research interest in Material Science. Aluminum alloys are widely used in aerospace and automobile industries due to their low density and good mechanical properties, better corrosion resistance and wear, low thermal coefficient of expansion as compared to conventional metals and alloys.

Composite material is defined as the material which has two or more distinct phases like matrix phase and reinforcing phase and having bulk properties significantly different from those of any of the constituents present in the matrix material. Many of common materials also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents. Favorable properties of composites materials are high stiffness and high tensile strength, low density, high temperature stability, and also in some of the applications electrical and thermal conductivity properties are also taken into consideration, the properties like coefficient of thermal expansion, corrosion resistance should be low with improved wear resistance. By keeping all these parameters in mind the metal matrix composites are being produced. Improved mechanical properties can be incorporated in Metal Matrix Composites very easily. That is the reason why these MMC materials are getting more attention in recent years.Before preparing the aluminium alloy (LM25) metal matrix composite material I have studied some papers in which the addition of Fly ash and Al2O3 has been made and mechanical properties were studied. Few of them are as follows.

1.1 Wear behavior

Wear behavior of different composite was studied with different parameter like sliding velocity and applied loads.Aluminium alloy(LM25) based Fly ash and Alumina particulate metal matrix composites fabricated using stir casting technique by varying the volume fraction of Fly ash and Alumina (4%,8%,12%).The tribological properties are considered to be one of the major factors controlling the performance. The tribological properties of aluminium alloy matrix composites reinforced with short steel fibers prepared by Stir casting have been investigated [10]. In this case, the wear rate and coefficient of friction was determined using pin-on-disc type apparatus by varying the applied load from 10-30 N with a constant sliding velocity of 1.8m/s and a sliding distance of 2000 m. A Numerical analysis of pin on disc tests on LM25–Alumina/SiC composites at different loads and temperature has been reported [11] .

Figure no.1Pin on Disc apparatus

1.2 Wear Behaviour

A pin on disc test apparatus was performed to determine the sliding wear characteristics of the composite. Specimens of size 5 mm diameter and 30 mm length were cut from the cast samples, machined and then polished. The contact surface of the cast sample (pin) has to be flat and will be in contact with the rotating disk. During the test, the pin is held pressed against a rotating EN32 steel disc (hardness of 65HRC) by applying load that acts as counterweight and balances the pin. A LVDT (load cell) on the lever arm helps determine the wear at any point of time by monitoring the movement of the arm. Once the surface in contact wears out, the load pushes the arm to remain in contact with the disc. This movement of the arm generates a signal which is used to determine the maximum wear and the coefficient of friction is monitored continuously as wear occurs.

Table 1 Process parameters and levels

Level	L (N)	S (m/s)	D (m)
1	**10**	**.3534**	**636**
2	**20**	**.7068**	**1272**
3	**30**	**1.0629**	**1902**

L=Load(N),S=Sliding velocity(m/s),D=sliding Distance (m)

The aim of the experimental plan is to find the important factors and combination of factors influencing the wear process to to achieve the minimum wear rate and coefficient of friction.

The experiments were developed based on an orthogonal array, with the aim of relating the influence of sliding speed, applied load and sliding distance. These design parameters are distinct and intrinsic feature of the process that influence and determine the composite performance.

1.3 Results of Statistical Analysis of Experiments

The results for various combinations of parameters were obtained by conducting the experiment as per Taguchi's L9 Orthogonal array. The measured results were analysed using the commercial software MINITAB 16 specifically used for design of experiment applications. Table 4 shows the experimental results average of two repetitions for wear rate and Coefficient of friction.

1.4 Analysis of Variance Results for Wear Test

The experimental results were analysed with regression which is used to investigate the influence of the considered wear parameters namely, applied load, sliding speed, and sliding distance that significantly affect the performance measures. By performing Regression, it can be decided which independent factor dominates over the other and the percentage contribution of that particular independent variable. Table 2 and 3 show the Regression results for wear and coefficient of friction for three factors varied at three levels and interactions of those factors.

Table 2 Orthogonal array and results of HMMC.

