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OPTIMIZATION AND EROSION WEAR RESPONSE OF UNCOATED PUMP IMPELLER MATERIAL SS-404 USING FLY ASH

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Original Article

ABSTRACT

BACKGROUND/OBJECTIVES

The paper deals with the Optimization and Erosion Wear Response of Uncoated Pump Impeller Material SS-404 using fly ash; investigated and evaluated using a pot tester under varying impact parameters.

METHODS/STATISTICAL ANALYSIS

SS-404 was considered for experimentation and the experiments were conducted under the influence of varying factors of solid concentration, rotational speed and time period using Taguchi approach. Pot tester was used for experimentation at the rotational speeds of 700, 900, 1100 and 1300 rpm while time periods were 75, 100, 125 and 150 minutes. The solid to liquid concentrations of erodent fly ash were kept at 40, 50, 60 and 70%.

FINDINGS

Taguchi approach was employed to investigate the erosion wear response of pump impeller material stainless steel SS-404 and a slurry pot tester was used for the purpose of experimentation. The experiments were performed randomly at the varying impact parameters of speed, concentration and time. It was found that speed contributes the most in erosion wear of the pump impeller material followed by concentration and time, respectively. At the lowest impact parameters, ploughing was found to be the major wear mechanism and erosion wear as the minor wear mechanism. However, at the highest impact parameters erosion wear was found to be the major wear mechanism while ploughing was found to be the minor wear mechanism.

IMPROVEMENTS/APPLICATIONS

Erosion wear response is investigated with HVOF spayed coatings. It is also observed that the erosion wear response of WC-12Co-4Cr and Stellite-6 coated pipeline material SS-317L increase with the increase in the impingement angle till 30 degree observe maximum value and decreases with the impingement angle 90 degree.

KEYWORDS: Optimization, Erosion Wear, Stainless Steel SS-404, Rotational Speed, Concentration, Time Period & Fly Ash Slurry

1. INTRODUCTION

Erosion wear is the process which takes place when a substrate or base material is hit by another material allowing the removal or shifting of material from the surface of the base material. The impacting material and the substrate material undergo various mechanisms throughout the process of erosion wear. These mechanisms include brittle fractures, ploughing, abrasion etc. In case of brittle materials, when the target material is acted upon by a hard abrasive material, a cutting action comes into work in the direction of the slurry flow. The constant action of the abrasive particles on the surface cracks propagates, removing the material from that of the substrate or the base material.

However, in ductile materials, there are two stage processes in which erosion wear takes place. High velocity eroded materials impact on the target surface resulting in plastic deformation. This happens in the first stage. And in the second stage, the continuous attack of abrasive particles on the material generates shear lip formation. It, then breaks down and move out with the fluid in the direction of the flow.

Erosion wear occurs due to a number of impacting factors. As an assumption, that localization of plastic flow underneath the impacting particle is responsible for the lip formation resulting in erosion wear of the material, G. Sundararajan (1991) prepared a model considering all the impact angles, which acted as an extension for model proposed for normal impact erosion. In comparison to uncoated mild steel high erosion resistance was found when H. W. Wang et al. (1998) conducted the study of PVD TiN coated mild steel BS623 under corrosion during erosion in a particle based alkaline slurry but on increasing the speed of the particle erosion negligible effect on the erosion of coated mild steel was observed. To ensure the erosion wear due to parallel flow of the mixture by the cutting action of solid particles, B. K. Gandhi et al. (1999) studied the erosion wear performance caused in solid-liquid mixture using slurry pot tester. Scratching was found to be the main cause of the material removal and the velocity was found to act as an important factor effecting erosion.

Erosion wear variations were studied along the volute casing of centrifugal slurry pumps and increase in the wear along the periphery of the volute on increasing the amount of solids suspended in the mixture was observed (B. K. Gandhi et al. 2001). J. Wu et al. (2005) conducted experimental tests on the erosion rate in austenitic stainless steel by changing the hardness of the steel specimens using cold rolling and case hardening. It was seen that on increasing the hardness due to compressive stress, resistance to erosion was high. Also, erosion rate increased when impact velocity was increased. On studying the effect of angle of impingement and particle size in slurry-jet erosion behavior of pulse plasma nitrided and laser hardened 13Cr-4Ni steels, laser hardening exhibited good performance at all the angles, due to martensitic transformation of arsenite (T. Manisekeran et al. 2006).

