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RESEARCH ARTICLE

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OPTIMIZATION OF PROCESS PARAMETERS OF FRICTION AND WEAR BEHAVIOUR OF TiB_2 REINFORCED IN-SITU COMPOSITES

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ABSTRACT

For the past few years materials research has been shifted to composite materials adjusting to the need for reduced weight, low cost and high performance of the composites. The present investigation was focussed on the study of effect of different process parameters such as load, sliding speed and sliding time on the wear behaviour and friction coefficient. Three levels for each factor were set. Taguchi design was used to analyze the reduction of wear and friction coefficients of the Al-4%TiB_2 In-Situ Composites. L9 orthogonal array was designed to optimise the process parameters for wear resistance and friction coefficient. Signal-to Noise (S/N) ratio was used to determine the ranking and optimum conditions of process parameters on the wear resistance and friction coefficient. Optical microscope results reveal evenly distributed TiB_2 reinforcement particle along the matrix.

KEY WORDS: In -Situ composites,TiB_2 particles, Stirring, Wear rate, Coefficient of friction, Microstructure properties

INTRODUCTION

Aluminium composites, especially particles reinforced aluminium matrix composites, with low density, high specific strength and stiffness, good thermal stability and wear resistance, play an important role in aerospace, automotive, military and other fields. Common reinforced particles in the composites include Al2O3, SiC, TiC, WC, TiB2, TiO2, B4C, Graphite and ZrB2 .Among these reinforcement particles TiB2 has been found to be the one with properties like high hardness, high elastic modulus, high melting point and high wear resistance. The In-Situ developed composites are superior to conventional Ex-Situ composites in the fact that it eliminates Segregation, Poor interface adhesion and Thermodynamic instability. Furthermore, these TiB2 particles don't react with matrix to form any detrimental products at the matrix/reinforcements interface. The mechanical properties are known to be highly sensitive to process parameters in the production. In the present work, the stir casting furnace was used to fabricate TiB2 reinforced In-Situ Aluminium based MMC's using the halide salt route. The effects of process parameter i.e.; applied load, sliding speed and sliding distance were studied.Fei Chan et al.,[1] explained the enhancement of mechanical properties with the addition of TiB2 particles with pure Aluminium through nonconventional method of production. M.O.LOI et al.,[2] discussed the traditional method of producing TiB2 from Al, TiO2 and B2O3.Rakesh kumar et al.,[3] discussed the enhancement of properties on Al2009 alloy with ZrB2 reinforcement. K.Niranjan et al.,[4] investigated the effect of load and sliding speed on aluminium matrix and found that load has the highest influence on wear rate. Dinharan et al.,[5] researched on the Al 6061 alloy reinforced with ZrB2 and found thatsliding speed, distance and load bears proportional relationship towards wear rate and friction coefficient. Shouvik Ghosh et al.,[6] effectively used Taguchi's L27 orthogonal design to find out the optimum condition for wear rate. Ravindra singh rana et al.,[7] discussed the Taguchi's L9 orthogonal array for finding out the optimum condition for wear resistance.

EXPERIMENTAL DETAILS

Al-TiB_2 In-Situ composites were synthesized by the reaction of halide salts (K_2TiF_6 and KBF_4) with the molten Aluminium matrix materials. The reaction is as follows:

$3K_2TiF_6+13Al \rightarrow 3K_2AlF_6+3TiAl_3$

$2KBF_4+3Al \rightarrow 2KAlF_4+AlB_2$

$TiAl_3+AlB_2 \rightarrow TiB_2+4Al$

Al 6063 alloy, KBF_4 and K_2TiF_6 powders were used as starting materials. For each experiment, 700 gm of Aluminium was melted to about 900ºC. The predried KBF_4 and K_2TiF_6 powders at a preheating temperature of about 200ºC with the mixing ratio of 1:2 were added into the melt. The load on the specimen (10, 20 and 30) was varied for the investigation of its effect on the wear and coefficient of friction of the composites. Also the Sliding Speed(1,2,3 m/s) and the Sliding distance (500, 1000, 1500) were varied along with the above load and the combination of 3^3 experiment number was reduced to 9 using Taguchi technique of optimisation. L9 orthogonal array was formed. A Linear Variable Differential Transformer (LVDT) monitored the motion of the left arm thereby helping to determine the wear rate at any point of time.Once the surface in contact wears out, the load pushes down the arm to remain in contact with the disc. This generates a signal by means of which it monitors the maximum wear rate on a continuous scale. The weight loss was found by measuring the specimen before and after the experiment on an electronic weighing machine.

PLAN OF EXPERIMENTS

Experiments were conducted by considering three process parameters namely load applied ,Sliding Speed and Sliding distance. Each of the above process parameter consists of three different levels. The parameters and the levels were shown in table1. The degree of freedom must be greater than number of parameters considered . Hence orthogonal array of 9 was selected. The responses considered are wear rate and friction coefficient. The orthogonal array of experiments conducted were shown in table2.