Exp.no	%	L	N	S	D	W	C
1	4	10	150	.3534	636	.000246	0.386
2	4	20	300	.7068	1272	.0000941	0.375
3	4	30	450	1.0629	1902	.0000538	0.350
4	8	10	300	.7068	1272	.0001144	0.462
5	8	20	450	1.0629	1902	.0000821	0.422
6	8	30	150	.3534	636	.0000881	0.559
7	12	10	450	1.0629	1902	.0000079	0.490
8	12	20	150	.3534	636	.0001503	0.524
9	12	30	300	.7068	1272	.0000714	0.498

W=Wear ,C=Coefficient of Friction

This analysis is carried out for a significance level of α=0.05, i.e. for a confidence level of 95%. Sources with a P-value less than 0.05 were considered to have a statistically significant contribution to the performance measures. In

Table 2 and 3, the last column shows the percentage contribution (Pr) of each parameter onthe total variation indicating their degree of influence on the result.

Table 3 Orthogonal array and results of HMMC.

Sr.no	R	L	N	W
1	4	10	150	81
2	4	20	300	120
3	4	30	450	160
4	8	10	300	97
5	8	20	450	168
6	8	30	150	88
7	12	10	450	96
8	12	20	150	94
9	12	30	300	140

Table 4 Analysis of Variance for wear rate (mm3/Nm)

Source	DF	Seq SS	P	Regression coefficient
				34
R	**1**	**160.2**	0.539	-1.29
L	**1**	**2166**	0.06	1.9
S	**1**	4320.2	0.019	-0.17889
Residual error	**5**	**5486**		
Total	**8**			

S = 19.181 R-Sq = 78.3% R-Sq(adj) = 65.3%

The adequacy of developed models were tested using analysis of variance (ANOVA) technique and the results of second-order response model fitting in the form of ANOVA is given in Table 4. The determination coefficient (R2) indicates the goodness of fit for the model. In this case, R2 value for wear is 78.3 % after considering significant factors. The value of adjusted determination coefficient, adjusted R2 = 65.3% is also high, which indicates a high significance of the model. Lack of fit is insignificant and therefore indicates that these models fit well with the experimental data.

1.5 Main Effects plot for Means –Wear

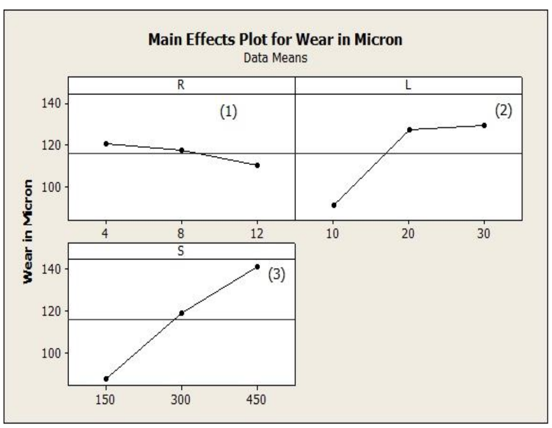

Fig.2 Main Effects plot for Means -Wear

It can be observed from Fig 2, that the speed of disc (S) and applied load has the highest influence on Wear. First graph shows that when the reinforcement increases wear of Composite material decreases .second graph shows that when the load increases wear of Composite material increases. Third graph shows that when the speed increases wear of composite material increases.

Table 5 Analysis of Variance for wear rate (mm3/Nm)

Sr.no	R	l	N	COF
1	4	10	150	0.3859
2	4	20	300	0.37487
3	4	30	450	0.350123
4	8	10	300	0.4621
5	8	20	450	0.4215
6	8	30	150	0.5585
7	12	10	450	0.49
8	12	20	150	0.5244
9	12	30	300	0.498

Table 6 Analysis of Variance for Co-efficient of friction

Source	DF	Seq SS	P	Regression coefficient
Constant	-	-	0.001	0.36406
R	1	0.026868	0.007	0.016729
L	1	0.000785	0.490	0.001144
S	1	0.007154	0.074	-0.0002302
Residual error	5	0.007066		
Total	8			

S = 0.0375929 R-Sq = 83.1% R-Sq(adj) = 73.0%

it can be observed from above table that reinforcement factor has significant effect on Coefficient of friction because Value of P is .007 as per Confidence level value should be .05 or less than that. And second factor Speed of disc has little effect on co-efficient of friction.

