Analysis of Erosion wears on coated and uncoated ductile material.

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Abstract—The base material is taken as steel for the study of erosion wear of pumps and piping system. To improve the wear resistance of 18Cr8Ni steel powder coatings is done by HVOF thermal spray coating method. The erosion wear evaluated with varying the parameters impact angle, flow rate and time and using jet tester as test apparatus. Weight loss of specimens is the measure of erosion wear. In present erosion wear study, 18Cr8Ni steel used as base material. This material is currently being used for fabrication of pumps for different applications and under water parts in hydroelectric projects because its nickel content, associated with low carbon ensures better erosion resistance, weld ability, ductility, impact resistance and fatigue resistance properties. This steel alloy has also good corrosion resistance to fresh water and performs well under erosion-corrosion phenomena. The alloy is specially designed for all applications requiring high mechanical properties combined with high toughness and may be used in erosive - corrosive conditions. Typical applications are shafts or pump impellers, particularly for hydraulic applications.

The experiments are conduct at different impact angles, slurry flow rates, and different time.

Keywords—Ductile materials [coated and uncoated steel], slurry, jet erosion tester and different working conditions (impact angles, slurry flow rates and times).

1. INTRODUCTION

Wear is most common problem occurs in the industry like Mining industry, food processing industry, hydro power plants and thermal power plants in which mixture of solid and liquid is transported from one place to another place with the help of the pumps and pipes. Water is used as carrying medium. Erosion of ductile materials due to slurries occurs in many engineering applications.

Wear is the loss of material from a component due to a mechanical interaction with another object. Many types of solids, liquids, and even high-velocity gases can remove material and change the physical dimensions and functionality of a part. Corrosion and erosion are the main causes of wear. Erosion wear is due to exposure to moving liquids and gases, which may or may not contain hard particles. Effect of erosion wear in slurry pumps and pipes is predominantly more as compared to the corrosion. The service life of equipment of slurry transport system is reduced by erosion caused by solid-liquid mixture following through the slurry transport system. So slurry erosion is important field should be investigated.

1.1 Mechanism of Erosion wears

To identify the effect of parameters it is necessary to understand the mechanism of material removal due to erosion wear. Erosion wear depends on impact angle, impact velocity, erodent material, carrier fluid, erodent size and shape, and target material. Both ductile and brittle material show different erosion wear mechanism. The erosion wear mechanism are classified as cutting, plugging and subsurface deformation and cracking.

Cutting Mechanism

Wear occurs when a hard particle cuts through a soft target material. Cutting mechanism takes place when the impacting particle contacts the target material at positive rack angle and cut a chip from target material resulting in the generation of new surface. The shape of impinging particle is main factor in cutting wear. Angular shaped impinging particles claims higher wear

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due to cutting. Because sharp edges of incident particles act as a cutting tool. The shape of abrasive particle is main factor in cutting wear.

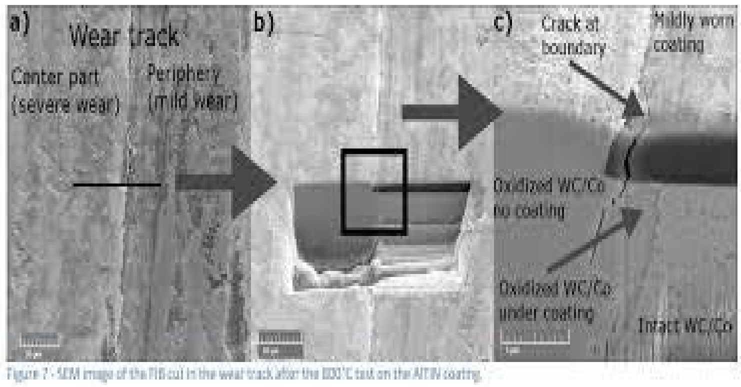


Figure 1.1.1 Cutting Mechanisms (Reference-Scholarly articles of cutting mechanism SEM view)

