Investigation of Dry Sliding Wear Behavior of Aluminium 6061 with Ferro-Titanium Metal Matrix Composite

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Abstract- **Dry sliding wear characteristics are most predominant in behavior of aluminum matrix composite with Ferro-titanium elements as reinforcement were investigated using a pin-on-disc wear machine under the influence of dry sliding conditions. Influence parameters are load (N) in Newton's, Sliding speed(S) in RPM, Sliding distance (L) in mm & also percentage of reinforcement (%R). Wear loss were investigated experimentally by applying Taguchi's L27 orthogonal array. The composite specimens were fabricated by stir casting process with volume percentage 15% of Ferro-Titanium. Design of experiments (DOE) established on the Taguchi orthogonal array techniques, were accomplished to procure data. Analysis of variance (ANOVA) were established to explore the impact of process parameters on wear loss of composites specimens. The results showed that the inclusion of Ferro-titanium reinforcements in aluminum matrix composite will increases the wear resistance of the composite significantly. The testing specimens are prepared according to the ASTM G99 standards.**

Index Terms - Aluminummetal matrix composites, Ferro-Titanium, Wear, Taguchi Technique, Orthogonal Array, ANOVA, ASTM G99 standards.

I. INTRODUCTION

The composite has good potential & it has challenge to produce in a cost effective way to meet the requirements [1]. In present era engineering automobile and aerospace industries aluminum and its alloy acts a vital role. Aluminum Metal Matrix Composites (AMMCs) are common materials for numerous applications. The primary usage Aluminum as a base metal matrix composites materials due to strength to weight ratio and low density. In precise, MMCs have recently originate distinct curiosity because of their specific strength and specific stiffness at room or elevated temperatures. It is recognized that the elastic properties of the metal matrix composite are strongly influenced by micro-structural parameters of the reinforcement such as shape, size, orientation, distribution and volume or weight [1].It has been reported by several researchers that the volumetric wear loss of the particlereinforced composites decrease with the increasing weight percentage of particles. In general sir casting of MMCs involves producing a melt of the selected matrix material, followed introducing reinforcement material in to the melt, obtain a suitable dispersion through stirring. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle this method suitable for engineering application in terms of production capacity and cost efficiency [3].

II.Material Selection

Al-6061 material were used as a material matrix along with Ferro-titanium as reinforcement in 15% in the preparation of metal matrix composites specimens.By addition of reinforcement improves the strength, stiffness and the temperature resistance capacity and lowers the density of MMC's. In order to accomplish these properties in MMCs the choice depends on the type of reinforcement, and it's method of production and chemical compatibility with the matrix for composites. Considering all these factors, the reinforcement material selected for study is "Ferro-titanium" particulates of size 50μm are procured from Forum Enterprises, Mumbai.

Fig.1. Ferro-titanium particulates

Ferro-titanium is a Ferroalloy, consisting of iron 10-20% and titanium 45-75% sometimes small amount of carbon.Alloy is highly reactive with nitrogen, oxygen, carbon and sulfur, forming insoluble compounds. It has low density, high strength and excellent corrosion resistance. The physical properties of Ferro-titanium are density 3845 kg/m^3 & melting point 1450-1500^oC.

III. Development of Composites

A Stir casting technique used to development of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring.

Fig. 3. Prepared specimensAl+15% Ferro-titanium

Al-6061 was reinforced with Ferrotitanium concentration of 15% & grit sizes 50 microns. Fabrication of MMC's was carried out by liquid metallurgy technique. The specimens are prepared as per the ASTM (G99) standard.

IV. Experimentation

The Pin-on-Disc type Friction and wear monitor (DUCOM TL-20) with data acquisition system, which was used to evaluate the wear behavior of the composite, against hardened ground steel disc (En-32) having hardness of 65 HRC and surface roughness (Ra) 0.5 microns. It is versatile equipment designed to study wear under sliding condition only. Sliding generally occurs between a stationary pin and rotating disc. The disc rotates with the help of the DC motor, having speed of range 0-2000 rpm with wear track of diameter 15-160mm which could yield sliding speed 0-10m/s. Load is to be applied on pin (specimen) by dead weight through pulley-string arrangement. The system has a maximum loading capacity of 200 N.

Table 1. Process Parameters and Levels

Level	Load(N)	Speed(m/s)	Sliding Distance(m)
1	20	2	500
2	40	3	1000
3	60	4	1500

Taguchi L27 orthogonal array were developed. The response for the model is wear rate and coefficient of friction. The objective of model is to minimize wear rate and coefficient of friction. The Signal to Noise ratio (S/N), which condenses the multiple data points within a trial, depends on the type of characteristic being evaluated.

