Comparative Study of Slurry Erosion Behaviour on SS304 and SS202 in a Slurry Erosion Test Pot Rig under Different Operating Parameters

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Abstract- **A slurry erosion wear problem occurs generally in transportation of solid liquid mixtures, pumps, hydro turbines, petroleum extraction well. In this project test samples of stainless steel (304) and stainless steel (202) were casted and their slurry erosion behaviours were statically studied by using slurry pot tester machine. Study of slurry erosion is important as it adversely affects the useful life and performance of the equipment handling slurries such as heat exchangers, pumps etc. The main objective of the present study is to find the effect of change in operating parameters on erosion wear of sample subjected to sand-water slurry. The main operating parameters which are examined are molarity and slurry concentration. Experiments are conducted in nine sets with three combinations of particle velocity, slurry concentration and molarity. The erosion of the samples was measured by mass loss of the materials. In this study the design of experiments was considered using Taguchi technique. A comparison has been made for the experimental and Taguchi technique results.**

Keywords-**slurry erosion, ss304, ss202, speed**

I. INTRODUCTION

In the contemporary industrial world, fluidpower, particularly the hydraulics branch of it, is a magic world for energy transmission. The major elements used in hydraulics systems are pumps,valves,pipes, etc. These elements play a major role in power transmission and controls. In the passage of time, these components undergo erosion and corrosion and leads to the fatigue failure.Erosion-corrosion dominates the overall failure of the materials of many components, such as pumps, valves, coupling, etc., which encounter high velocity of acidic and alkaline flow. Erosion is a physical phenomenon of degradation process. Ductile erosion occurs when the impacting particles cause severe localized plastic strain on the material. Material removal occurs when the strain to the failure of the deformed material is exceeded. However, brittle mode of erosion damage of material is based on cracking, fragmentation, and removal of flakes. Slurry Erosion is a complex phenomenon which influenced by the factors, such as flow field parameters, target material properties, and erodent particle characteristics.

II.DEFINITION

A.Erosion

Erosion in tribology is the progressive loss of original material from a solid surface due to mechanical interaction between that surface and a fluid,or impinging liquid or solid particles. Erosion rate is the determination of the rate of loss of material [erosion] with exposure duration.

B.Types of erosion

a) Solid particle impingement

Solid particle impingement is a form of erosion produced by a continuing succession of impacts from solid particles on a surface. The impacting particles are smaller than the solid subjected to the erosion, and if all the impacts are superimposed on the same spot, the them repeated impact is used

b) Fluid impingement

Fluid impingement is a form of erosion caused by a continuing succession of impact from a jet of fluid on a surface

III. SLURRY EROSION

Slurryis the suspension of solid material in liquid. Slurries are transported and processed by a wide range of equipment in the mining, power generation and dredging industries. Centrifugal pumps and cyclone are used extensively in these applications. A major consideration of equipment operators in these industries is the wear life of equipment.

The predominant type of wear in slurry handing equipment is erosion. Studies into the factors contributing to erosive wear have focused on particle size, shape,impingement angle, impact velocities and material characteristics.

IV.SELECTION OF THE MATERIAL

The two materials compared in this project are SS 304 and SS 202*A. Stainless Steel 304*

Type 304, with its chromium-nickel content and low carbon, is the most versatile and widely used of the austenitic stainless steel. They can meet a wide variety of physical requirements, making them excellent materials for applications including storage tanks, pressure vessels and piping.

Composition	
SS-304	
Element	**(Weight %)**
Mn	2.00
S	0.030
P	0.045
Mo	-
Cr	7.50-19.50
Si	0.75
Ni	8-12
N	0.10
C	0.030

B. Stainless Steel 202

To avoid the above fatigue failures by erosion the stainless steel202 with nitrogen content can be used. It is nitrogen enhanced duplex stainless steel that was developed to combat common Erosion problems encountered with the 300-series stainless ' steels. “Duplex” describes a family of stainless steels that are neither fully austenitic, like 304 stainless, nor purely ferritic, like 430 stainless steels.

Composition	
SS-202	
Element	**(Weight %)**
Mn	7.5-10
S	0.030
P	0.060
Mo	-
Cr	17-19
Si	1
Ni	4-6
C	0.15

Fig 1.Material before testing

V. PROBLEM IDENTIFICATION

At shallow impact angle 30°, the material removal pattern was observed in the form of micro displacing, scratching and ploughing with plastic deformation of the material. At 60° impact angle, mixed type of micro indentations and pitting action is observed. At normal impact angle 90°, the material removal pattern was observed in form of indentation and rounded lips. From the comparison of experimental and Taguchi experimental design results it is found that the percentage deviation was very small with a higher correlation coefficient (r2) 0.987 which is agreeable.

The E-C 29123 coating applied by OFP process onto AISI304 stainless steel reported the best slurry erosion resistance of the studied materials, mainly as a consequence of the combined properties of hard, wear-resistant particles and a ductile metallic matrix.