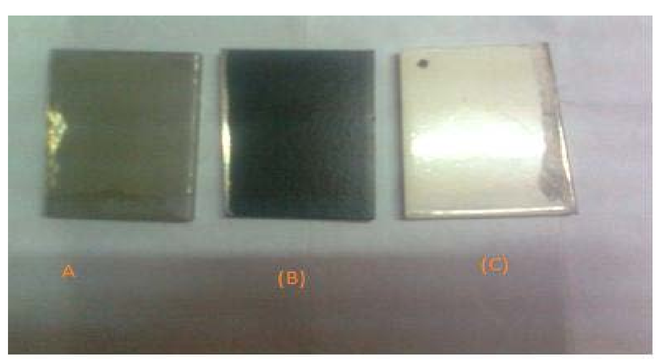
2. EXPERIMENTAL PROCEDURE

2.1 Raw materials

In present erosion wear study, 18Cr8Ni steel used as base material. This material is currently being used for fabrication of pumps for different applications and under water parts in hydroelectric projects because its nickel content, associated with low carbon ensures better erosion resistance, weld ability, ductility, impact resistance and fatigue resistance properties. This steel alloy has also good corrosion resistance to fresh water and performs well under erosion-corrosion phenomena. The alloy is specially designed for all applications requiring high mechanical properties combined with high toughness and may be used in erosive - corrosive conditions. Typical applications are shafts or pump impellers, particularly for hydraulic applications.

2.2SAMPLES PREPARATION

The steel mostly used in slurry transportation system i.e. 18Cr8Ni is to be used for erosion wear testing purpose. By using power hacksaw, the samples of 5 mm thickness are cut from a long bar of cross-sectional area. Surface grinder is used to finish the surface of each sample. As per the requirement the coating of Epoxy Polyester and Epoxy Powder is to be done on the sample by Powder coating technique. The samples were used from both sides for testing for coated and non-coated materials.



(a)Uncoated 18Cr8Ni Steel (b) Epoxy Powder coated (c) Epoxy Polyester Coated Steel
Figure 2.2.1 Samples Images

The coating of Epoxy Polyester and Epoxy Powder over the samples is done with Powder coating technique, at Ravi Forb infotech Ambala. Abrasive blasting is done on the samples by alumina grits before applying the coatings. Grit blasting of samples is necessary before applying the coating so as to supplement the adhesion of the coatings to the surface of sample.

2.3 EXPERIMENTAL SETUP

The jet erosion tester (figure 2.4.2 consists of a centrifugal pump, conical tank, nozzle, specimen holder, valves and flow meter. The centrifugal pump is driven by a 7.5 HP, 1400 rpm electric motor having a capacity of max pressure 13.5 bar at a discharge of 240L/min. Slurry available in conical tank is sucked through a 100mm GI pipe with help of pump and delivered to the nozzle through 25 mm pipe having control valves and electromagnetic flow meter located at upstream. Slurry is re-circulated during test. The mechanical action of slurry pump increase the temperature of slurry to a certain level and thereafter it remains constant. The flow rate of the slurry is controlled with help of main valve and bypass regulator valve between delivery side and nozzle. The tank is rectangular tapered having size 650×650 mm at top which converges to 100×100 mm at the bottom through a length of 700 mm is used to store the slurry. A mesh is provided in the bottom of the tank to avoid the object from falling into the tank and get struck inside the pipeline. Slurry flowing through the pump at high pressure is converted into high velocity stream while passing through the converging section of the nozzle, which is 125mm long, and having diameter of 8 mm. The standoff distance between the nozzle and specimen can be varied from 25mm to 90mm. The slurry falls back into the tank after striking to specimen. The holder is located on the top of tank enclosed in a casing made of steel angle and fitted with fiber sheet, to facilitate the removal and clamping of the specimen. The electronic magnetic flow meter (Elmag-200M arranged in between control valves and nozzle, is equipped with digital display and contains PTEF coated liner through which the slurry flows and discharge is calculated, when a conductive fluid passes through magnetic field (applied a voltage is induced in an electrically conductive body which is proportional to the mean flow velocity according to Faraday's law of induction.

I. Centrifugal pump.
II. Electronic magnetic flow meter.
III. Nozzle and holder assembly.
IV. Conical tank.

2.4 EXPERIMENTAL PROCEDURE

Erosion wear experiments performed through a sequence of steps, in which most of the observations recorded manually and graphs plotted accordingly.