V. Results & Discussion

For Al 6061 Reinforced with 15% Ferro-Titanium (α) table shows the Orthogonal array L27

Table 2. Orthogonal array L27

Sl.No	**Load (N)**	**Sliding speed (m/s)**	**Sliding Distance (m)**	**Weight loss (gm)**
1	20	2	500	0.0062
2	20	2	1000	0.0026
3	20	2	1500	0.0170
4	20	3	500	0.0075
5	20	3	1000	0.0066
6	20	3	1500	0.0142
7	20	4	500	0.0019
8	20	4	1000	0.0080
9	20	4	1500	0.0155
10	40	2	500	0.0107
11	40	2	1000	0.0226
12	40	2	1500	0.0277
13	40	3	500	0.0189
14	40	3	1000	0.0189
15	40	3	1500	0.0355
16	40	4	500	0.0282
17	40	4	1000	0.0244

18	40	4	1500	0.0172
19	60	2	500	0.0262
20	60	2	1000	0.0410
21	60	2	1500	0.0480
22	60	3	500	0.0344
23	60	3	1000	0.0250
24	60	3	1500	0.0916
25	60	4	500	0.0334
26	60	4	1000	0.0289
27	60	4	1500	0.0578

A. Analysis of Variance (ANOVA)

The experimental results were analyzed with Analysis of Variance (ANOVA) which is used to investigate the influence of the considered wear parameters namely Load, Sliding Speed and Sliding Distance that significantly affect the performance measures.By performing ANOVA, it can be decided which independent factor dominates over the other and the percentage of contribution of that particular independent variable. This analysis is carried out for a significant level of α=0.05, that is for a confidence level of 95% sources with a p-value less than 0.05 were considered to have a statistical contribution to the performance measures.

It can be observed from the table 3, that the applied load has highest influence (P=55.47%) on wear loss. Hence load is an important control factor to be taken in to consideration during the wear phenomenon followed by sliding distance (P=17.95%) and sliding speed (P=1.60%) on wear loss. The interaction between load and speed is 1.33%, the interaction between load and distance is 9.79% and the interaction between speed and distance is 5.47%. The error associated in the ANOVA is 8.37%. This shows clearly, as the applied load and sliding distance increases wear loss also increases. This is because, whenever applied load increases the friction at the contact surface of the rotating disc increases. From the analysis of ANOVA table 6.4 it reveals that load has the major contribution for the wear loss compared to other parameters.

Table 3. ANOVA results forAl+15% Ferro-titanium composite

Source	DF	Means SS	Adj SS	Adj MS	F	P	P%
Load (N)	2	0.005291	0.005291	0.002645	26.49	0.000	55.47
Speed (m/s)	2	0.000153	0.000153	0.000076	0.77	0.496	1.60
Distance (m)	2	0.001713	0.001713	0.000857	8.58	0.010	17.95
Load*Speed	4	0.000127	0.000127	0.000032	0.32	0.859	1.33
Load*Distance	4	0.000934	0.000934	0.000234	2.34	0.143	9.79
Speed*Distance	4	0.000522	0.000522	0.000130	1.31	0.346	5.47
Error	8	0.000799	0.000799	0.000100			8.37
Total	26	0.009538					

From figure 4, main effect plot for means, that the Load parameter is the most significant parameter, while distance and speed parameters has relatively less influence. The values are chosen from table 2. Fig.4 of the main effects plot for means shows the influence of the various testing parameters on wear loss of the composite. In main effect plot, if the line for a particular parameter is near horizontal, then the parameter has no significant effect. In contrast, a parameter for which the line has the highest inclination has the most significant effect. It is clear from the main effect plot that, the Load parameter is the most significant parameter, while speed and distance parameters has relatively less influence.

Load: As the load increases the wear loss increases accordingly, at higher loads wear loss increases rapidly. Due to the higher load, the friction between the contact area increases, due to the higher friction the real area of contact increases, which in turn led to the formation of wear debris and increased wear of the composite.

Sliding Speed: As the sliding speed increases the wear increases gradually, at higher sliding speed the wear decreases gradually. As sliding speed increases wear increases and later increase in sliding speed the wear decrease, therefore sliding speed does not have large effect on wear. Because the reinforcement is highly reactive with oxygen, so oxide layers can form at higher load and higher speed due to this layer the wear loss is less.

