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Study of Wear Behaviour of Titanium Grade 2 Using Application of Taguchi Method

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Abstract: ***Titanium Grade 2 sample piece were subjected to wear on standard linear reciprocating tribometer machine for dry sliding condition in the constant temperature. Taguchi method were use to predict the wear rate against parameter such as Load, Frequency, and time. Signal to noise ratio and ANOVA were used study the impact of these three parameter on the wear rate. In conclusion, the major statistical factor affecting wear rate is load, followed by frequency and duration. Multiple linear regression equations are developed.***

Keywords: Titanium grade 2, wear rate, Tribometer, ANOVA

I. INTRODUCTION

Wear measurement in tribological testing usually involves measurement of mass loss. The amount of these can be desired in the terms of loss of mass (g). The observation of mass loss can be measured the initial and final weight of sample. Titanium is light in weight and having highly corrosion resistance. [1] It have an excellence balance of strength and ductility. Due to various mechanical application of titanium there is a need to continuously monitor wear sliding. There has been a lot of study done to improve its wear resistance and the only way to get significant improvement is to use any proven surface treatment that involves changes in surface chemistry. [1, 2] The use of titanium in the purest form such as medical implants for bones and joints, which had to be created with the influence of various process parameter as per the service condition. The statistical method is used to understand the behaviour titanium wear and to predicts the wear against service condition. In this study, a statistical approach based on taguchi [3-5] and ANOVA approaches was used to assess the degree of impact of each process parameter on the variation of the titanium grade 2 wear loss, as well as a mathematical model linking the variable and its wear behaviour.

II. EXPERIMENTAL AND STATISTICAL PROCEDURE

1) *Material Selection:* The study subject is titanium and its alloy which is widely used in industry. Table 1 show the chemical composition of titanium grade 2 and its alloy. Ti grade for industrial used with exceptional resistance to mildly reducing to extensively oxidising, with or without chloride, sample was cut 40*40*5mm square plate, which approvan for sour service used under NACE-MR-1-75 standard.

Table 1. Chemical composition of Ti-2 wt%

Component	C	Fe	H	N	O	Ti
Wt. %	Max 0.1	Max 0.3	Max 0.015	Max 0.03	Max 0.025	99.2

At 882.5 ℃ pure titanium undergoes an allotrope change from the hexagonal closed packed alpha phase to the body centre cubic beta phase. Its popular because it has good formability and moderate strength as well as good corrosion resistance. Ti 2 is employed marine, aerospace and medical. The specimen shown in fig 1.

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Figure 1. Titanium sample

2) *Wear test on Tribometer (LRT):* The following component are included in the wear test measurement equipment: Tribometer, weighing scale, data acquisition system and computer. On the LRT setup, tribological test are performed under sliding condition. Figure 2 shows the DUCOM tribometer. EN31 is clamped and held against the specimen. Through the loading pin the load is applied to the specimen. During the test the weight loss is measured for the variable of load, frequency and time. As per standard following formula used to calculate wear rate.

$$wear\ rate = \Delta m \times 10^3 / \rho * L * F\ mm^3/Nm \text{----- (1)}$$





Figure 2 : Tribometer Figure 3: Weighing Scale

3) *Plant of Experiment:* The control factor and its level were determined using an orthogonal array shown in table 2. Three variable are being tested at three distinct level in this experiment. A full factorial experiment would neccessiated as many trial as possible. The orthogonal array used in this study is provided in table 3.

Table 2. Process parameter with their ranges and values at three levels

Level	Load (N)	Frequency (Hz)	Time (s)
1	10	2	900
2	25	6	1350
3	40	10	1800

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Table 3.Taguchi L_9 orthogonal array

Test Run	Load (N)	Frequency (Hz)	Time (s)
1	10	2	900
2	10	6	1350
3	10	10	1800
4	25	2	1350
5	25	6	1800
6	25	10	900
7	40	2	1800
8	40	6	900
9	40	10	1350

III. RESULT AND DISCUSSION

A statistical analysis of wear loss was carried out using software MINITAB -18 specifically is use for design of experiment application. The result using L9 orthogonal array as shown in table 4.