Table1. Parameters and levels

Level	Load N	Sliding Speed m/s	Sliding Distance M
1	10	1	500
2	20	2	1000
3	30	3	1500

Those have to be minimum and hence "Smaller the better" of S/N ratio is selected among the three types of characteristics. S/N ratio is given by,

$$S/N= -10\log \{1/[n(y_1^2+y_2^2+.....y_n^2)]\}$$

Where $y_1,y_2,...y_n$ are the responses and n is the number of observations for each test.

RESULTS AND DISCUSSIONS

MiniTab14 was used to analyze the wear resistance. S/N ratio was found.

Analysis using S/N Ratio

a) WEAR: Experiments were conducted according to the Taguchi L_9 orthogonal array and the results were shown on table 2. The influence of process parameters on Wear rate and Friction coefficient was determined using S/N ratio. The parameter with the highest S/N ratio gives minimum wear rate and minimum Coefficient of friction

Table 2. Experimental results

S.No	Load N	Sliding Speed m/s	Sliding distance M	Friction coefficient	Wear rate mm^3/m	S/N Ratio(wear)	S/N Ratio(friction)
1	1	200	750	0.033	0.001407	29.6297	57.0341
2	1	300	1000	0.106	0.001753	19.4939	55.1244
3	1	400	1250	0.209	0.002134	13.5971	53.4161
4	2	200l	1000	0.303	0.002478	10.3711	52.1180
5	2	300	1250	0.358	0.002365	8.9223	52.5234
6	2	400	750	0.365	0.001780	8.7541	54.9916
7	3	200	1250	0.338	0.004739	9.4217	46.4863
8	3	300	750	0.398	0.002489	8.0023	52.0795
9	3	400	1000	0.327	0.003200	9.7090	49.8970

The main effects plot for S/N ratios for wear rate is shown in fig1. It is found that wear rate increases with increase of load and sliding distance. But it decreases with increase in speed. The main effects plot for S/N ratios of wear was shown in fig2. Process parameter with highest S/N ratio gives optimum condition for wear rate. . It is to be noted that the formula used for finding out S/N ratio comes under 'smaller the better' characteristic. But the S/N ratio value must be high among the parameters for getting out the optimum condition for the responses. From fig2 it is evident that the set of parameters L=1 kg, S=300 rpm, D=750m gives the optimum condition for wear.

Table 4:Response Table for S/N Ratio(wear)

S.No	Load(N)	Speed(m/s)	Distance(m)
1	20.906	16.47	15.462
2	9.35	12.14	13.191
3	9.044	10.686	10.647
Delta	11.862	5.784	4.815
Rank	1	2	3

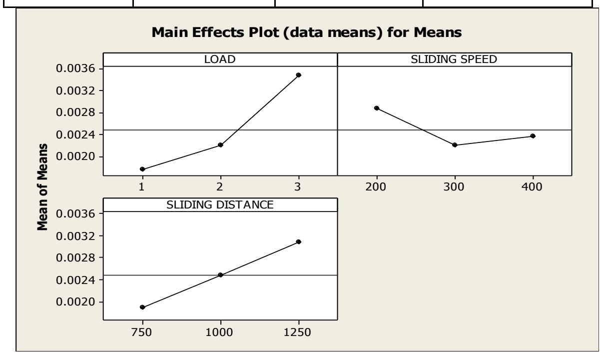

Fig 1. Main effects plot for means-wear.

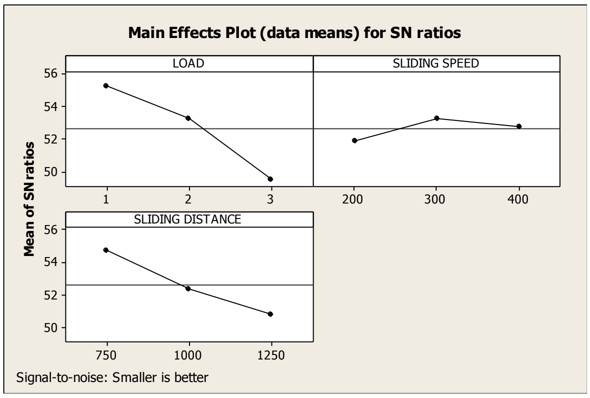

Fig 2. Main effects plot for S/N ratio-wear

b) COF

The main effects plot for S/N ratios for coefficient of friction is shown in fig 3. It is found that friction coefficient increases with increase of load and sliding speed. But it decreases with increase in sliding distance. The main effects plot for S/N ratio for friction coefficient was shown in fig4. From the fig4, it was found that the set of parameters L=1kg, S= 200m/s, and D= 750m gives the optimum condition for Coefficient of friction.