The mass loss of the specimen after each test is the measure of erosion wear. The sequence of steps of experimental procedure is as given below

(i) The wear sample is rinsed in acetone and clean with emery paper.
(ii) Dry the sample properly.
(iii) Weighing the specimen (initial weight).
(iv) Fix the sample in holder.
(v) Set the holder at a certain angle.
(vi) Weight the required amount of fly ash as per concentration of slurry.
(vii) Mixing the proper amount of water and fly ash in tank.
(viii) Start the pump.
(ix) Control the slurry flow rate by mean of flow meter and a by-pass valve to obtain desired value of velocity.
(x) Perform the test for different flow rate, impact angle and required time interval.
(xi) Unclamp the specimen from specimen holder.
(xii) Cleaning specimen with acetone and drying it.
(**xiii)**Weighing the specimen after erosion to measure the mass loss. For further observations repeat the procedure steps from 4 to 13 as per requirement.

Dimensions of Specimen	40 mm × 40 mm × 5 mm
Flow Rate	Maximum 3.5 lit/sec
Angle	30°,60° and 90°
Slurry Concentration	20% by weight
Fly Ash particle Size	50 -350 micron
Time	Maximum 4 hours
Nozzle Diameter	8 mm
Stand Off Distance	45 mm

Table 2.4.1Experimentation Parameters

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Figure 2.4.2 Jet Erosion Testers

3. Results and discussion

The erosion wear tests of coated and uncoated 18Cr8Ni steel were performed at various ash particles impingement angles, flow rate and time. The particle size of the fly ash used in this experimentation was varied between 50 and 350 μm and 20% slurry concentration was taken. The results of wear with all above mentioned parameters will be discussed in this chapter.

3.1 EFFECT OF FLOW RATE ON EROSION WEAR

To study the effect of flow rate on erosion wear of 18Cr8Ni steel and same with coatings of Epoxy Polyester and Epoxy Powder coating the wear tests are performed at three different flow rates 1.5 lit/sec, 2.5 lit/sec and 3.5 lit/sec. The effect of flow rate is be calculated by measuring the weight loss at each level of flow rate. The effect of increase in flow rate on weight loss and comparison of effect of flow rate on coated and uncoated steel. From it is clear that with the increase in flow rate erosion wear also increases. The weight loss increases with increase in flow rate is because of the increase in impingement velocity of solid particles of slurry and hence kinetic energy of impacting particles increases. This increased of kinetic energy of ash particles imparted to target surface and results in higher deformation and weight loss. The curve of uncoated steel shows a little increase in weight loss initially but a larger weight loss is reported after a flow rate of 2.5 lit/sec. The erosion of coatings takes place by fatigue mechanism leading to micro cracks. The high kinetic energy of solid particles of slurry causes the cracks and with repetitive action, the fracture of coatings takes place with advancing of these cracks. Both coating clearly shows better erosion wear resistance than 18Cr8Ni steel at all different levels of flow rates. Among the both coating, Epoxy Powder coating shows better resistance to erosion wear than Epoxy Polyester coating.

3.2 EFFECT OF IMPACT ANGLE ON EROSION WEAR

The angle at which fly ash particles impacted at sample surface has a significant effect on erosion wear and its mechanism.

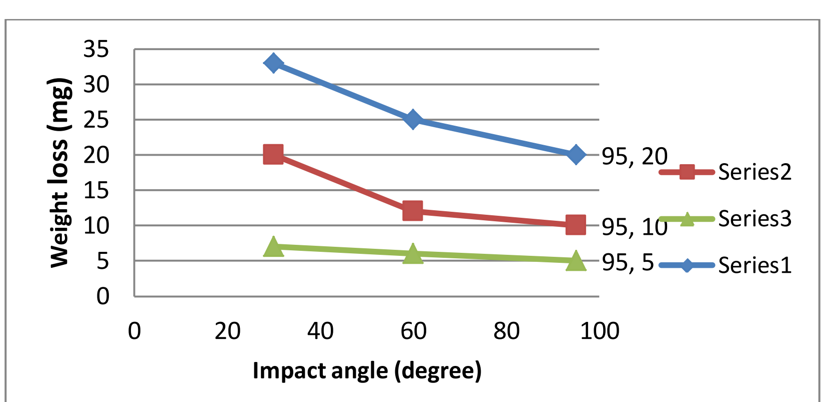

Figure 3.2.1 Variation in weight loss with respect to different impact angle at different flow rate.

