



Comparative study of the effect due to slurry concentration and normal load on wear life of Mild steel and hard faced Martensitic stainless steel

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Abstract: Wear is defined as removal of material from solid surfaces as a result of mechanical action. It is a characteristic feature of the wear process that the amount of material removed is quite small. However wear in sliding systems is usually a very slow process that is very steady and continuous. Slurry abrasion is defined as progressive loss of material from the component in which liquid media carries abrasive particles. The wear life of components used under slurry abrasion conditions is governed by the process parameters, properties of abrasive particles in slurry and material properties. Extruders, slurry pumps, and pipes carrying slurry of minerals and ores in mineral processing industries are subjected to slurry abrasion. The objective of project work is to study slurry abrasion behaviour on weld deposited hard faced martensitic stainless steel. The result of present work shall be useful in development of alloys for slurry abrasion applications. The slurry abrasion experiments were performed using slurry abrasion tester. Silica sand was used as abrasive particles for both mild steel as well as hard faced martensitic stainless steel. The effect of test parameters such as slurry concentration and normal load on slurry abrasion volume loss was investigated. The results of investigation suggest that slurry concentration had relatively stronger effect on mild steel specimens as compared to hard faced martensitic stainless steel specimens operated under a normal load and abrasion tester revolution. Scanning electron microscope studies revealed different morphology of the worn surfaces which was attributed to different slurry abrasion test conditions.

Keywords: Mild steel, hard faced martensitic stainless steel, wear, normal load, slurry concentration

I. Introduction

The wear is basically the process of actual peeling off the surface of a material due to the mating of two solid bodies. This ultimately leads to the change in dimension of the respective material which makes the material to loose down and subsequent improper operation. The most important wear which leads to maximum destruction to industries was wear due to abrasion. It accounts more than 50% of wear failure occurs in extruders, slurry pumps, pipes etc. which not only responsible for material degradation but leads to premature failure of machine components. Abrasive wear is commonly classified according to the type of contact and the contact environment which determines the mode of abrasive wear. Abrasive wear is the removal of material by ploughing, cutting, or scratching processes. Abrasive wear is the removal of material by ploughing, cutting, or scratching processes. Abrasive wear only occurs when the sharp materials produce loose grains that have a higher hardness than the surface subject to the abrasive wear. Wear rates are controlled by a balance between the rates of wear, particle generation and particle loss. Particle generation rates are influenced by many factors including the nature and amount of retained particles. But our study deals with the effect of slurry abrasion which is basically the progressive loss of materials from the component when liquid media carries abrasive particles. The evaluation of slurry abrasion under actual service conditions is a difficult task to handle because it depends on lots of different parameters like slurry concentration, flow rate of abrasive particles, velocity and properties of abrasive medium [1-4]. The wear life of the components used under slurry abrasion conditions is governed by various process parameters like slurry concentration, velocity and properties of abrasives. Most of the engineering components are made up of steels and cast irons which enhance the wear life of components under abrasive wear situations. Most of the work is already performed to know the wear resistance behaviour of steels which is influenced by properties of abrasives used, working conditions and mechanical and material properties also [4,5,6-12]. Hard facing by welding is one of the lean method to improve the abrasion resistance of engineering components. In present work as very little investigation had been done on the slurry abrasion behaviour on weld deposited hard faced martensitic stainless steel, experiments were performed using silica sand slurry with

different slurry concentrations ranging from 0.4 gm/lit to 1.5 gm/lit considering normal load of 120N and at total revolution of 2000 revolutions which was kept constant for slurry abrasion wear testing machine. The morphology of the worn out surfaces of the mild steel and hard faced martensitic stainless steel specimens under varying slurry concentrations, normal load and revolutions was studied under scanning electron microscope. The morphological studies of the worn out surfaces revealed the characteristics differences in the wear pattern under different slurry concentrations.