This paper has been written keeping in consideration the effect of the influencing factors and determining the erosion wear response of the uncoated pump impeller target material SS-404 when employed and experimented using fly ash as slurry with varying time periods, concentration and rotational speeds. In order to optimize the erosion wear, Taguchi`s approach was used, so as, to get minimum experimental runs allowing us to get very mean results and conclusions. This approach helps in reducing the experimental cost, as such.

2. MATERIALS AND METHOD

2.1. Testing Material

For the experimental purpose, stainless steel SS-404 was taken as a target or substrate material. Stainless steel is very often used in various thermal power plants and industries. The material was cut in specimens of dimensions as 50 mm * 25 mm * 5 mm, while each of the specimen was the drilled with an 8-mm drill bit in the center. Figure 1 represents the work piece geometry.

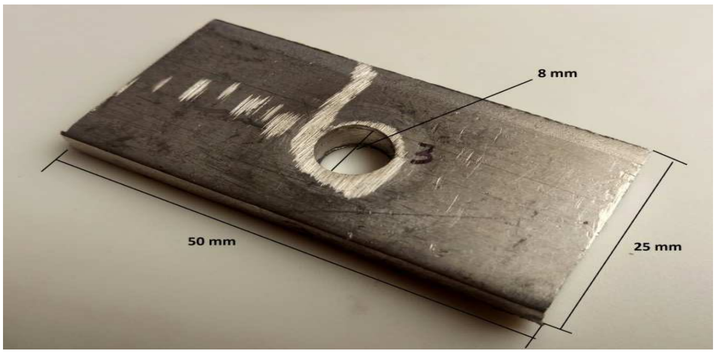


Figure 1: Work Piece Geometry.

Table 1: The Chemical Composition of Pump Impeller Material SS-404

Element	Content (%)
Fe	Balance
Cr	11-12.5
Ni	1.25-2
Mn	1
Si	0.5
C	0.05
P	0.03
S	0.03

2.2. Erodent

For carrying the experiments, fly ash was used as an erodent. The fly ash was collected from Sri Guru Gobind Singh Super Thermal power plant (Punjab), India. In order to analyze the surface morphology of the erodent material, Scanning Electron microscopy was conducted which was found to be ceno-spherical and clustered-spherical particles.

2.3. Slurry Pot Tester

Slurry pot tester (Ducom erosion pot tester Model: TR-41, Bangalore, India) was used for the experimental purposes. A slurry pot tester is a test rig, suitable for steel and rubber used to provide a rapid erosion wear responses. Components of Slurry pot tester include:

- Cylindrical pot: used to pour the slurry mixture.
- Rotating shaft: to which the testing material is attached.
- Electric motor: it rotates the shaft and is placed at the top of the pot tester, having the maximum speed of 1500RPM.

  Slurry pot tester shown in figure 2 was used for the experimental work.

Figure 2: Slurry Pot Tester.

The cylindrical pot can be adjusted as per the requirements, using adjustable fixtures. Also, the speed of the rotating shaft can be adjusted using the speed knob present on the system. The shaft can gain maximum of 1500 rpm.

2.4. Method

The experiments were performed by clamping the base material SS-404, and each experiment was carried out with different combinations of influencing parameters including speed, concentration and time. The experiments were carried at rotational speeds of 700, 900, 1100 and 1300 rpm while time periods were kept at 75, 100, 125 and 150 minutes. The concentrations of fly ash to water were 40, 50, 60 and 70 in terms of percentage (%) by weight.

Taguchi method to establish the erosion wear rate of the pump impeller material SS-404 was used, and mass losses were calculated from the initial and the final masses of the specimen. These results were then converted to S/N (signal-to-noise) ratio using MINITAB 17 shown in Table II, while considering the smaller the better approach.

