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EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF WEAR CHARACTERISTICS OF METAL MATRIX COMPOSITES.

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ABSTRACT

Metal matrix composites are become a highly important material in automotive industries due to its light weight and high strength properties. In this work, Al6061/SiC_p reinforced metal matrix composites were fabricated with varying weight fraction of 5%, 10% and 15% SiC_p particles. Wear test was conducted using pin-on-disk apparatus. Parameters that were varied are load, sliding speed and percentage reinforcement of SiC_p. Taguchi L27 orthogonal array of experimental design is used for analyzing the performance measures such as wear loss, and frictional force. Optimization of parameters were done using grey fuzzy algorithm using MATLAB in order to obtain minimum wear and frictional force. The results indicate that increasing of reinforced particle increases wear resistance.

***Keywords*: -** *Metal matrix composites, wear loss, grey fuzzy, and speed.*

1. Introduction

Metal matrix composites have mainly preferred because of its good specific strength. Reinforced metal matrix composites have been gaining its positive effects due to its low cost. Cast aluminium has good wear resistance among many methods. stir casting is the cheapest way to produce. Problem associated with it is that particulates are non-uniformly distributed due to very low wettability. Taguchi design of experiments is an effective way which can be employed for analyzing the frictional force and dry sliding wear of composites by Ajay[1]. Al6061 can be successfully synthesized from stir casting technique [2]. From the research it is concluded that increase in load leads to maximum on wear volume loss by Chowdhury [4]. Wear generally occurs when two body comes in contact with each other. The weakness of material leads to rupture due to repeated action. wear can be of various types they are of abrasive, corrosive, surface fatigue. Wear rate gradually increases with applied load. Taguchi based experimental designs proves to be highly productive as it reduces the number of experiments there by reducing the cost as well as time for experiment but it fails to optimize the multiple objective . In order to overcome this problem various researchers have employed various theories along with Taguchi method to achieve multi response optimization by Issam Hanafiet.a(2012),Rajmohan et.al (2013) and Krishnamoorthy et.al.(2012The purpose is to conglomerate the multiple objectives into single objective (multi-response into equivalent quality index)In this study optimization of parameters like load, sliding speed and percentage of reinforcement being carried out by the grey fuzzy algorithm in MATLAB in order to obtain minimum wear rate and frictional force.

2.Fabrication of MMC using Stir casting

Al-6061 is used as Metal matrix composites with various wt% of SiC_p particulates. steel crucible was used for melting for 2 hours it was preheated to 400-700 degree Celsius .For melting the matrix, temperature of the furnace was increased to 800 degree Celsius. Mixing was carried out mechanically about 22 minutes at 400 rpm of about stirring speed. Molten metal has been poured in to mould of about 150 mm length. Temperature of pouring is estimated around 680 degree. Melt was solidified in the mould then wear test had been carried out for 5%.This method can be altered for other composition like 10% &15%.

fig. 1 :stir casting setup

Wettability is the major reason affecting which was between the two components, Porosity is the another major issue which affects .Chemical reaction also plays a major role.

3. Wear Test Procedure

After obtaining the required material by using turning operation diameter was reduced to around 10mm and length was around 50mm and 27 pins were made from al-6061/Sic of 5% 10% &15% of each samples of pin were made. and disk used is EN32 of diameter 70 mm. The surface of the pin was rubbed with emery paper to remove debris..when the pin is rubbed with disk corresponding frictional force was obtained for varying load of 2 kgf ,4kgf and 6 kgf and also for the varying speed of 400 ,600 & 800 rpm. in the system and the sample is weighed and the wear loss is measured
by weight loss method..The test was carried out for 15 minutes for each sample.