Series1 uncoated, Series2 Epoxy Powder coating, Series3 Epoxy Polyester coating

Figure3.2.1 and table 3.2.1 shows the effect of impact angle on erosion wear of 18Cr8Ni steel, Epoxy polyester and Epoxy Powder coatings. The erosion wear of different samples evaluated at three different impact angles 30°, 60° and 90°. Among all the three impact angles, 30° impact angle shows the maximum erosion wear and impact angle 90° shows minimum erosion wear. Higher erosion wear at 30^0 impact angle indicates that 18Cr8Ni steel is ductile material.

Higher erosion wear at 30° is because of the presence of austenitic phase. At lower angle micro cutting and ploughing mechanisms are predominant. The tangential component of velocity is responsible for higher erosion wear at lower angles. At higher angles, crack intimation is more predominant and responsible for erosion wear of materials. At higher angle, the normal component of velocity is responsible for erosion wear. The plastic deformation of surface and work hardening are the phenomenon, which occurs at higher angles and leads to reduction in weight loss. Erosion at 90^0 is because of normal component of velocity, causing fatigue and fracture of grain boundaries.

Time (hr)	WEIGHT LOSS IN MILLIGRAMS								
	At Impact Angle 30°			At Impact Angle 60°			At Impact Angle 90°		
	Uncoated Steel	Epoxy Polyester Coated	Epoxy Powder Coated	Uncoated Steel	Epoxy Polyester Coated	Epoxy Powder Coated	Uncoated Steel	Epoxy Polyester Coated	Epoxy Powder Coated
1	30	15.5	8	20.5	12.5	5	17	9.75	3
2	32.5	19	10.5	29.5	15.5	10.25	20	13.5	9
3	37.5	21.5	14	38	19	14.5	23	16	11

Table3.2.1 Variation in weight loss with respect to time and impact angle at 2.5 lit/sec slurry flow rate

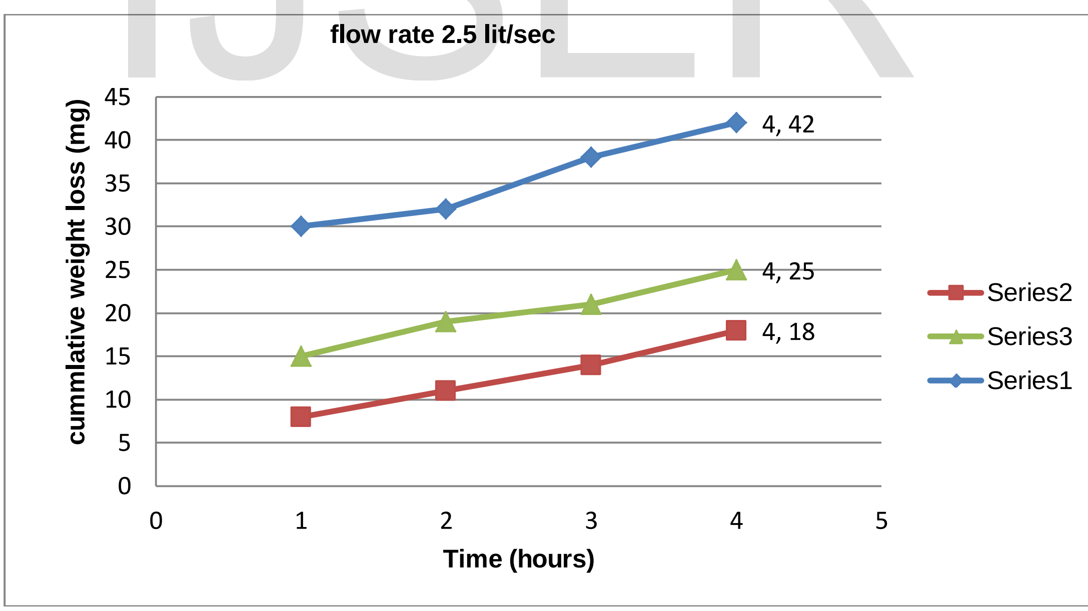

Figure 3.2.2 Variation in cumulative weight loss with respect to time at 30° impact angle
Series1 uncoated, Series2 Epoxy Powder coating, Series3 Epoxy Polyester coating

