Optimization of Dry Sliding Wear Parameters of Titanium Alloy using Taguchi Method

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Abstract-:The present work focuses on the study of mechanical and tribological properties of Ti-3Al-2.5V titanium alloy. The most influencing process parameters of wear process are investigated in this work. Taguchi technique was used to carry out the experiments. The results indicate that load, sliding distance and sliding velocity were the process parameters which make significant contribution in wear properties. The optimal wear process parameters were found using the regression equation developed by the taguchi method.

Keywords: Titanium alloy, Wear Rate, Taguchi Method

I. INTRODUCTION

Light weight materials play a vital role in aerospace and automobile sectors due to their excellent combination of properties. Compared to all other materials, titanium alloys are widely used in various applications due to its inherent properties. It is also used in biomedical applications due to its high corrosive resistance and biocompatability. Galling, abrasive wear, plastic deformations are some of the wear mechanisms observed during the dry sliding treatment of titanium alloys [1, 2, 3].

Though most of the authors studied the effect of sliding distance and load on wear behavior of titanium alloys but its effect at different working environments viz., atmospheric, vacuum, High temperature condition , simulated body fluid and cryogenic conditions has been merely explored [5, 6]. Chauhan, et al [7] discussed about the wear behaviour of titanium alloy using response surface methodology technique. Sahoo, et al [8] reported the effect of microstructure on dry sliding wear behaviour of titanium alloy. Sharma, et al [9] reported the tribological behaviour of Ti-3Al-2.5V alloy sliding against EN32 steel disc of hardness 62HRC, under dry sliding condition. In 2016, Sharma, et al [10] investigated the optimization of friction and wear characteristics of Ti-3Al-2.5V alloy sliding against EN32 steel disc. It is clearly understood from the literature survey that very few studies have been published on the wear behaviour of Ti-3Al-2.5V alloy. Thus main objective of this study is to predict the wear rate of Ti-3Al-2.5V alloy and analyse its wear process parameters.

II. MATERIALS AND METHODS

2.1 Materials:

Commercially available Ti-3Al-2.5V titanium alloy with the dimensions (100*100*8mm) is used as the workpeice material. The EN32 steel disc is used as counterface material. The experiments were performed using pin-on-disk tribometer.The layout of the control factors and their levels are shown in Table 2.

Table 1. Chemical composition of Titanium alloy.

Elements	Al	V	Ti
%	3	2.50	Remaining

2.2 Testing details

Tensile Test. The tensile tests were carried out using electronic tensile testing machine as per the ASTM standard. The specimens were machined and prepared using the Wire Electrical Discharge Machine (WEDM).Figure 4 shows the specimens for tensile testing. In order to observe the nature of fracture in the tensile specimens, SEM images were taken for all the samples. Figure 5 shows the fracture surfaces of tensile specimens. From the micrographs, it is evident that the titanium alloy posseses ductile fracture.

Figure 1. Tensile specimen samples

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Table 2. Tensile properties of Titanium alloy