Table 4. L_9 orthogonal array mean wear loss and S/N ratio

Load (N)	Frequency (Hz)	Time (s)	Wear Rate (mm3/Nm)	SNRA1	MEAN1
10	2	900	0.0123	38.2019	0.01230
10	6	1350	0.0048	46.3752	0.00480
10	10	1800	0.00554	45.1298	0.00554
25	2	1350	0.00903	40.8862	0.00903
25	6	1800	0.00328	49.6825	0.00328
25	10	900	0.00518	45.7134	0.00518
40	2	1800	0.00429	47.4732	0.00423
40	6	900	0.00616	44.2084	0.00616
40	10	1350	0.00277	51.1504	0.00277

A. S/N Ratio Analysis

Considering the different factor the S/N ratio was computed for the wear loss of sample as per the response. The S/N ratio was calculated using the equation 2 for smaller is better quality characteristic.

$$\text{S/N} = -10log10\left(\frac{1}{n}\right)\sum(y)^2 \quad \text{-------2}$$

All the responses and S/N ratio were plotted for each factor against its level with a smaller is better condition as shown in figure 4 and figure. The analysis of the result leads to the conclusion that the factors in the consideration shown in increase in mean wear loss the sample due to the increasing abrasion level of the factor. With increasing load, frequency and time, wear loss increases linearly. In terms of minimizing wear the combination of A3, B3, C3 results in the least amount of wear, analysis of variance is carried out in order to comply or justify the factor and relevance. Table 5 shows the response for signal to noise ratio for smaller is better.

Table 5. Response Table for Signal to Noise Ratios Smaller is better

Level	Load (N)	Frequency (Hz)	Time(s)
1	43.24	42.15	42.71
2	45.43	46.76	46.14
3	47.57	47.33	47.39
Delta	4.33	5.18	4.68
Rank	3	1	2

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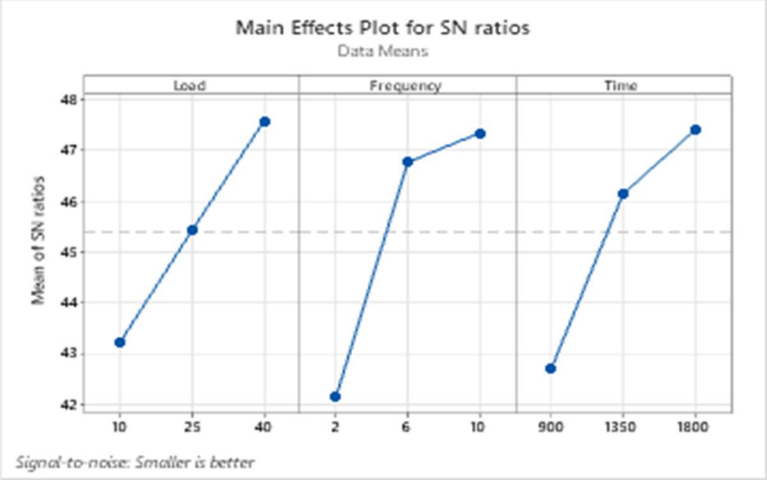