During the experimentation on 18Cr8Ni with the velocity rate of 2.5lit/sec with a striking angle of 30 degrees there is an increased in metal loss is observed with increased velocity rate. During the experimentation work in first two hours there is loss of 7 mg of metal in epoxy powder coating whereas as this loss of metal is higher in epoxy polyester coating about 15 mg. While the loss of metal in uncoated metal strips of 18Cr8Ni is about 30 mg.

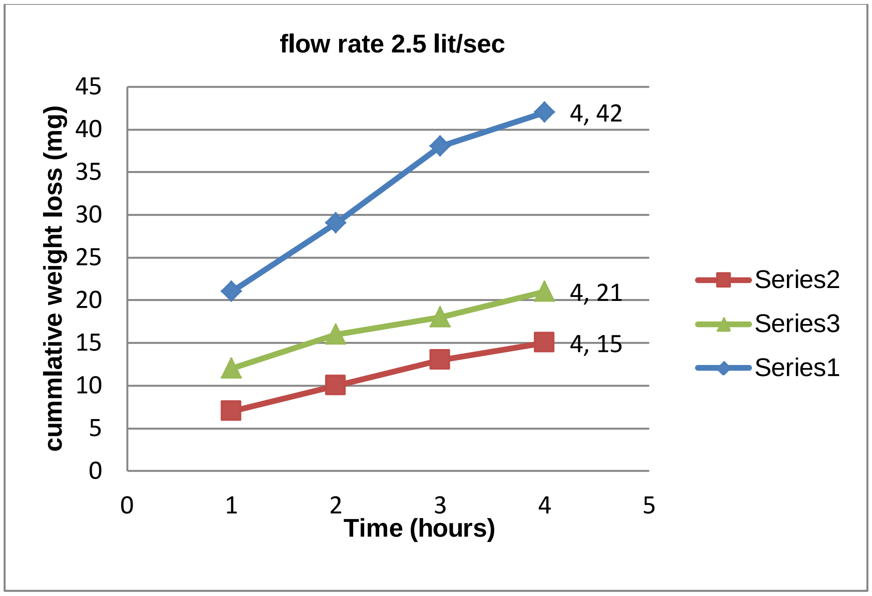

Figure 3.2.3 Variation in cumulative weight loss with respect to time at 60° impact angle
Series1 uncoated, Series2 Epoxy Powder coating, Series3 Epoxy Polyester coating

During the experimentation on 18Cr8Ni with the flow rate of 2.5lit/sec with a striking angle of 60 degrees there is an increased in metal loss is observed with increased velocity rate. During the experimentation work in first two hours there is loss of 5 mg of metal in epoxy powder coating whereas as this loss of metal is higher in epoxy polyester coating about 12 mg. While the loss of metal in uncoated metal strip of 18Cr8Ni is about 21 mg.