The adequacy of developed models were tested using analysis of variance (ANOVA) technique and the results of second-order response model fitting in the form of ANOVA is given in Table 6 . The determination coefficient (R2) indicates the goodness of fit for the model. In this case, R2 value for Co-efficient of friction is 83.1% percent after considering significant factors. The value of adjusted determination coefficient, adjusted R2 = 0.73 is also high, which indicates a high significance of the model. Lack of fit is insignificant and therefore indicates that these models fit well with the experimental data.

1.6 Main Effects plot for Means –coefficient of friction

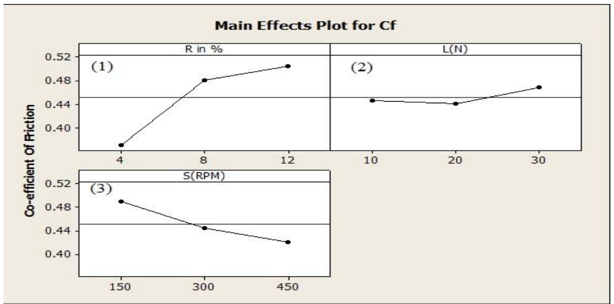

Fig.3 Main Effects plot for Means –Coefficients of Frictions

It can be observed from Fig 3, that the speed of disc (S) and applied load has the highest influence on COF. First graph shows that when the reinforcement increases COF of composite material increases .second graph shows that when the load increases COF of composite material increases. Third graph shows that when the speed increases COF of composite material decreases.

II. MULTIPLE LINEAR REGRESSION MODELS

A multiple linear regression model is developed using statistical software “MINITAB R16”.This model gives the relationship between an independent / predictor variable and a response variable by fitting a linear equation to observed data. Regression equation thus generated establishes correlation between the significant terms obtained from ANOVA analysis, namely, applied load, reinforcement, speed of disc and their interactions.

The regression equation developed for wear is

$$W=34.7-1.29R+1.9L+1.79S \qquad (1)$$

Where R= reinforcement
L=Load (N)
S=Speed of Disc (RPM)

The regression equation developed for coefficient of friction is

$$C=0.364+0.0167R+0.00114L-0.000230S \qquad (2)$$

Where R= reinforcement
L=Load (N)
S=Speed of Disc (RPM)

From Eq(1) and Eq(2), it is observed that the speed of Disc (sliding speed)plays a major role on Wear and coefficient of friction followed by applied load and sliding distance. So the important factor affecting the dry sliding wear behaviour is speed of Disc. It can also be inferred from the Eq(1) and Eq(2) that the negative value of the co-efficient of speed reveals that increase in sliding speed decreases the Wear and coefficient of friction. This can be attributed to the oxidation of Aluminium alloy, which forms an oxide layer at higher interfacial temperature thus preventing the sliding, thereby by decreasing the wear and coefficient of friction and a similar behaviour has been observed [15].

The effect of applied load is directly proportional to Wear, i.e., as applied load increases, wear also increases. The positive coefficient of load indicates that dry sliding wear of the composite decreases by increasing load. This is because, the temperature at the interface between the disc and the pin increases with increase in the applied load and the same has been observed in LM25 composites . Abrasive wear is possible at low loads, where the reinforcing hard alumina particles remain intact without fracture during wear and thus act as load bearing elements. Thus at low loads, the abrasion wear mechanism becomes dominant and as the load increases, the induced stresses exceed the fracture strength of the particles causing their fracture. Thus material transfer from pin onto the disc can also occur due to the rubbing action of the fractured alumina particles against steel disc and the removal of material from the surface of the pin increases with increase in load. These results in an increase in wear and coefficient of friction and the matrix result in deterioration of the wear resistance of the composite. The negative value of distance is indicative that increase in sliding distance decreases the Wear as well as coefficient of friction and this can be attributed to the presence of hard alumina particle which provides abrasion resistance, resulting in enhanced dry sliding wear performance. The addition of fly ash as reinforcement in the aluminium composites improves the friction and wear behaviour due to its self lubrication property [13]. The interaction between the variables has less effect on Wear.

III. CONCLUSIONS

Speed of disc (S) and applied load has the highest influence on wear in micron. when the reinforcement increases wear in micron of Composite material decreases . when the load increases wear in micron of Composite material increases. When the speed increases wear in micron of Composite material increases.

Thus from above conclusion it is found that wear properties of hybrid MMCs (LM25+Fly ash +Alumina) are superior as compare to LM25.

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