S.No	Material	YS (Pa)	UTS (Pa)
1.	Ti-3Al-2.5V alloy	384	500

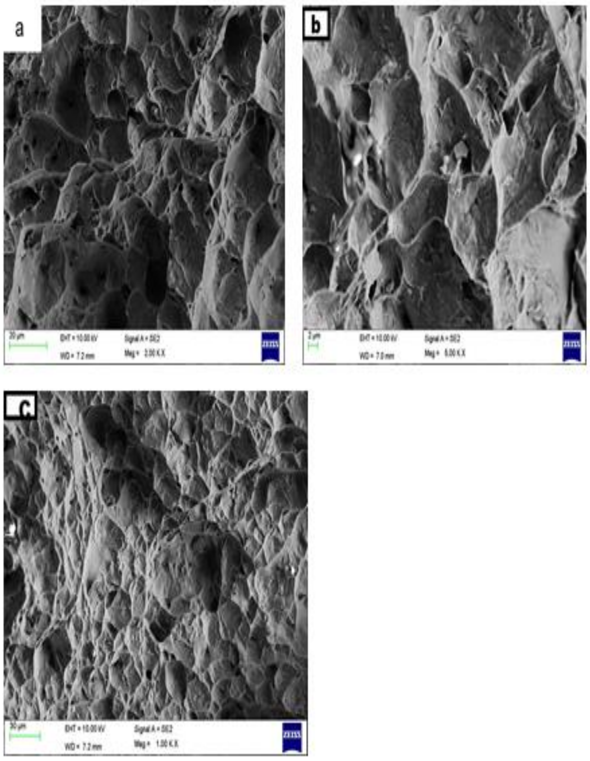

Figure 2. SEM micrographs of fractured tensile specimens

Hardness Test.

The hardness tests were performed using Rockwell hardness testing machine with the diamond indentor of load with 150 kg with dwell time of 15 s. The specimens were prepared as per the standards. The hardness value of the specimen is found to be 25HRC.

Impact Test.

The IZOD impact test was performed on the material to find the total energy observed. The dimension of the test specimen 64*12.7*3.2mm was obtained from WEDM. The test specimen was prepared as per the standards. The impact energy value is found to be 42 Joules.

Pin-on-Disk Test.

Wear tests were carried out using pin on disc tribometer. Figure 5(a) shows the setup of pin on disk tribometer. The investigating parameters were set as load applied, sliding distance, and sliding speed. The dimension of the test specimen is 10*10 mm. The significant parameters affecting the wear rate and coefficient of friction was to found to be the load, sliding speed, and sliding distance. ANOVA method has been used to find the interactions between the process parameters carried out during the experiment.

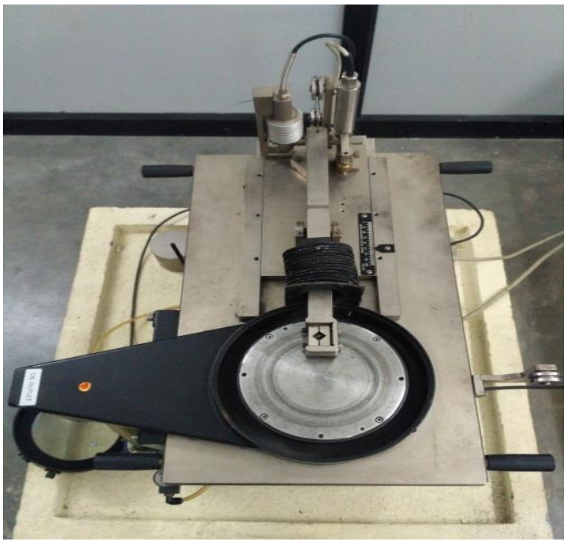

Figure.3 Pin on disc apparatus setup

III. DOE USING TAGUCHI TECHNIQUE

The effect of process parameters on the wear parameters was studied using the Taguchi's technique. It is a tool used to optimize the process variables. After conducting the pilot test, it was decided to select the levels of experiments. For the present case, input parameters considered are load, sliding distance, and sliding speed varying at three different levels. Wear experiments were conducted in accordance to aforesaid experimental design and response was measured as indicated in Table 3. Wear samples are shown in the Fig. 2.

The process parameters such as load (A), sliding distance (B) and sliding velocity(C) at three different levels were considered for this present work. The experiments were conducted and the average values are taken into consideration. With the support of L27 Taguchi's orthogonal array, the experimental levels were decided and it is shown in Table 2. The below mentioned equations the characteristics of process parameters using S/N ratio:

$$LB : Signal\ to\ Ratio\,(S/N) = -10\log_{10}\left[\frac{1}{m}\sum_{i=1}^{m} X^2\right] \qquad (1)$$

Table 3. Input variables and their levels.