Fig. 2 : Pin on disk setup

4.Experimental results of wear test

4.1 Effect of applied normal load

Applied load affects the wear rate of alloy and composites significantly and is the most dominating factor controlling the wear behavior. The wear rate varies with normal load, which is an indicative of Archard's law and is significantly lower in case of composites. The cumulative volume loss increases with increasing applied normal load. Further, with increased applied load the contact surface temperature increases. By measuring the wear rate as a function of applied load, it has been reported that a critical load exists below this load, where the wear rate is mild and steady; above this load a severe wear rate occurs and the critical
load decreases with temperature. If the load is further increased, then the unreinforced and reinforced composites eventually seize. The seizure event was accompanied by a sudden increase in wear rate, heavy noise and vibration. This type of seizure has been referred to as galling seizure. As the wear rate increases with increased applied load, the wear mechanism reported was oxidation at lower loads and adhesion and delamination at higher loads

Table 1: Results of wear test

load	sliding speed	% SiCp	wear loss	frictional force
2	400	5	0.0215	6.3
2	400	10	0.024	7.3
2	400	15	0.026	8.2
2	600	5	0.039	6.8
2	600	10	0.033	9.2
2	600	15	0.032	9.6
2	800	5	0.0422	9.85
2	800	10	0.0366	10.092
2	800	15	0.0317	10.53
4	400	5	0.043	12.3
4	400	10	0.0483	13.4
4	400	15	0.0431	13.98
4	600	5	0.045	16.8
4	600	10	0.059	17.2
4	600	15	0.036	18.5
4	800	5	0.0533	16.7
4	800	10	0.0684	17.8
4	800	15	0.0415	18.9
6	400	5	0.0436	20.4
6	400	10	0.0514	24.6
6	400	15	0.048	21.9
6	600	5	0.052	27.3
6	600	10	0.0691	26.8
6	600	15	0.0635	23
6	800	5	0.052	29
6	800	10	0.0637	34.6
6	800	15	0.0645	33

4.2 Effect of reinforcements

The SiC_p reinforcement in the Al-MMCs is more fracture resistant compared to other reinforcements. The SiC_p particles are harder than other reinforcements and will provide a more effective barrier to subsurface shear by the motion of the adjacent steel counter-face and this result is likely due to differences in particles shape. An additional drawback of Al-MMCs with reinforcing phases, such SiC_p is the tendency of the reinforcement to act as a second-body abrasive against the counter-face increasing its wear rates. In addition, reinforcement liberated as wear debris acts as a third-body abrasive to both surfaces. The two effects result in a higher wear rate for the system as a whole when MMC is used compared to the monolith, while the extent of this problem depends on the mechanical properties of the counter face material

5.Grey fuzzy reasoning analysis

Grey relational analysis is used for optimization of input parameters of the wear test to achieve better quality of minimized wear loss and fictional force. The grey system to adequate for studies which involves poor, incomplete, and uncertain data which are designated as "Grey" data. It is used for solving the complicated interrelationship among the multiple responses. Concept of fuzzy logic is then incorporated into this multivariate system so as to get an improved grey-fuzzy grade. The grey fuzzy grades were calculated using MATLAB. The fuzzy inference system so developed incorporated triangular membership function and a set of 9 IF…THEN rules were formulated to fuzzify the grey relational coefficient of each

$$\xi_i(k) = \frac{\Delta_{\min} + \zeta\Delta_{\max}}{\Delta_{0i}(k) + \zeta\Delta_{\max}}$$

response(....(1) Grey grade is calculated from. αi=1/n∑έ(k) ...(2). where αi is the grey relational grade for the *ith* experiment and *k is the number of performance* characteristics.From the analysis optimum condition arrived load(2),sliding speed(400 rpm) and percentage of reinforcement(5%).

6.Fuzzy inference system

Prof. Lotfi A. Zedah introduced the concepts of fuzzy sets and systems. A fuzzy inference system uses fuzzy set theory to map inputs to outputs. There are basically two types of fuzzy inference systems viz. Mamdani and Sugino. Mamdani type system gives the fuzzy output, which if required has to be converted into crisp value using defuzzification method. It is intuitive and suitable to human inputs and so is widely used.

Sugino type inference system gives an output that is either constant or a weighted linear model. It can only be used to model those systems in which the output membership functions are either linear or constant. In the present study, Mamdani type fuzzy system is used.

7.Membership function

Membership functions are the building blocks of Fuzzy set theory i.e. Fuzziness in a fuzzy set is determined by its MF. Accordingly the shape of MFs are important for a particular problem since they effect on fuzzy inference system. In this present study triangular membership function is used because it represent fuzzy numbers and it is used because of its easy computation.