Figure 4: Main effect plot for S/N ratio

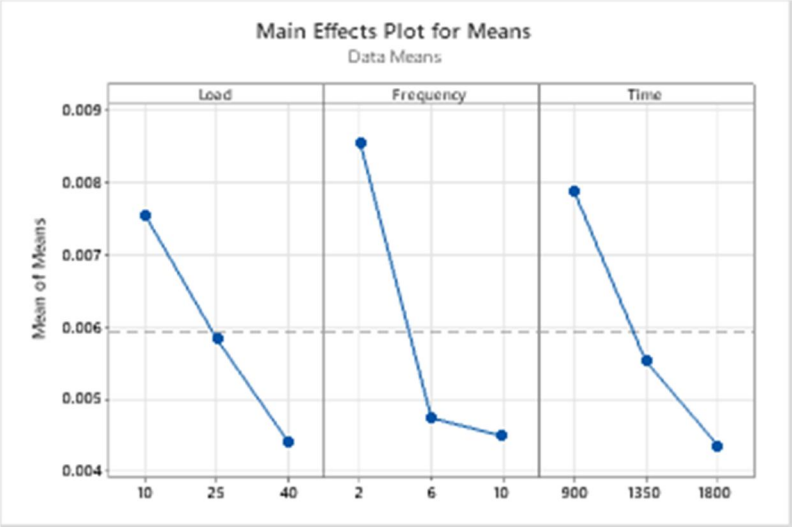


Figure 5: main effect for mean

B. Analysis of Variance

A statistical analysis of variance is conducted along with the Taguchi technique to find the contribution of each of the parameter for the wear loss. ANOVA can estimate the contribution of various process parameters to selected performance characteristics. The table 5 shows the result of the ANOVA is analyzed for a confidence level of 95%. Sources with a p-value of less than 0.07 were considered to have a statistically significant contribution and it can be observed that the load has the highest influence of 36.11% on the wear loss followed by frequency and duration considering the S/N ratio ; the frequency and time have an influence of 25% and 29.167% respectively. Hence load is most important parameter to be considered during calculating wear rate of titanium grade 2. [6, 7

Table 5: Analysis of Variance for S/N ratio, using Adjusted SS for tests

Source	DF	Adj SS	Adj MS	F- Value	P-Value	% of contribution
Load (N)	2	0.000026	0.000018	5.28	0.070	36.11
Frequency (Hz)	2	0.000018	0.000026	8.56	0.033	25
Time (s)	2	0.000021	0.000021	6.59	0.050	29.167
Error	2	0.000007	0.000003			9.722
Total	8	0.000072				

C. Multiple Linear Regression Model Analysis

In order to establish the correlations between wear parameter i.e. load, frequency and time with the wear loss, multiple linear regression model was used.

$$\textbf{Wear Rate (mm}^3\textbf{/Nm)} = \textbf{0.01684 - 0.000105 Load - 0.000505 Frequency - 0.000004 Time} \quad \text{----------(3)}$$

The confirmation test is carried out by to test the accuracy of the model by selecting different variables given in table 6 shows comparison obtain mathematical and experimental value. The result obtained by comparing the equation correlate the evaluation of the wear rate in the titanium with the degree of approximation. It can be observed from table that the calculated error varied 5.0% for wear.

Table 6. Parameter used in the Confirmation Test

Sr. No.	Parameter	Optimum Level
1	Load (N)	40 N
2	Frequency (Hz)	10 Hz
3	Time (s)	1800s

D. Taguchi Confirmation Experiment

Taguchi confirmation test is performed to validate the experiment results and to evaluate and to evaluate the accuracy of the analysis. In table 7, the experimental and predicted values are compared.

Table 7: Comparison of confirmation test

Parameter	Predicted Value	Experimental Value	Error %
Wear Rate	0.0044	0.00418	5%

IV. CONCLUSION

This study covers the observation about the wear rate of titanium grade2 for the different parameter like load, frequency and time to thoroughly study the effects of these parameter on the wear rate. The major finding of this study are as below.