II. Experimental Details

The slurry abrasion experiments were carried out on the mild steel and hard faced martensitic stainless steel by manual metal arc welding process over 10mm thick mild steel plate. The consumable used for deposition was in the form of electrodes. The welding parameters were; Voltage ~ 22 V and current ~ 120 A (direct current). The thickness of weld deposit was typically 4mm. The chemical compositions of the investigated mild steel (Table I) and hard faced martensitic stainless steel (Table II) is given below, determined by spark emission spectroscopy was:-

Table I Chemical composition of mild steel

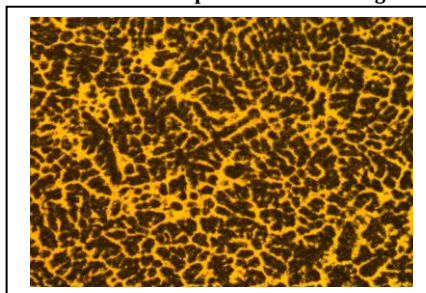
Element	C	Si	Mn	Cr	Ni	Cu	P	S	Fe
Wt.%	0.118	0.229	0.806	0.0407	0.009	0.0065	0.0296	0.0174	Balance

Table II Chemical composition of hard faced martensitic stainless steel

Element	C	Si	Mn	Cr	Ni	Mo	P	S	Fe
Wt.%	0.052	1.07	2.54	15.25	3.64	0.0491	0.0339	0.0167	Balance

The specimens for chemical analysis, metallography and abrasion testing were ground and polished with successive silicon carbide emery papers of grade 1/0, 2/0, 3/0 and 4/0, after that the specimens were subjected to alumina wheel polishing to obtain excellent surface finish. The well-polished specimen of mild steel & hard faced martensitic stainless steel was etched with kalling's etching reagent to reveal the microstructure shown in Figure 1. Silica sand was used as abrasive particle in slurry abrasion test. Abrasive particle used was required sieves to obtain 250-300 μm , size which was obtained by sieve analysis. The abrasive particles were having irregular to angular shapes.

Figure 1 Microstructure of weld deposited steel showing martensite at 200X



The slurry abrasion wear tests were performed using slurry abrasion test apparatus (Ducom make, India) whose photograph is shown in Figure 2. Ducom TR 44 test instrument is designed such that a flat test sample is pressed radially against a wheel with a known force. The test area is submerged in wet abrasive media (slurry). The arrangement is such that the wheel carries the abrasive media between the sample and the wheel creating a scenario of three body wear using the slurry in the chamber. This testing machine allows users to test under a variety of loads, flow rates and types of abrasive media. Loss of weight of test specimens indicates wear resistance. Slurry abrasion tester is designed to evaluate the resistance of material to slurry abrasion using a wet abrasive media and a rubber wheel. This technique is used to determine the accurate wear result of mild steel as well as hard faced martensitic stainless steel in liquid media at various slurry concentrations. Specimens used for slurry abrasion testing were rectangular blocks measuring 57.2 mm (length) $\times$ 25.4 mm (width) $\times$ 9 mm (thickness). The specimens were polished using emery papers of 1/0 and 2/0 and cleaned with alcohol and dried with compressed air and then weighed using a digital electronic balance to the accuracy of 0.1 mg. The specimen was placed in the holder assembly. The desired load was placed on the loading lever and loading lever was released so that specimen comes in contact with rubber wheel. After the test was over the specimens were

removed from the slurry chamber, cleaned with alcohol and weighed. The weight loss (ΔW) was calculated as the difference of initial weight (W_i) and final weight (W_f) of the specimen. In addition wear volume loss (ΔV) was also determined along with sliding distance (S). In the present work slurry abrasion tests were carried out on mild steel as well as on hard faced martensitic stainless steel. The size of particles used in experiment is 250-300 μm . The total numbers of revolutions were 2000, which was kept constant in all the tests.

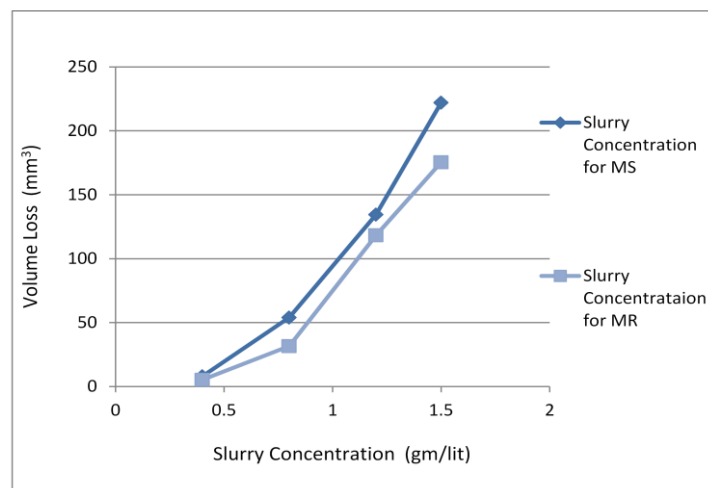
Figure 2 Photograph of the slurry abrasion test apparatus