The studied coatings showed ability to deform plastically when submitted to slurry erosion conditions, with little evidence of mass removal by brittle fracture mechanisms. Un-melted particles and droplets are easily removed from the surface, but this does not affect the overall performance of the coatings in terms of volume loss and main wear mechanisms.The applied coatings are an interesting alternative to enhance the wear resistance of components used in hydraulic machines, in particular under grazing incidence conditions and moderate-to-low mean impactvelocities.

VI. EXPERIMENTAL PROCEDURE

A.Slurry Erosion Test

The method used for testing the erosion wear rate under varying experimental conditions is known as slurry erosion test this carried out by Using a slurry erosion tester. The test is carried-out by measuring the loss of mass of the specimen by weighing it before and after the process in the tester.

B.Construction

The samples or specimen are fixed on a slot along its surface through the holding arrangement, which is attached to the shaft. The assembly is immersed in the acrylic container drum containing the slurry. Other end of the shaft is attached to a motor through the bearing arrangement. So that when the motor starts rotating the shaft holding the samples will also rotate.

S.NO	COMPONENTS	SPECIFICATION
1	AC Motor	Three Phase (0-2880rpm)
2	Variable Frequency Drive (VFD)	0-1500HZ
3	Container	Height-250mm Dia-200/190mm
4	Shaft	Height-20mm Dia-32mm
5	Sample Holder	I)Length-160mm, Height-38mm, Thickness-13mm Ii)Two Slots 25.4X25.4 Mm^2 Depth- 5mm
6	Samples	25X25 mm^2

Fig.2. Slurry Pot Rig

C. Working Principle

The specimen to be tested are first thoroughly cleaned and weighed in Precisions weighing machine. These Specimens having a standard size fixed onto the slots with the help of alien screws. The holder along with the specimens is dipped into the slurry contained in the container. The motor is then started and the specimens are rotated at the desired speed for a given duration. The specimen are removed, cleaned and weighed after the test is over.

The loss of mass of the specimen during the test is found out. The rate of erosion is calculated as the rate of loss of mass with respect to various experimental parameters.

VII. DESIGN OF EXPERIMENTS

A.Erosion Test

The erosion tests were conducted based on three-factor three-level L9 orthogonal array using slurry erosion tester, as shown in the Fig, The surfaces and edges of the cast test specimens of size 3125 m3 were polished and ground, to remove oxide scales and dirt, using standard metallographic techniques. The testing parameters as shown in the Table were varied according to the design matrix, for each test. Silica sand particles of mesh size 90 microns were used as erodent. The weight of each sample was measured, before and after the test, to find thedifference in the mass loss.

B.Taguchi Method

Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and more recently also applied to engineering, biotechnology, marketing and advertising. Professional statisticians have welcome the goals and improvements brought about by Taguchi methods, particularly by Taguchi's development of designs for studying variations, but have criticized the inefficiency of some Taguchi's proposals.

Taguchi method is an efficient problem-solving tool, which can upgrade/improve the performance of the product, process, design and system with a significant slash in experimental time and cost. This method that combines the experimental design theory and quality loss function concept has been applied for carrying out robust design of processes and products and solving several complex problems in manufacturing industries. Further this technique determines the most influential parameters in the overall performance.

Furthermore, a statistical analysis of variance (ANOVA) can be performed to see which process parameter is statistically significant for each quality characteristics.

FACTORS	LEVEL 1	LEVEL 2	LEVEL 3
SPEED (rpm)	1200	1500	1800
SLURRYCONCENTRATION %	5	10	5
MOLARITY (M)	0.1	0.5	1

VIII.RESULTS AND DISCUSSION

A.Result of the experiment after completion of test

a) Stainless 304

S.NO	Solution Concentration	Slurry Concentration	Speed	Mass Loss
1	0.1	5	1200	0.005
2	0.1	10	1500	0.020
3	0.1	15	1800	0.035
4	0.5	5	1500	0.056
5	0.5	10	1800	0.080
6	0.5	15	1200	0.043
7	1.0	5	1800	0.075
8	1.0	10	1200	0.054
9	1.0	15	1500	0.062

b) Stainless Steel 202

S.NO	Solution Concentration	Slurry Concentration	Speed	Mass Loss
1	0.1	5	1200	0.010
2	0.1	10	1500	0.024
3	0.1	15	1800	0.075
4	0.5	5	1500	0.083
5	0.5	10	1800	0.190
6	0.5	15	1200	0.097
7	1.0	5	1800	0.130
8	1.0	10	1200	0.093
9	1.0	15	1500	0.112

B. Interaction plots

An interaction plots displays the levels of one variable on the X axis and has a separate line for the means of each levels of the other variable. The Y axis is the dependent variable. An interaction occurs when the response achieved by one factor depends on the levels of another factor. On interaction plot when lines are not parallel, there is an interaction.

Based on the results, contour plots for the interaction effects of the factors influencing mass loss have been generated using MINITAB 18.