A. It is observed that wear rate of the titanium grade 2 is moderate gives good wear properties.
B. The optimal value obtained from Taguchi study is combination of input parameter which affect on the wear rate; Load at 40N Frequency at 10Hz and Time at 1800s
C. Load and frequency are most significant parameter affecting the wear rate whereas the time is less significant.
D. Multiple linear regression equation has been developed with value 95%. Confirmation experiment shoes the error associated with the wear loss of specimen varies from 0% to 5%

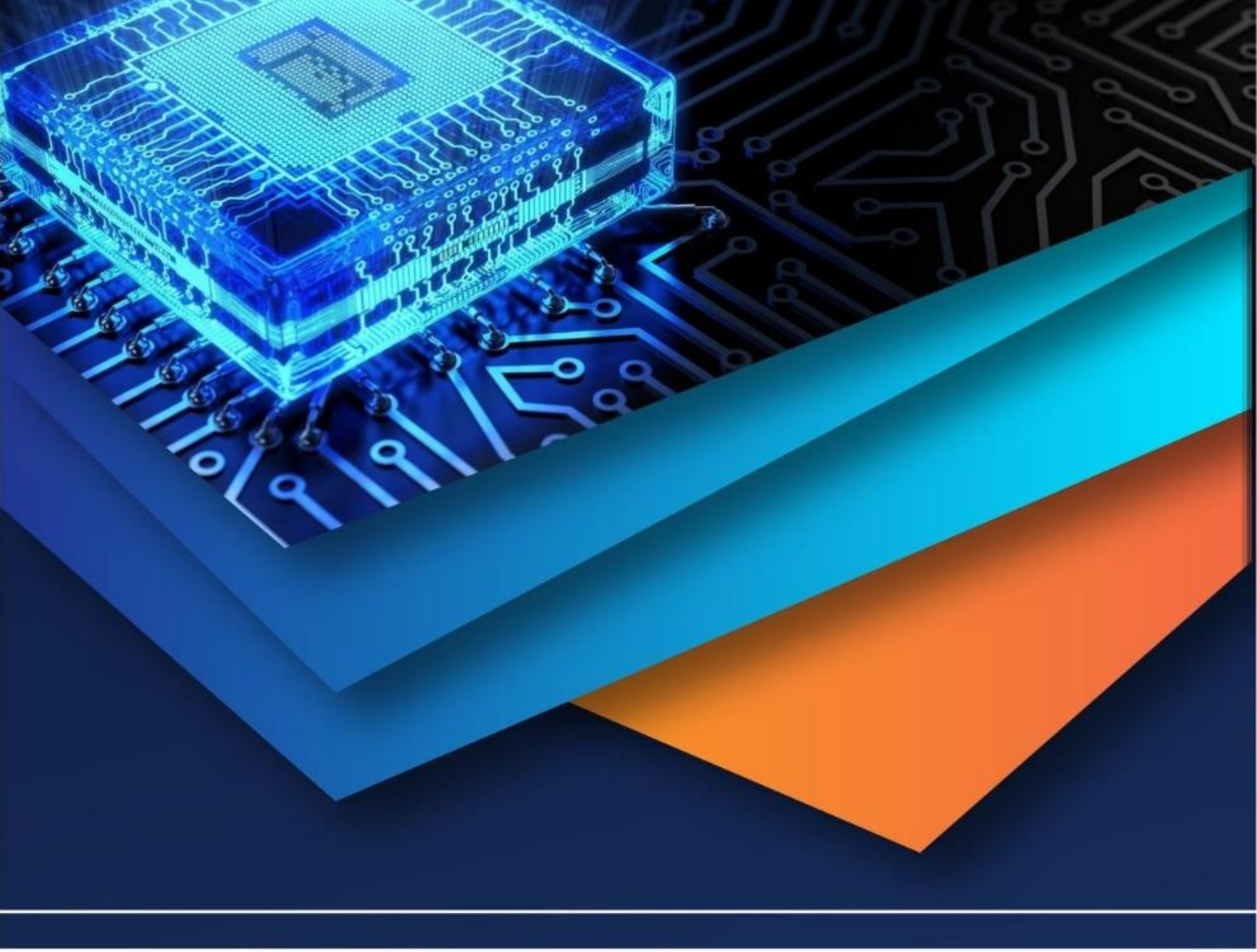
V. ACKNOWLEDGEMENTS

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