Table 2: Experimental Data

Exp. no.	Speed (RPM)	Concentration (%)	Time (min)	Mass loss	S/N Ratio
1	700	40	75	0.0054	45.3521
2	700	50	100	0.0061	44.2934
3	700	60	125	0.0066	43.6091
4	700	70	150	0.0074	42.6154
5	900	40	100	0.0063	44.0132
6	900	50	75	0.0064	43.8764
7	900	60	150	0.0072	42.8534
8	900	70	125	0.0074	42.6154
9	1100	40	125	0.0068	43.3498
10	1100	50	150	0.0070	43.0980
11	1100	60	75	0.0073	42.7335
12	1100	70	100	0.0076	42.3837
13	1300	40	150	0.0074	42.6154
14	1300	50	125	0.0076	42.3837
15	1300	60	100	0.0080	41.9382
16	1300	70	75	0.0089	41.0122

While,

$S/N = -10\log[\sum Ei^2/n]$: n - no. of observations

3. RESULTS

Pump impeller material SS-404 was experimented upon using Taguchi approach to erosion wear rate and the analysis was carried using MINITAB 17. The results were recorded and S/N ratio was calculated keeping in consideration the impact parameters such as speed, concentration and time. Table III represents the response table for signal to noise ratio for the pump impeller material SS-404. It was observed that the impact parameter speed calculated in RPM has the largest impact contributing to the erosion wear of the material followed by the concentration in %. Time was observed to contribute the minimum in erosion wear of the material. Thus, ranking in the below mentioned order.

SPEED > CONCENTRATION > TIME

Table 3: Response Table for S/N Ratio for SS-404.

Parameter	Level 1	Level 2	Level 3	Level 4	Rank
Speed (RPM)	43.97	43.34	42.89	41.99	1
Concentration (%)	43.83	43.41	42.78	42.16	2
Time (min)	43.24	43.16	42.99	42.80	3

Mean erosion rate for the pump impeller was also calculated and is show in table IV. Erosion in the material occurred minimum when the rpm was 700 and maximum at rpm of 1300. Increasing the speed clearly showed increase in the erosion rate. However, concentration and time were also the factors upon which the erosion rate depended.

Table 4: Mean Erosion Rate for SS-404 in Accordance to the Impact Parameters.

Parameter	Level 1	Level 2	Level 3	Level 4
Speed	0.006375	0.006825	0.007175	0.007975
Concentration	0.006475	0.006775	0.007275	0.007825
Time	0.007000	0.007000	0.007100	0.007250

On performing the SEM analysis of the experimented specimen at the lowest impact parameters of speed of 700 rpm, concentration of 40%, time as 75 minutes, craters were found to be present in the majority while as minor erosion wear traces were found to be minimum, shown in figure 3.