Table 2: Grey Fuzzy grade

Exp.No	*Grey relational coefficient*		*Grey grade*	*Grey fuzzy*	*Rank*
	wear loss	*frictional force*			
1	1	1	0.99	0.920	1
2	0.90	0.93	0.92	0.765	2
3	0.84	0.88	0.86	0.716	4
4	0.58	0.97	0.77	0.733	3
5	0.67	0.83	0.75	0.674	5
6	0.69	0.81	0.75	0.669	6
7	0.53	0.80	0.67	0.646	9
8	0.61	0.79	0.70	0.649	8
9	0.70	0.77	0.73	0.655	7
10	0.53	0.70	0.61	0.606	10
11	0.47	0.67	0.57	0.571	13
12	0.52	0.65	0.59	0.584	11
13	0.50	0.57	0.54	0.545	14
14	0.39	0.56	0.48	0.474	19
15	0.62	0.54	0.58	0.572	12
16	0.43	0.58	0.50	0.505	17
17	0.34	0.55	0.44	0.446	21
18	0.54	0.53	0.54	0.529	15
19	0.52	0.50	0.51	0.514	16
20	0.44	0.44	0.44	0.457	20
21	0.47	0.48	0.47	0.478	18
22	0.44	0.40	0.42	0.436	22
23	0.33	0.41	0.37	0.401	26
24	0.36	0.46	0.41	0.419	24
25	0.44	0.38	0.41	0.427	23
26	0.36	0.35	0.35	0.394	27
27	0.36	0.35	0.35	0.402	25

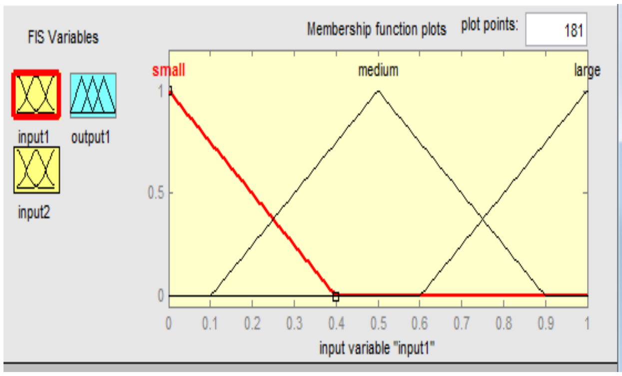

Fig. 3: Membership function for input 1

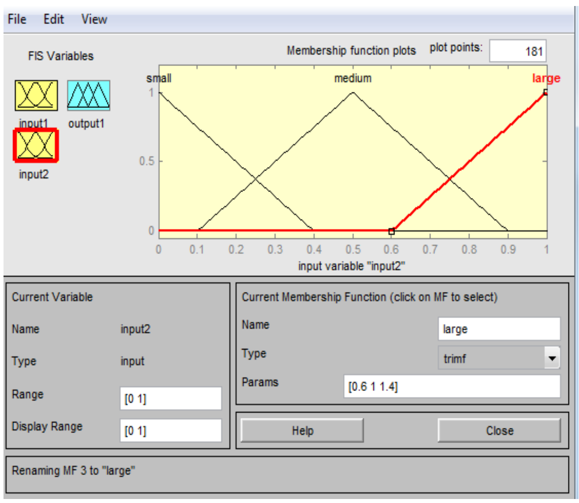

Fig. 4: Membership function for input 2

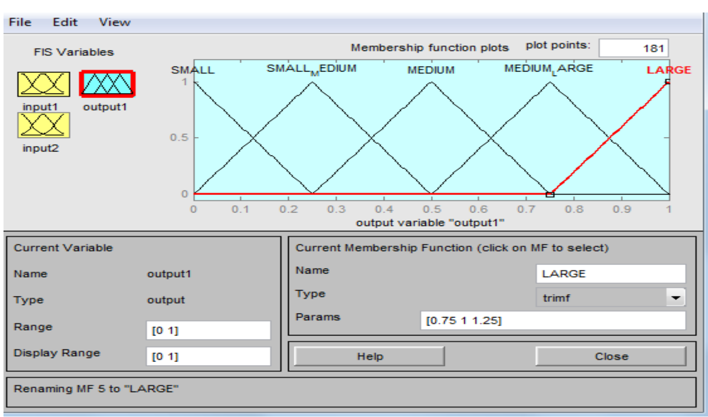

Fig. 5: Membership function for output

8. Fuzzy rule formation

In the step of rules evaluation, the rule base containing a number of 9 fuzzy IF-THEN rules is used to map the inputs to the output membership function. The rule formation is given in the table 3