Factor	Input variables	1	2	3
A	Load (N)	50	70	90
B	Sliding Distance (m)	2000	2500	3000
C	Sliding Velocity (m/s)	2	4	6

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Table 4. Experimental observations for wear rate.

Runs	Load	Sliding Distance	Sliding Velocity	Wear Rate (mg/m)					S/N ratio for wear rate
				WR1	WR2	WR3	WR4	WR_{avg}	Y(dB)
1	50	2000	2	0.0459	0.0462	0.0461	0.0460	0.0461	26.42
2	50	2000	2	0.0478	0.0477	0.0479	0.0480	0.0478	26.42
3	50	2000	2	0.0490	0.0491	0.0492	0.0493	0.0492	26.42
4	50	2500	4	0.0540	0.0541	0.0542	0.0543	0.0542	25.15
5	50	2500	4	0.0550	0.0551	0.0552	0.449	0.0551	25.15
6	50	2500	4	0.0565	0.0564	0.0561	0.0563	0.0564	25.15
7	50	3000	6	0.0570	0.0571	0.0571	0.0573	0.0571	24.71
8	50	3000	6	0.0580	0.0581	0.0582	0.0583	0.0582	24.71
9	50	3000	6	0.0592	0.0591	0.0593	0.0590	0.0591	24.71
10	70	2000	4	0.0610	0.0614	0.0613	0.0611	0.0612	24.21
11	70	2000	4	0.0616	0.615	0.614	0.613	0.0615	24.21
12	70	2000	4	0.0621	0.0599	0.0610	0.061	0.062	24.21
13	70	2500	6	0.0642	0.0641	0.0640	0.0643	0.0643	23.74
14	70	2500	6	0.0648	0.0650	0.0651	0.0649	0.0649	23.74
15	70	2500	6	0.0658	0.0657	0.0659	0.0660	0.0658	23.74
16	70	3000	2	0.0660	0.0661	0.0662	0.0659	0.0661	23.39
17	70	3000	2	0.0666	0.0667	0.0668	0.0665	0.0667	23.39
18	70	3000	2	0.0701	0.0702	0.0700	0.0701	0.0701	23.39
19	90	2000	6	0.0718	0.0719	0.0720	0.0719	0.0718	22.75
20	90	2000	6	0.0730	0.0728	0.0729	0.0731	0.0729	22.75
21	90	2000	6	0.0737	0.0736	0.0738	0.0739	0.0738	22.75
22	90	2500	2	0.0757	0.0756	0.0758	0.0756	0.0756	22.34
23	90	2500	2	0.0765	0.0763	0.0764	0.0766	0.0764	22.34
24	90	2500	2	0.0769	0.0768	0.0770	0.0771	0.0769	22.34
25	90	3000	4	0.0780	0.0782	0.0781	0.0783	0.0782	22.04
26	90	3000	4	0.0790	0.0791	0.0793	0.0792	0.0791	22.04
27	90	3000	4	0.0798	0.0799	0.0796	0.0797	0.0797	22.04
								Mean	23.86

IV. RESULTS AND DISCUSSION

The input variables such as load (A), sliding distance (B) and sliding velocity(C) were considered for this present work. The standard L27 orthogonal array design was used in this study. The experimental observations for wear rate and their values are given in Table 3. The S/N ratio values are also tabulated to find the optimal value for wear rate based on ranking, it is shown in Table 4. Fig. 2 shows the graphical representation of each factors and their effect on wear rate. The optimal values obtained are A1 (load of 50N), B1 (sliding distance of 2000m) and C3 (sliding velocity of 2m/s). ANOVA analysis was performed to identify the significant input variable and it is shown in Tables 5. Based on the S/N ratio levels, the overall optimum results thus obtained were A1, B1 and C1. The percentage contributions of input variables are shown in Fig. 3.