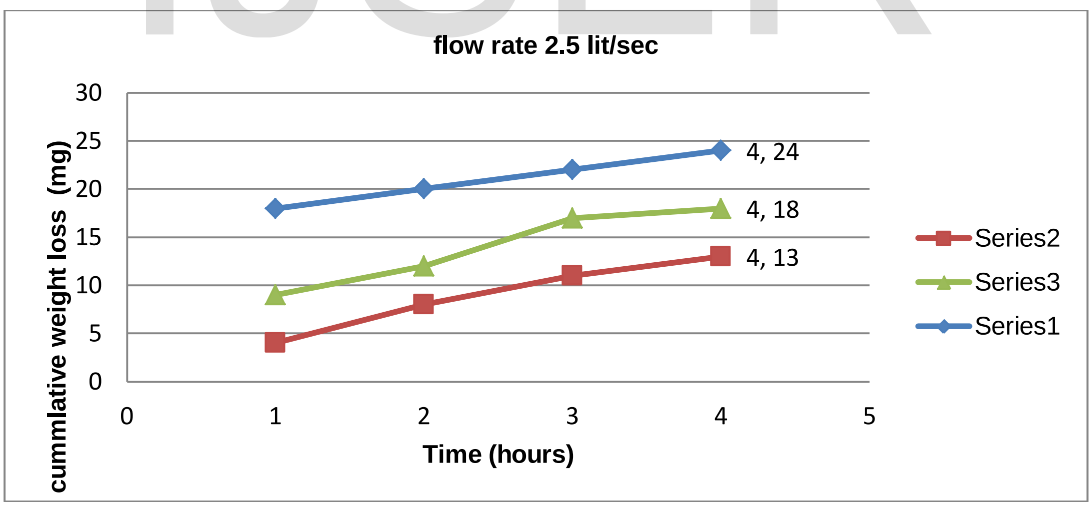

Figure 3.2.4 Variation in cumulative weight loss with respect to time at 90° impact angle
Series1 uncoated, Series2 Epoxy Powder coating, Series3 Epoxy Polyester coating

During the experimentation on 18Cr8Ni with the velocity rate of 2.5lit/sec with a striking angle of 90 degrees there is an increased in metal loss is observed with increased velocity rate. During the experimentation work of four hours there is loss of 14 mg of metal in epoxy powder coating whereas as this loss of metal is higher in epoxy polyester coating about 18 mg. While the loss of metal in uncoated metal strips of 18Cr8Ni is about 25 mg.

3.3 EFFECT OF TIME ON EROSION WEAR

The effect of time on erosion wear is determined by calculating the cumulative weight loss of specimen. To understand the effect of time on erosion wear, a graph (figure 3.3.1) is plotted between cumulative weight loss and time at a flow rate of 3.5 lit/sec. The erosion wear test duration was up to 4 hours and impact angle was 90°. It can be clearly seen in graph that amount of material loss increase with time. It slope of graphs is almost same throughout the run. It shows that the nearly equal amount of weight get lost in each interval of time depending upon the controlling parameters.

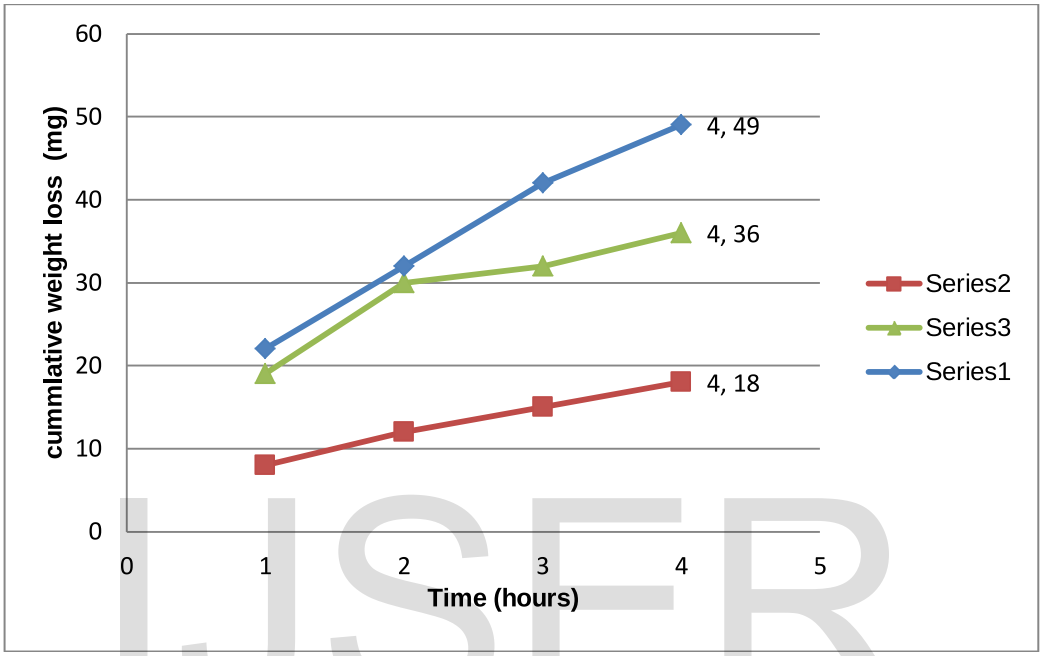

Figure 3.3.1 Variation in cumulative weight loss and time at a flow rate of 3.5 lit/sec.
Series1 uncoated, Series2 Epoxy Powder coating, Series3 Epoxy Polyester coating