Table 3: Fuzzy rule formation

INPUT 1	*INPUT 2*	*OUTPUT*
Small	Small	Small
Small	Medium	Small Medium
Small	Large	Medium
Medium	Small	Small Medium
Medium	Medium	Medium
Medium	Large	Medium Large
Large	Small	Medium
Large	Medium	Medium Large
Large	Large	Large

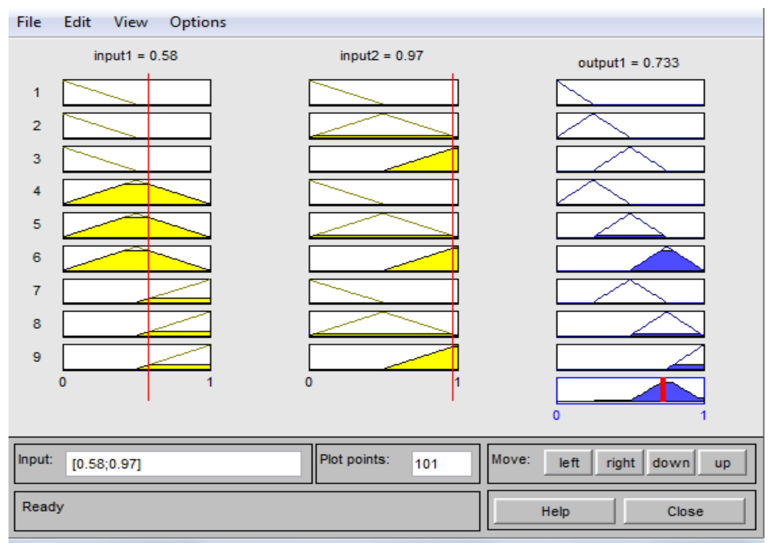

Fig. 6: rule box in matlab(input1=0.58,input2=0.97)

Table 4: Anova for Grey Fuzzy Grade

Source	*Df*	*SS*	*MS*	*F*	*P%*
Load	2	0.35578	0.17789	124.84	78.5
Sliding speed	2	0.05422	0.02711	19.03	11.9
%	2	0.01418	0.00709	4.98	3.13
Error	20	0.02850	0.00142		6.29
Total	26	0.45269			100

9.Results and discussion

In the grey fuzzy algorithm triangular membership function has been used because of simple formulas and computational efficiency. Grey relational analysis based on the grey system theory is adopted for solving interrelationship among multiple response.Grey relational grade is obtained from the average of the grey relational degree of the multiple response.In grey relational analysis experimental data are first normalised in range between 0 and 1.Grey relational coefficient is calculated from normalised experimental data to express relationship b/w desired and actual experimental data.Fuzzifier uses membership function to fuzzify the grey relational coefficient first.Inference engine then performs a fuzzy rule in order to generate fuzzy value.Defuzzifier converts the fuzzy value in to grey fuzzy reasoning grade.From the table 2 Larger the grey fuzzy reasoning grade the better multiple process response.

10.Conclusion

The paper present a study about optimization of parameters based on Grey-Fuzzy logic analysis coupled with Taguchi method. The major conclusions drawn from the present investigation are

[1]Analysis of Variance (ANOVA) was employed to verify
the fitness of the statistical model. Regression coefficient of the fit is 93.70 % for Aluminium6061 reinforced with Sic , signifying that the regression model provides an excellent description of the correlation between the factors and the response. Contribution of various variable and the interactions.

[2]Load is the most contributing factor i.e (78.5%) sliding speed(11.9%) and reinforcement(3.13%) by applying grey fuzzy logic analysis.

[3]Optimum parameters value for aluminium 6061 reinforced with Sic is load (2),sliding speed(400rpm),percentage of reinforcement(5%).

[4]It is observed that simultaneous improvement in multiple responses of wear study parameter is greatly improved by Grey-Fuzzy Logic Analysis.

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