To Study the Slurry Erosion Behaviour of Hard Faced Alloy SS304

Amandeep Singh, Roshal Lal Viridi, Khushdeep Goyal*

Department of Mechanical Engineering, Punjabi University, India

*Corresponding Author: khushgoyal@yahoo.com

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Abstract Slurry erosion of impellers decreases the efficiency of impellers up to 5-10%. The slurry erosion depends upon many parameters viz. silt size, concentration, hardness of particles, velocity of water etc. In this research work the effect of these parameters has studied on the hard facing of SS 304 with hard alloy III and titanium alloy. It is found that hard facing helps to increase the erosion resistance properties of the substrate material.

Keywords Slurry, Erosion, Hard Facing, Impact Angle, Slurry Concentration

1. Introduction

Slurry erosion is the removal of material from the surface by the repeated impingement of hard particles moving at considerable velocities. It is a serious problem in flow through pipes, hydraulic systems and impellers. Erosion of hydroturbine components has received important attention in recent past [1]. Hard facing is one of important method to increase the erosion resistance of these components. It helps to increase the life of the components. Welding is important process to apply hard facing alloys on a substrate material [2].

In recent past, many researches had tried to improve the erosion resistance of hydro components such as impellers. Goyal et al. [3] investigated the erosion performance of WC-10Co-4Cr and Al₂O₃ and 13TiO₂ coatings on CF8M turbine steel. It was found that WC-10Co-4Cr coatings are more useful to increase slurry erosion than other coatings. Grewal et al. [4] investigated performance of Ni-Al₂O₃ based composite coatings. The authors found that fracture toughness controls the erosion resistance of coatings. It was also found that the content of alumina have significant influence on erosion performance of the coatings. Wood et al. [5] studied the surface response of stainless 316 alloy. The authors tested the samples in slurry pot apparatus using 1% uncrushed silica at 7m/s for 60min, both in water and 3.5% NaCl solution. Influence of cooling rate on the microstructure and wear performance of Fe-Cr-C

hardfacings was studied by Hornung et al. [6]. Kin et al. [7] investigated the effect of manganese and boron on the erosion behavior of austenitic Fe-Cr-C-Si-xMn-yB ($x = 0, 10 \text{ wt\%}, y = 0, 0.3 \text{ wt\%}$) hardfacing alloys. Tefler et al. [20] make a comparison between erosion-corrosion mechanisms of Fe, Ni, Al, and Cu under different conditions of particle size and concentration. Bermudez et al. [8] investigated erosion-corrosion behavior of stainless steel AISI 304L and 316L. It was found that higher amount of mass loss was due to angular silicon carbide particles. Singh et al. [9] investigated the effect of various parameters on slurry erosion mechanism of uncoated and coated CA6NM steel. It was found that maximum erosion takes place at 90° impingement angle. The SEM analysis revealed that erosion mechanism of CA6NM steel under normal impact is platelet mechanism but for coating under similar condition is due to crack formation. It is clear from the literature survey that many authors have done studies of erosion performance of different type of coatings, but less literature is available on erosion behaviour of hard facing alloys. Therefore, in this research work slurry erosion behaviour has been investigated by studying the effect of hard facing of SS 304 with hard alloy III and Titanium alloy. Hard facing is comparatively less expensive than the coatings, and it increases the erosion resistance of different types of steels.

2. Experimentation

Test Material

The substrate material was selected on the basis of its cost and the availability. The SS 304 material was procured from Bombay Steels, Ludhiana (Punjab). The detailed composition of material used i.e. SS 304 is shown in table 1.

Hard Facing

The hard facing of SS 304 was done with submerged arc welding technique with Hard Alloy III and Titanium alloy. The two types of hard facing coatings were obtained from these two alloys. The hard-facing of SS 304 was done at Punjabi university, Patiala.

Table 1. Chemical composition of SS 304

Element	C	Si	Mn	P	S	Cr	Mo	Ni	Co	Ti	V	Fe
% age	0.078	0.346	1.02	0.031	0.006	18.78	0.203	8.18	0.07	0.003	0.064	71.12

Figure 1. Jet Erosion Tester

Experimentation Apparatus

Figure 1 shows the test apparatus which has been designed and developed at Punjabi University, Patiala.

3. Results and Discussions

Erosion Performance of SS 304, Hard Alloy III and Titanium coating

The erosion performance of SS 304, Hard Alloy III and Titanium coating has been evaluated by varying velocity, impact angle and concentration level. The effect of time on weight loss while varying different parameters is also evaluated with effect of each parameter. The effect of time on weight loss is reported first. Nine experiments were performed for each parameter. Hard alloy III hard facing is named as Alloy 1 and hard facing of titanium is named as Alloy 2

Table 2. Mass loss in mg/cm² w. r. t. time at various runs for hard alloy III

	0 min	30 min	60 min	90 min	120 min
Run 1	0	0.5333	1.0666	1.8666	2.4
Run 2	0	0.8	1.4666	2.6666	3.8666
Run 3	0	2	3.0666	5.6	7.7333
Run 4	0	0.6666	1.4666	3.3333	5.2
Run 5	0	0.8	2.1333	3.3333	4.5333
Run 6	0	0.5333	1.4666	3.0666	4.6666
Run 7	0	0.9333	2.8	4.8	6.2666
Run 8	0	0.8	2.1333	3.4666	5.7333
Run 9	0	1.3333	2.8	4.6666	6

Mass loss for Hard Alloy III at different runs

The mass loss for hard alloy III at different experimental runs is shown in table 2.