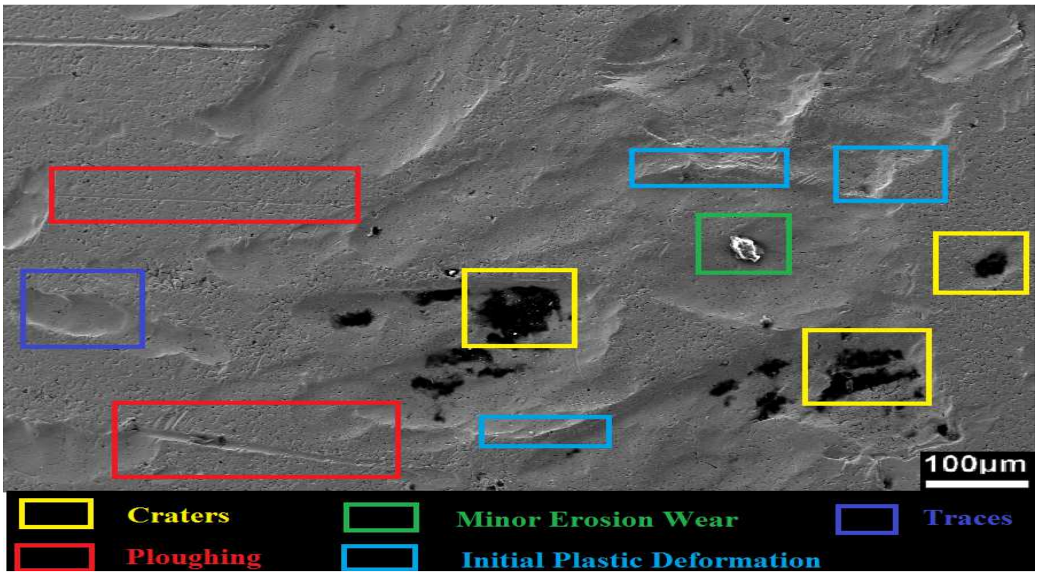


Figure 3: SEM Image at the Lowest Impact Parameters.

Figure 4 shows highly eroded surface in the majority while as craters are seen to be minimum, upon performing the SEM analysis at the lowest impact parameters of speed of 1300 rpm, concentration of 70% and time at 150 minutes.

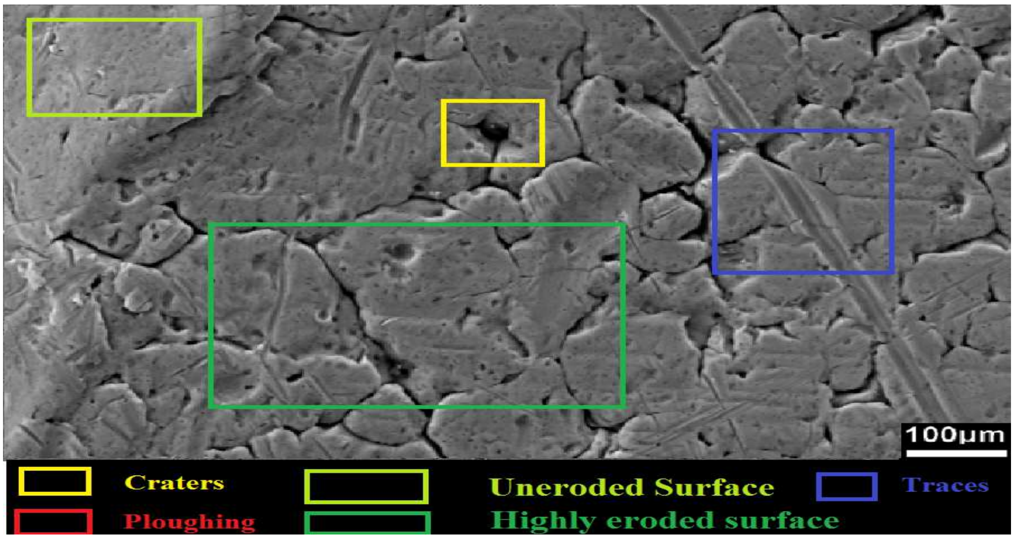
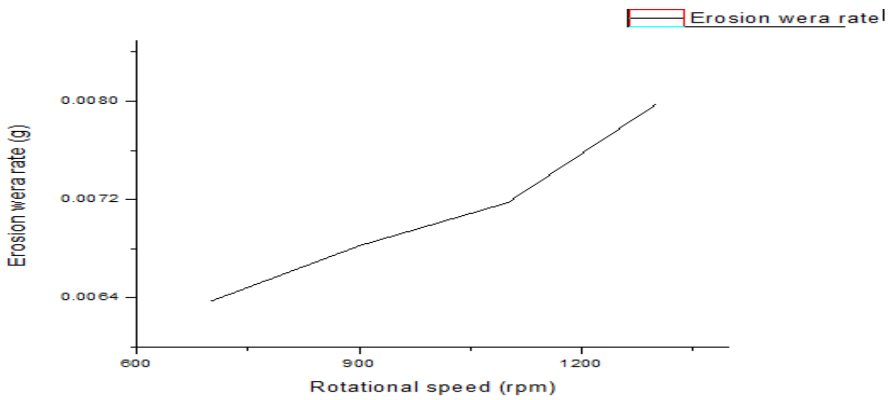
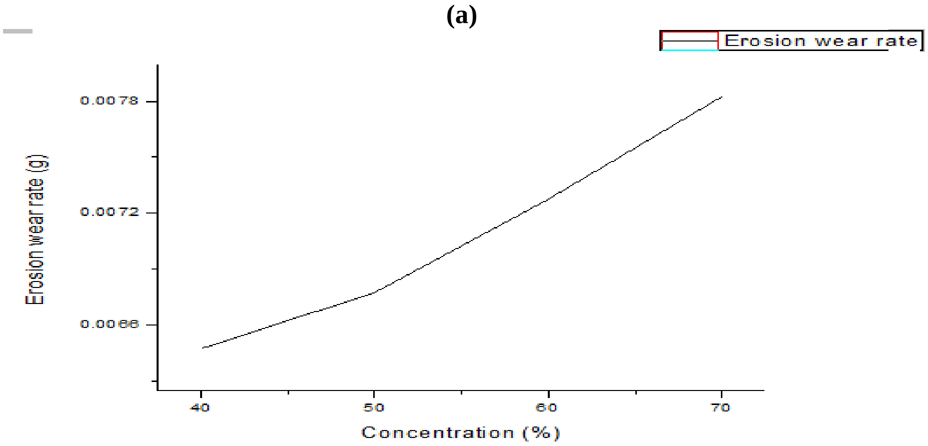


