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Research Paper

Dry Sliding Wear Study of Mild Steel Coated With Titania-Taguchi Approach

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ABSTRACT:
Friction in rubbing surfaces causes wear and loss of energy. One way of improving surface resistance to wear is by applying coatings. Steel is the material of present day world where almost every component contains an element of steel. Mild steel is widely used in the fields of automobile, aero-space, domestic use, etc. Tribological studies are gaining importance in the present day world where machinery with high speeds is a trend. In the present work, dry sliding wear behaviour of mild steel coated with Titania is studied for which Taguchi's and ANOVA techniques are applied.
Using pin-on-disc wear apparatus, the tribological behaviour of mild steel coated with Titania coating was studied under dry sliding conditions. The objective is to establish a correlation between dry sliding wear behaviour of mild steel coated with Titania with wear parameters. The influence of wear parameters like applied load, sliding distance and time on the sliding wear rate was investigated. Based on the Taguchi technique, a plan of experiments was performed to acquire data in a controlled way. The need for repeated experiments is eliminated by the Taguchi's orthogonal arrays and thus time, material and cost can be saved. The magnitude of effect of input parameters influencing wear rate was determined using ANOVA.
The results showed that increase in load and sliding time decreases the wear rate of mild steel coated with Titania significantly. It is found that the sliding speed is the most powerful influencing factor for the dry sliding wear of the coatings.

KEY WORDS — *Mild steel, Titania, Taguchi Technique, Orthogonal Array, ANOVA*

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I. INTRODUCTION

Mild steel is one of the most common metals which finds its application in fabrication and manufacturing processes and hence inevitably makes contact with the other metal surfaces resulting in wear and subsequently reduced life and efficiency. Mild Steel operates in environmentally hostile locations and critical components and hence undergoes wear and corrosion rapidly resulting in decreased reliability. Further, the availability is limited and turnaround times are long for spare parts of ageing platforms [7]. Thermally sprayed coatings are very promising candidates to improve wear resistance. The thermal spraying process has many advantages including its low cost, thicker coating by a fast forming rate, a wide selection of materials and a more simple process than other coating processes. Therefore thermal spray coating is considered to be the optimal method for TiO_2 coatings for most industrial applications [2, 3]

Coating the substrate with Titanium dioxide produces hard surface which can resist wear by abrasion or motion. Air plasma spray (APS) technique is used for applying the ceramic oxide coatings. This APS process is preferred due to the high temperature of the plasma jet, which is necessary to thermal spray high melting point materials in an effective way. During the thermal spraying of ceramic oxides, it is necessary to totally or partially melt the powder particles to make coatings [1].

The Taguchi approach to experimentation provides an orderly way to collect, analyze, and interpret data to satisfy the objectives of the study. By using these methods in the design of experiment, one can obtain the maximum amount of information for the amount of experimentation used. This is accomplished by the efficient use of experimental runs to the combinations of variables studied. This technique is a powerful tool for acquiring the data in a controlled way and to analyze the influence of process variables over some specific variable which is unknown function of these process variables. The overall aim of this technique is to make the products that are robust with respect to influencing parameters. The most important stage in the plan of experiments is selection of factors. Taguchi creates a standard orthogonal array to accommodate the effect of several factors on the target value and defines the plan of experiment [4, 5, 6]

II EXPERIMENTAL PROCEDURE

A. Procedure of Coating

Titania coating was applied on mild steel substrate using atmospheric plasma spray coating method. The substrate was cleaned with trichloroethylene to remove all dust particles and then grit blasted using Alumina to create enough surface roughness to ensure a strong mechanical bond between coating and substrate. Titania powder is heated to about 10000ºk so that it is melted and ionized to plasma state and then it is sprayed using a plasma spray gun to obtain a thickness of about 100 µm.

B. Wear Testing

Wear test was conducted using computerized pin-on-disc wear testing machine. The wear specimen (pin) size of diameter 10 mm and height 20 mm were machined and then coated. During the test, the pin was pressed against the counter surface by applying the load and rotated. After running through a fixed sliding distance, the specimens were removed, cleaned with acetone, dried and weighed to determine the weight loss due to wear. The difference in the weight measured before and after test gives the wear of the specimen. The wear of the specimen was studied as a function of the applied load, the sliding velocity and time.

III. PLAN OF EXPERIMENTS

The experiments were conducted as per the standard orthogonal array. The selection of the orthogonal array is based on the degrees of freedom.
Total degree of freedom in this study is calculated as;
Total degrees of freedom = Degree of freedom for the mean + Degree of freedom for each control factor
= Degree of freedom for the mean + 3 X (No. of levels of each parameter-1)
= 1+3 X (4-1)
= 10
Therefore, there are 10 degrees of freedom for the present work. So based on this degrees of freedom, at least 10 experiments should be conducted to estimate the effect of each factor. Thus the smallest array that can be used must have 10 or more rows. From the standard orthogonal arrays tables; smallest array which has 10 rows is L’16 array. The L’16 array has 5 four level columns and hence fits this work. The L’16 array has 5 columns (Each factor should be assigned to the single column), but in the present work, only 3 factors are considered. So L’16 array can’t be used directly to conduct the experiments. This is modified as shown in Table I.