III. Results and Discussions

In the present work two different approaches were used to study slurry abrasive behaviour of mild steel and weld deposited hard faced martensitic stainless steel. The first approach aimed at measurement of material loss and second approach was based on visual and microscopic observations of work out surfaces. Figure 3 shows the effect of varying slurry concentrations on wear volume loss of mild steel as well as hard faced martensitic stainless steel specimens at a normal load of 120N and 2000 revolutions.

Figure 3 Effect of varying slurry concentrations on wear volume loss of mild steel (MS) and hard faced martensitic steel (MR)



The slurry abrasion wear test of mild steel at varying slurry concentrations are given below in Table III while for hard faced martensitic stainless steel are given below in Table IV.

Test data for specimen of mild steel at 120N & varying slurry concentration:-

1. Size of specimen 57.2× 25.4 ×9 mm
2. Density of specimen 7.889 gm/cc (constant)
3. Abrasive particle size 250-300 μm
4. Normal load 120 N

Table III Test data values of slurry abrasion wear test on mild steel at varying slurry concentrations

S.N	Slurry Concentration. (gm/lit)	Initial weight W_i (gm)	Final weight W_f (gm)	Weight loss ΔW (gm)	Volume loss ΔV (mm ³)	Sliding distance S(m)
1.	1.5	120.514	118.76	1.754	222.02	88
2.	1.2	117.799	116.738	1.061	134.50	86
3.	0.8	122.768	122.342	0.425	53.98	84
4.	0.4	136.021	135.957	0.063	8.087	81

Test data for specimen of hard faced martensitic stainless steel at 120N & varying slurry concentration:-

1. Size of specimen 57.2× 25.4 ×9 mm
2. Density of specimen 7.889 gm/cc (constant)
3. Abrasive particle size 250-300µm
4. Normal load 120 N

Table IV Test data values of slurry abrasion wear test on hard faced martensitic stainless steel at varying slurry concentrations

S.N	Slurry Concentration. (gm/lit)	Initial weight W_i (gm)	Final weight W_f (gm)	Weight loss ΔW (gm)	Volume loss ΔV (mm ³)	Sliding distance S(m)
1.	1.5	120.608	119.223	1.3846	175.510	86
2.	1.2	111.988	111.055	0.9336	118.341	82
3.	0.8	123.873	123.624	0.249	31.5629	81
4.	0.4	115.476	115.435	0.0413	5.23513	78

With increase in slurry concentration, slurry abrasion volume loss increased. For mild Steel and hard faced martensitic stainless steel specimen abrasion wear test was performed at 2000 revolution, 120 N & particle size 250-300µm, at slurry concentration of 0.4 gm/lit. the volume wear loss for mild steel was 8.087 mm³ and for hard faced martensitic stainless steel 5.235mm³ which is 1.6 times less than volume wear loss of mild steel and at slurry concentration of 0.8gm/lit volume wear loss for mild steel was 53.98mm³ and for hard faced martensitic stainless steel 31.56mm³ and at slurry concentration of 1.2gm/lit. the volume wear loss for mild steel was 134.503mm³ and for hard faced martensitic stainless steel it was 118.34mm³ and for slurry concentration of 1.5gm/lit. the volume wear loss for mild steel was 222.081mm³ and for hard faced martensitic stainless steel 175.510 mm³ as shown in Table III and Table IV it has been seen that for every slurry concentration the volume wear loss for mild steel is more than hard faced martensitic stainless steel because hard faced martensitic is a hardfaced steel which has 55HRc hardness as compared to 25HRc of mild steel.