Figure 2 shows the mass loss at various time intervals for all nine experimental runs. It is clear that erosion is maximum for run 3, where velocity is 60 m/sec, concentration is maximum, the angle of impingement if 90°. Similar results have been reported by Singh et al. [9].

Mass loss for titanium based hardfacing at different runs

The mass loss for titanium based hard facing at all nine experimental is shown in table 3 and figure 3 shows the comparative line chart for all runs.

Table 3. mass loss in mg/cm² w. r. t. time at various runs for titanium based alloy

	0 min	30 min	60 min	90 min	120 min
Run 1	0	0.4	0.9333	1.4666	2
Run 2	0	0.5333	1.2	2.1333	3.0666
Run 3	0	1.3333	2.8	5.2	7.4666
Run 4	0	0.4	1.0666	1.8666	3.0666
Run 5	0	0.5333	1.4666	3.0666	4.1333
Run 6	0	0.4	0.8	2.4	3.6
Run 7	0	0.4	0.9333	1.8666	3.0666
Run 8	0	0.6666	1.4666	2.9333	4.2666
Run 9	0	0.9333	2	4.2666	5.4666

Figure 2. Mass loss for hard alloy III at different runs

Figure 3. Mass loss for titanium based Hardfacing at different runs

It is clear that erosion is maximum for run 3, where velocity is 60 m/sec, concentration is maximum, the angle of impingement if 90° . The erosion is minimum for experiment run number 7 which is at 30° impingement angle. Similar results have been reported by Singh et al. [9].

Mass loss for uncoated SS 304 steel at different runs

Table 4 and figure 4 show the mass loss in mg/cm^2 w. r. t. time at various runs for SS 304 steel.

It is clear that erosion is maximum for run 3, where velocity is 60 m/sec, concentration is maximum, the angle of impingement if 90° and minimum for run 7, where the angle is 30° . Similar results have been reported by Singh et al. [9].

Table 4. Mass Loss with respect to time

	0 min	30 min	60 min	90 min	120 min
Run 1	0	0.5333	1.2	1.8666	2.6666
Run 2	0	1.2	2	3.2	5.6
Run 3	0	2.4	5.6	8.1333	10.9333
Run 4	0	1.3333	2.1333	4.2666	6
Run 5	0	1.2	2.5333	4.5333	7.7333
Run 6	0	1.066	2.4	3.8666	5.8666
Run 7	0	1.3333	2.5333	4.9333	7.3333
Run 8	0	1.4666	3.0666	5.2	6.9333
Run 9	0	1.8666	3.8666	6.5333	10.2666

Figure 4. Mass loss for uncoated SS 304 steel at different runs

4. Sem Analysis

The SEM analysis of samples used for erosion purpose was examined at the Sophisticated Instrument Centre, Punjabi University, Patiala with help of scanning electron microscope (JSM 6510) to visualize change in microstructure in order to know the mechanism of erosion.

Figure 5. SEM micrograph of Hard Alloy III

The figure 5 shows the SEM micrograph of hard alloy III at conditions 150 μ m particle size, 10000 ppm concentration level, 20 m/sec velocity and 30° angle of impingement. At these conditions least erosion has been studied and defects occurred are ploughing and platelet defects.

Figure 6. SEM micrograph of titanium based alloy

The figure 6 shows the SEM micrograph of Titanium at conditions 150 μ m particle size, 10000 ppm concentration level, 20 m/sec velocity and 30° angle of impingement. At these conditions least erosion has been studied and defects occurred are ploughing and micro cutting defects.

Figure 7. SEM micrograph of SS 304 at 150 μ m particle size, 10000 ppm concentration level, 20 m/sec velocity and 30° angle of impingement

The figure 7 shows the SEM micrograph of SS304 at conditions 150 μ m particle size, 10000 ppm concentration level, 20 m/sec velocity and 30° angle of impingement. At these conditions least erosion has been studied and defects occurred are chip formation, micro cutting, lip fracture, platelet and crater defects.

Figure 8. SEM micrograph of SS 304 at 150 μ m particle size, 30000 ppm concentration level, 60 m/sec velocity and 90° angle of impingement

The figure 8 shows the SEM micrograph of SS304 at conditions 150 μm particle size, 30000 ppm concentration level, 60 m/sec velocity and 90° angle of impingement. At these conditions more erosion has been studied and defects occurred are micro cutting and cutting action defects.

4. Conclusions

The conclusions of the experimentation result are listed below:

- The comparison of mass loss shows that erosion rate of SS 304 is more than hard Alloy III and titanium based alloy.
- Erosion resistance of titanium based alloy is better than hard alloy III.
- Hardfacing show better performance than uncoated SS 304 alloy in all experimental conditions.
- For all hard facings, the maximum erosion is at 90° impact angle and minimum erosion is at 30° .
- The SEM analysis shows that erosion mechanism of under normal impact is platelet mechanism and for substrate material it is due to crack formation.

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