The weight loss of uncoated steel is nearly equal in all time intervals and show maximum weight loss. Both coatings shows higher wear at initially intervals and then reduction in wear in lateral time intervals. Epoxy Powder coating shows a superior erosion wear resistance than both Epoxy Polyester coated and uncoated steels.

3.4 DISCUSSION

(i) An analysis of Erosion wear shows that the material shows maximum wear rate at shallow impact angles [15^0-30^0].
(ii) New improvement shows that the wear at any impact angle is the sum totals of these two wear components.
(iii) New theory shows that the cutting wear is caused by the particle velocity component to the target surface where as the normal component of the velocity are responsible for the deformation wear.
(iv)A model for estimation of the material removal rate as a function of the critical plastic-strain energy of the material.
(v) The erosion of uncoated steel under normal impact is due to platelet mechanism but for coatings under similar condition is due to crack formation.
(vi) Both coatings are considered as better insulators against the corrosion, shows better performance than uncoated steel in all conditions and to find erosion wear under various conditions erosion test is proposed to be carried out on it.
(vii) Maximum wear rate is assumed to be occurred on the inclined pipes so erosion testing is also proposed on various angles. I.e. at impact angles of 30^0, 45^0 60^0 and at 90^0.
(viii) Erosion wear increase with increase in flow rate and test time duration so for test various parameters like particle size and concentration of slurry to be used is also considered as important factor.
(ix) Erosion wear rate without coating is observed to be higher in initial running hours and causes failure of component with respect to time.

(x) Coatings is considered as better insulator against the corrosion also specially on ductile materials like steel and for test considered to be better in performance than any other simple coatings.

4. CONCLUSION AND FUTURE SCOPE

CONCLUSION

From the study of the erosion wear, it is found that it occurs only whenever there is the transfer of the solid-liquid mixture through the pumps and pipes and wear is the loss of the materials from a component, due to the mechanical interaction with another object. And it is the one of the main factor which causes the failure of the system/ machine.

This study is used to analysed to avoid losses occurs due to the erosion wear and find that there are various factors, which are responsible for erosion wear, and all are discussed in this study and find that, if we control these factors, we can minimize the possibility of the occurrence of the erosion wear and hence increase the life of the machine.

The conclusions of the experimental work are listed below-
(i) Coatings of Epoxy Polyester and Epoxy powder coating method are possible on 18Cr8Ni steel.

(ii) Both coatings show better performance than uncoated steel in all conditions in which erosion wear test was performed.

(iii) Epoxy Powder coating shows the minimum wear as among the other Epoxy Polyester coating and uncoated 18Cr8Ni steel.

(iv) Maximum erosion wear was reported at 30 impact angle and minimum at 90.

(v) Epoxy Powder coated steel shows approximately 3 times better performance than uncoated 18Cr8Ni steel.

(vi) Erosion wear rate with coating is observed that higher in initial running hours and reduces with respect to time.

(vii) The erosion of uncoated steel under normal impact is due to platelet mechanism but for coatings under similar condition is due to crack formation.

(viii) Erosion Wear increases with increase in flow rate and test time duration.

FUTURE SCOPE

(i) The erosion wear studies can be performed with other coating techniques.
(ii) The computational approach can be used to simulate the similar work with different operating conditions.
(iii) The similar erosion wear studies can be extended by using other types of pot tester and different slurry concentration.
(iv) The erosion wear analysis also proposed to the boiler tubes where temperature is quiet high.
(v) Such kind of wear testing can be performed on different metals of different composition such as casing of pumps, housing of turbines.
(vi) As the coating material is conductive so suitable circuit can linked with it which indicates when the coating material is wear out and layer of base metal begins.
(vii) Another complicated coatings techniques such as plasma coating, high velocity oxy-fuel coating method can be adapted to further analyses the wearing parameters.

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