Sliding Distance: up to some distance the wear is not noticeable, at higher sliding distance only the wear increases. Due to higher load and long distance the generated oxide layer is delaminated so in higher distance the wear loss is noticeable. Figure 6, shows interaction plots non-parallelism of the plots are observed. Non-parallel lines are indicates the presence of interaction, while intersecting lines are indicates the presence of strong interaction. From the interaction plots, it is evident that strong interaction exists between factors speed and distance while moderate interaction exists between rests of the factors as for as weight loss is concerned.

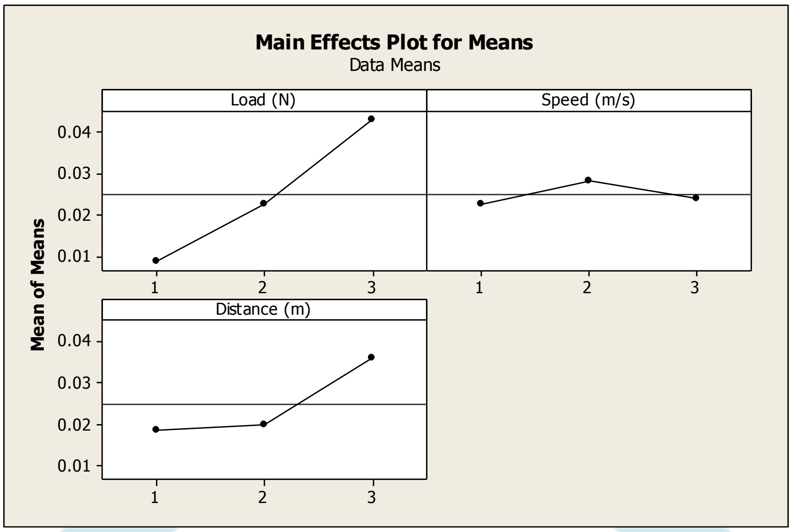

Fig. 4. Main Effects Plot for means of weight loss (Al+15% Ferro-titanium)

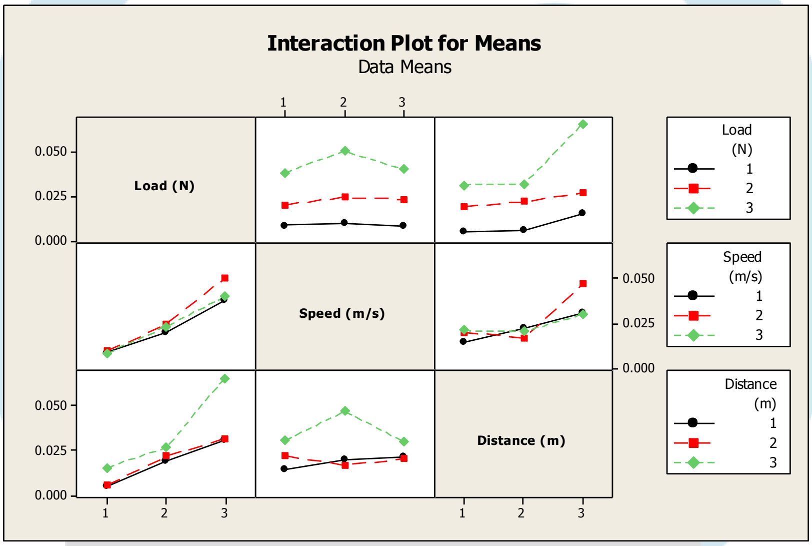

Fig 5.Interaction Plot for means of weight loss (Al+15% Ferro-titanium)

VI. CONCLUSIONS

The composites were successfully fabricated using liquid stir casting method.Load (55.47%) has the highest influence on wear loss followed by sliding distance (17.95%) and sliding speed (1.60%) for Al-6061+15% Ferro-titanium. Optimum wear loss was obtained from the experiment using Taguchi's method.Increasing the Ferro-titanium proportion 15% improves the wear resistance of the composite by forming the protective layer between contact surfaces. The incorporation of the Ferro-Titanium particles as reinforcement in metal matrix increases the wear resistance of the composite.Applied load is the wear factor, which has the highest physical as well as statistical influence on the wear loss of both composites.Design of experiments approach by Taguchi's method enables us to analyze successfully the wear behavior of the composites, with Load, Sliding Speed and Sliding Distance as test variables.Keeping load and sliding distance constant increasing the sliding speed decreases the wear.The study shows an error associated with dry sliding wear in composites 9.67%. Thus design of experiments by Taguchi method is successfully used to predict the wear behavior of composites.

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