Table I
L’16 Orthogonal Array with Parameters Assigned

Sl. No.	Speed in rpm	Load in N	Time in min
1.	**200**	**20**	**7.5**
2.	**200**	**30**	**15.0**
3.	**200**	**40**	**22.5**
4.	**200**	**50**	**30.0**
5.	**300**	**20**	**15.0**
6.	**300**	**30**	**7.5**
7.	**300**	**40**	**30.0**
8.	**300**	**50**	**22.5**
9.	**400**	**20**	**22.5**
10.	**400**	**30**	**30.0**
11.	**400**	**40**	**7.5**
12.	**400**	**50**	**15.0**
13.	**500**	**20**	**30.0**

14.	**500**	**30**	**22.5**
15.	**500**	**40**	**15.0**
16.	**500**	**50**	**7.5**

The wear parameters chosen for the experiment are (i) sliding speed (ii) load (iii) sliding time. Table I indicates the factors and their levels. The experiment consists of 16 tests (each row in the L'16 orthogonal array) and the columns were assigned with parameters. The first column was assigned to sliding speed, second column was assigned to load, and third column was assigned to sliding time. The response to be studied was the wear rate with the objective as smaller the better. The experiments were conducted as per the orthogonal array with level of parameters given in each array row. The wear test results were subject to the analysis of variance.

IV. RESULTS AND DISCUSSION

A. Wear test results

The wear tests were conducted on Pin on Disc tribometer. The speed was varied in steps of 200, 300, 400, 500rpm, load was varied in steps of 20, 30 40,50N and time was varied in steps of 7.5, 15, 22.5 and 30 minutes. To complete all the tests for all combinations, 16 tests were conducted as per the orthogonal array. The plan of tests was developed with the aim of relating the influence of sliding speeds, load, and sliding time with the wear rate. On conducting the experiments, the wear rate results for various combinations of parameters were obtained and are as shown in Table II.

Table II
Wear Rate Results of All Combination of Parameters by Taguchi Approach

Sl. No.	Speed in rpm	Load in N	Time in min	Wear in µm
1.	**200**	**20**	**7.5**	**3**
2.	**200**	**30**	**15.0**	**8**
3.	**200**	**40**	**22.5**	**14**
4.	**200**	**50**	**30.0**	**21**
5.	**300**	**20**	**15.0**	**8**
6.	**300**	**30**	**7.5**	**5**
7.	**300**	**40**	**30.0**	**19**
8.	**300**	**50**	**22.5**	**19**
9.	**400**	**20**	**22.5**	**13**
10.	**400**	**30**	**30.0**	**21**
11.	**400**	**40**	**7.5**	**9**
12.	**400**	**50**	**15.0**	**17**
13.	**500**	**20**	**30.0**	**19**
14.	**500**	**30**	**22.5**	**20**
15.	**500**	**40**	**15.0**	**16**
16.	**500**	**50**	**7.5**	**17**

B. Main Effects Plot

The main effect plot is shown in Fig. 2. It is clear from the Fig. 2 that the factor time has largest steep and hence has maximum effect on the wear . The optimum level for a factor is the level that gives the highest value of objective function. So the optimised parameters are at 400RPM, 40N and 30 Min.

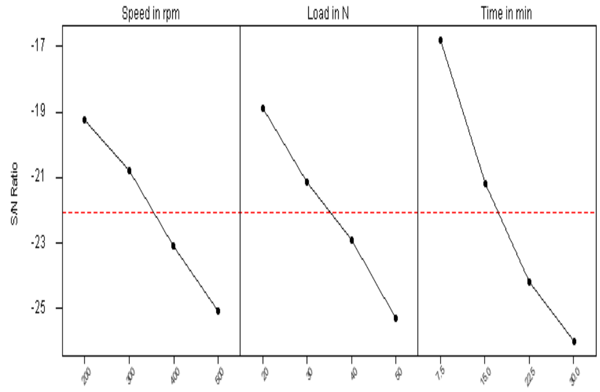

Fig. 2 Main effect plot for S-N Ratio

C. Analysis Of Variance

Table III shows the results of the ANOVA analysis. The purpose of conducting ANOVA is to determine the relative magnitude of the effect of each factor on the objective function and to estimate the error variance (F). The largeness of a factor effect relative to the error variance can be judged from the F column. The larger the F value, the larger is the factor effect compared to the error variance. Referring to the F column of the ANOVA Table, the largest value of F is in the factor time row while the load row has the least value of F. This means that the factor time has the greatest effect while the factor speed has the least effect on wear rate. The effect of load is in between the time and load.

Table III
ANOVA Results

Source	**F**
Load	**33..54**
Time	**81.54**
Speed	**26.49**

D. Regression Analysis

The general model considering the main effects is given by the following equation with R^2 = 96.8%

Wear in μm = - 11.5 + 0.0217 Speed in rpm + 0.242 Load in N + 0.517 Time in min

V. CONCLUSIONS

From the analysis of the results of wear of Titania coatings, the following conclusions are drawn.

1. Taguchi's robust design method can be used to analyze the wear problem of the coatings as described in this paper.

2. Sliding time is the wear factor that has the highest physical as well as statistical influence on the wear of the coatings.

3. The R square value of 96.8% shows that the regression equation gives satisfactory relation between Wear and input parameters of Load , Speed and Time.

4. The total time taken for conducting these tests was 300 minutes while the full factorial experiments for three factors with four levels each requires 1920 minutes. Thus use of Taguchi design results in saving of time and energy.

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