Figure 4: SEM Image at the Highest Impact Parameters.

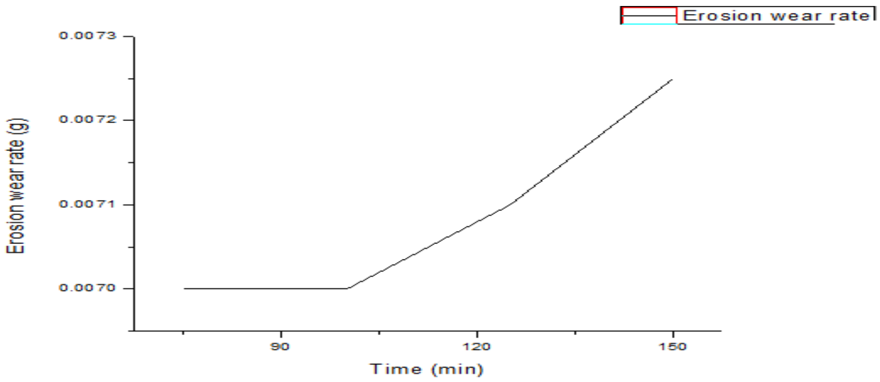
The signal to noise ratio i.e., S/N ratio values were used and plotted on graphs using MINITAB 17 and applying Taguchi analysis. The main effects plots for S/N ratios data means can be seen in figure 5. Smaller is better approach was employed to plot the graphs.



(a)



(b)



(c)

Figure 5: (a), (b) and (c) show The Effect of the Speed in rpm, Concentration in % and Time in Minutes on Erosion Wear of the Pump Impeller Material, Respectively.

4. CONCLUSIONS

Pump impeller material SS-404 was experimented upon and Taguchi approach was used to study the optimization and the erosion wear response of the material under varied impact parameters like speed, concentration and time. The following conclusion for the same has been withdrawn:

- Speed among the three impact parameters was seen to contribute the maximum to the erosion wear of the material followed by the concentration. Time was recorded to contribute the minimum in the order. Thus, in terms of effectiveness, speed ranks at 1, concentration at 2 and time at 3.
- Erosion wear mechanism shows ploughing as the major wear mechanism at the lowest impact parameters, and highly eroded surface as the major wear mechanism at the highest impact parameters.
- Erosion wear mechanism shows minor erosion wear at the lowest impact parameters, and craters as the major wear mechanism at the highest impact parameters.

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