Table 5. Response table for S/N ratio

Level	Load	SD	SV
1	25.43	24.46	24.06
2	23.78	23.75	23.80
3	22.38	23.38	23.73
Max-Min	3.05	1.08	0.32
Rank	1	2	3
Optimum level	A1	B1	C1

Table 6. ANOVA for wear rate

Source	DF	Adjusted SS	Adjusted MS	F-value	P-value
Load	2	0.002249	0.001125	632.12	0.000
SD	2	0.000263	0.000132	74.00	0.000
SV	2	0.000012	0.000006	3.39	0.054
Error	20	0.000036	0.000002		
Lack-of-Fit	2	0.000012	0.000006	4.31	0.029
Pure Error	18	0.000024	0.000001		

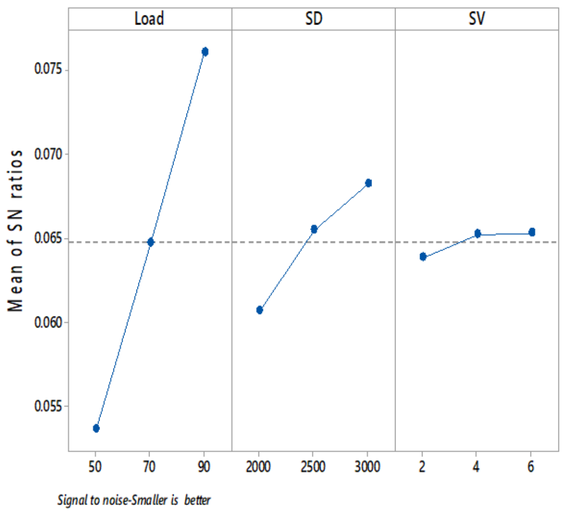

Figure 4. Response curve for SN ratios

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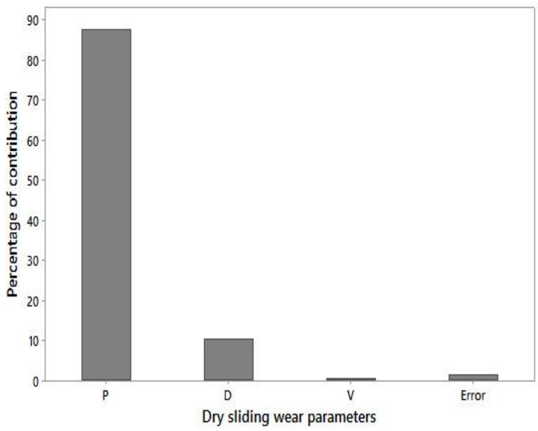

Figure5. Percentage contribution of process parameters

4.1 Confirmation test

The confirmation tests were conducted for the optimal values obtained from Taguchi method. The value of wear rate for optimal parameter is 0.4981mg/m and the S/N ratio value is found to be 26.50(dB). The values obtained were in coincidence with the experimental results.

4.2 Development of mathematical models

The regression equation for the desired output was obtained with the help of statistical software MINITAB 18. The relationship between the wear rate and the input variables were modelled in Eqs. 2

$$\text{Wear rate} = 0.064822 - 0.011133 - 0.000089\,\text{Load\_70} + 0.011222\,\text{Load\_90} - 0.004122\,\text{SD\_2000} + 0.000689\,\text{SD\_2500} + 0.003433\,\text{SD\_3000} - 0.000944\,\text{SV\_2} + 0.000444\,\text{SV\_4} + 0.000500\,\text{SV\_6} \quad \text{..... (2)}$$

From the above regression equation, it was found that R2=0.98 .The value of R2 indicates the closeness of the model representing the process. As R2 is nearing unity, this model can be considered for predicting the optimal process parameter combination.

V. CONCLUSION

In this work, Taguchi technique was used for determining the optimal dry sliding wear parameter for titanium alloy. The optimal value was found to be Load of 50N, Sliding Distance of 2000m and Sliding Velocity of 2m/s. The applied load is the most contributing input variable for the dry sliding wear of titanium alloy. Mathematical model has been developed for wear rate as a function of input variables. The predicted models will give you the optimum results for wear rate

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