It is also observed from the results of present work that wear volume loss obeys Archard's wear law;

$$V = K S L / H \quad (1)$$

Where V is volume loss, K is wear coefficient, S is sliding distance, L is normal load and H is the hardness of the surface [2]. However at higher loads and slurry concentrations some deviations were observed. It is also observed that slurry concentrations had relatively stronger influence on wear loss as compared to normal load [4, 13-14]. The photographs of worn out surfaces in Figure 4 shows deep grooves and scratches on the surface at higher slurry concentrations whereas at lower slurry concentrations the surface is relatively smooth. The material is removed by ploughing mechanism and lip of work hardened material can be seen attached to the grooves. It is also observed that with increasing normal load silica sand particles fractures generating additional fine particle which tends to have more angularity results in additional abrasion of surface and contribute to increase in wear volume loss [15].

Figure 4 shows photographs of typical worn out surfaces of mild steel and hard faced martensitic stainless steel at slurry concentrations of 0.4 gm/ lit (minimum wear) and 1.5 gm/lit (maximum wear).

Figure 4 Photographs of worn out surfaces after slurry abrasion at a load of 120N

S N	Slurry Concentration (gm/lit)	Mild Steel	Martensitic stainless steel
1.	0.4		
4.	1.5		

Figure 5 shows SEM photographs of worn out surfaces of mild steel at 1.5gm/lit (maximum wear) slurry concentration.

Figure 5 Effect of 1.5 gm/lit slurry concentration on mild steel at 120N load, 2000 revolutions and 200-

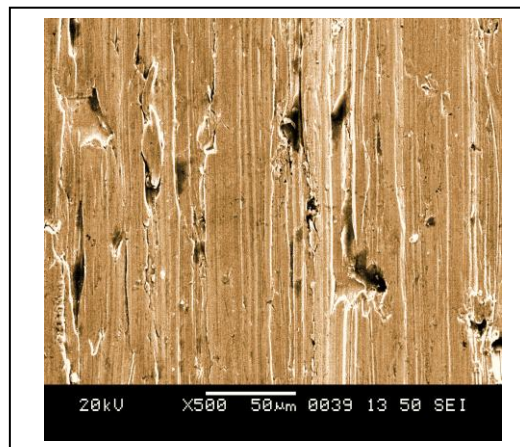
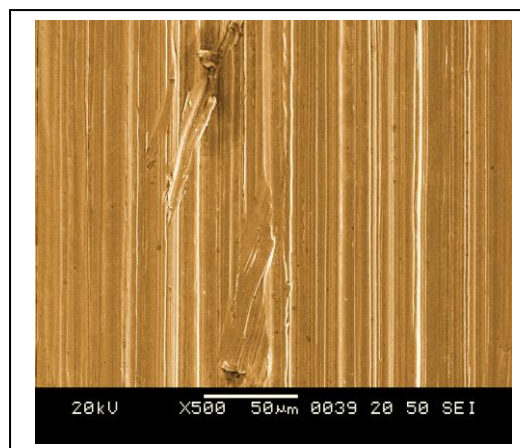


Figure 5 shows SEM photographs of worn out surfaces of hard faced martensitic stainless steel at 1.5gm/lit (maximum wear) slurry concentration.

Figure 5 Effect of 1.5 gm/lit slurry concentration on hard faced martensitic steel at 120N load, 2000



The above observations can explain significant increase in slurry abrasion volume loss with increase in slurry concentrations which can also explain deviations from Archard's equation at higher loads and higher slurry concentrations.

IV. Conclusions

- (1) The slurry abrasion volume loss of mild steel will be more as compared to hard faced martensitic stainless steel with varying slurry concentration.
- (2) The slurry concentration had more pronounced effect on slurry abrasion volume loss than normal load.
- (3) The morphology of worn out surfaces was influenced by test conditions.
- (4) The important mechanisms of material removal were ploughing, cutting and indentation. The predominant mechanisms of material removal by abrasion were influenced by severity of test conditions.
- (5) The slurry abrasion wear volume loss obeyed Archard's wear law although some deviations were observed at higher slurry concentrations which can be attributed to secondary abrasion caused by fragmented abrasive particles.

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