Table 5 Response Table for S/N Ratio(COF)

S.No	Load	Speed	Distance
1	55.19	51.879	54.707
2	53.21	53.242	52.379
3	49.487	52.768	50.808
Delta	5.703	1.363	3.8937
Rank	1	3	2

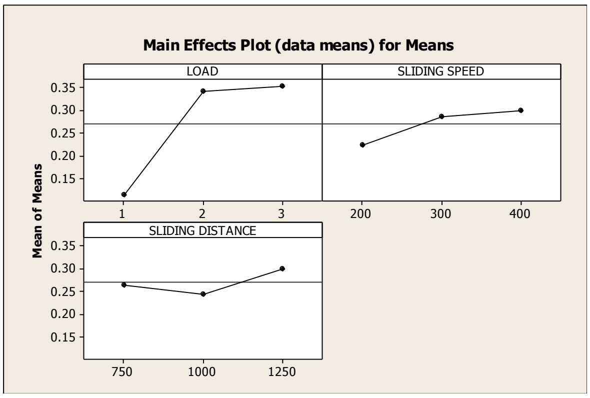

Fig 3. Main effects plot for means-COF

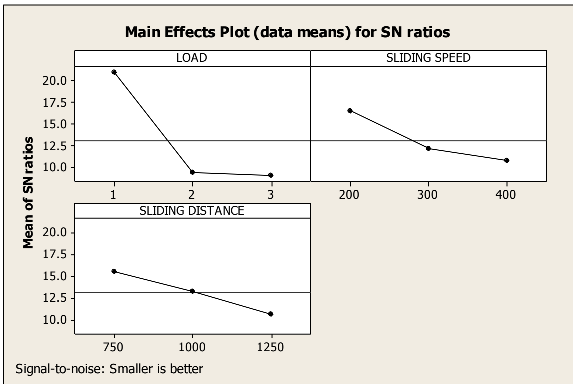

Fig 4. Main effects plot for S/N ratio- COF

MICROSTRUCTURE ANALYSIS: From the fig6 it is clearly seen that reinforcement particles (TiB_2) distributes more uniformly in the matrix and the agglomerates and coarse TiB_2 blocks are not present. This indicates the clear formation of TiB_2 particles from the reaction.

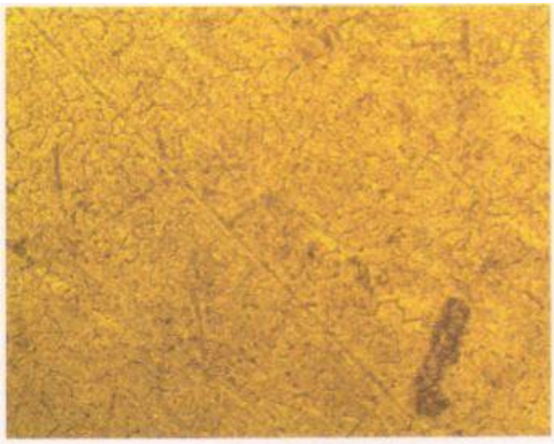

Fig 5. MAG 100X

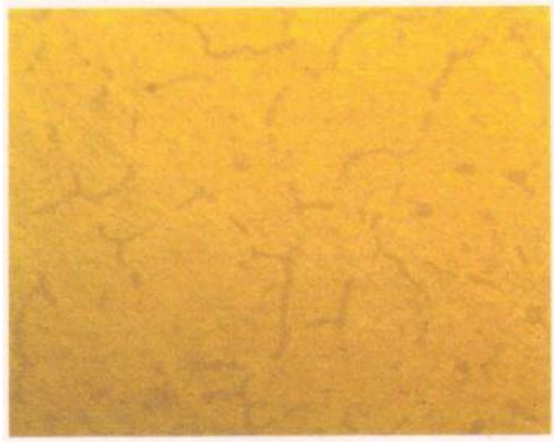

Fig 6. MAG400X

It exhibits preferred particulate features of TiB_2 particles. However the undesirable oxides have been seen frequently in the composite.

CONCLUSION

(1) Optimal conditions for minimum wear rate and friction coefficient were obtained using S/N ratio analysis.

(2) Analysis shows that wear rate increases with increase of load and sliding distance whereas decreases with sliding speed. With the main effects plot for S/N ratio it was found that at L=1kg, S=300rpm and D=750 m gives the optimum condition for minimum wear rate.

(3) Analysis shows that friction coefficient increases with increase of load and sliding speed whereas decreases with sliding distance. With the main effects plot for S/N ratio it was found that at L=1kg, S=200rpm and D=750 m gives the optimum condition for minimum coefficient of friction.

(4) Microscope analysis showed that segregation was eliminated as in conventional composites and the reinforcements were distributed uniformly over the matrix.

(5) Wear rate was minimised by adding TiB_2 particles in an economically efficient manner.

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