1. Interaction effect of slurry concentration with molarity on mass loss.

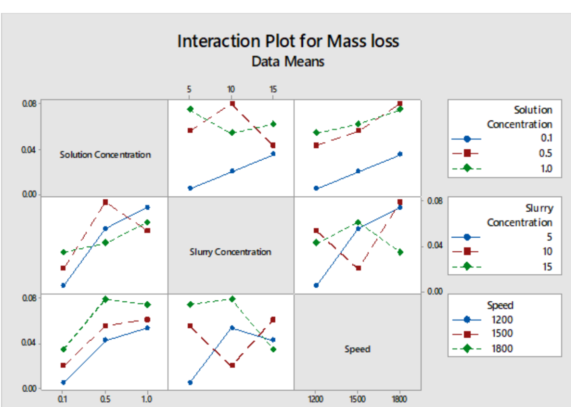
The figure predominantly depicts a marginal mass loss in the range of 0.00-0.50g confirming the influence on the mass loss to a very minimum level of contribution. Based on visual inspection, it is inferred that corrosion-dominated wear phenomenon appears to be operative at lower pH values.

2. Interaction effect of speed with molarity on mass loss.

Since the contribution of Molarity factor is low compared with all the factors influencing the mass loss, it is evident that velocity plays a major role in contributing to the mass loss of the material. The interactive trend as shown in Fig.3&4 for the interaction of the speed with molarity on the mass loss of stainless steel clearly depicts that at the maximum velocity and minimum value of molarity, a higher mass loss was observed.

Fig.3.Interaction Plot for SS202

Fig.4. Interaction Plot for SS304

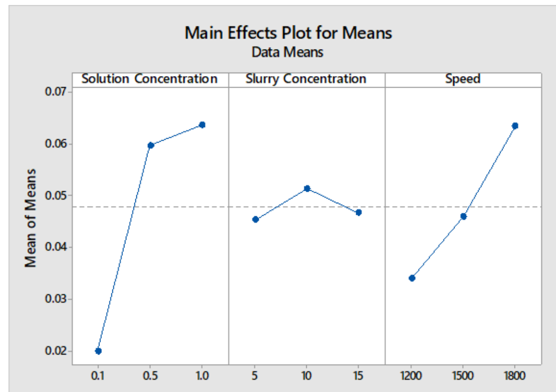


C. Direct effect on process parameters

1. Stainless steel 304

The direct effect of stainless steel 304 at solution concentration increases from 0.020gm and again increases to 0.052gmwhereas the direct effect of slurry concentration starts from 0.043gm and increases to 0.056gm and then decreases to 0. 047gm.For speed of 1200rpm it starts from 0.035gm mass loss and increases to 0.0.47gm and increases to 0.070 gm for 1800rpm.

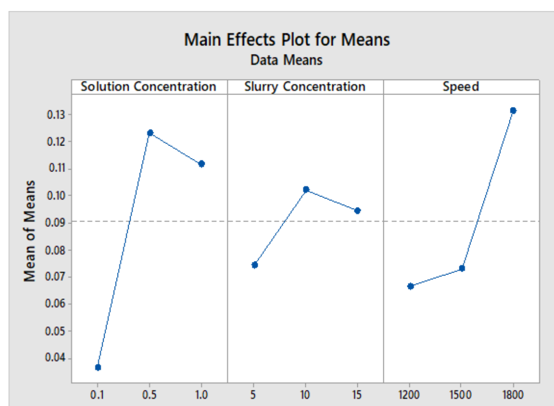
Fig.5.Main effects plot for 304



2. Stainless steel 202

The direct effect of stainless steel 202 at solution concentration increases from 0.010 gm and again increases to 0.024 gm whereas the direct effect of slurry concentration starts from 0.083gm and increases to 0.190 gm and then decreases to 0.097gm. For speed of 1200rpm it starts from 0.065gm mass loss and increases to 0.078gm and increases to 0.130 gm for 1800rpm.

Fig.6.Main effects of SS202

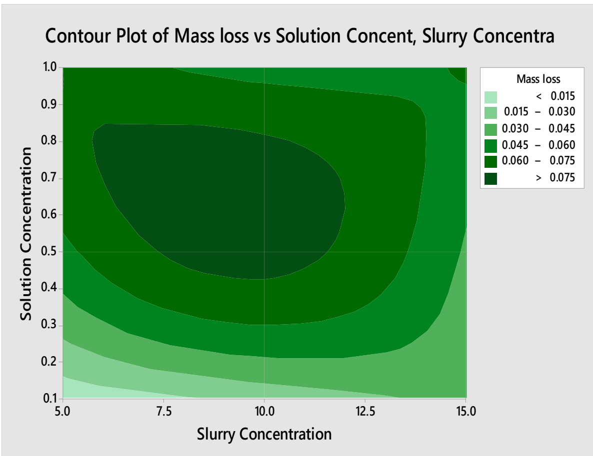


D.Contour plots

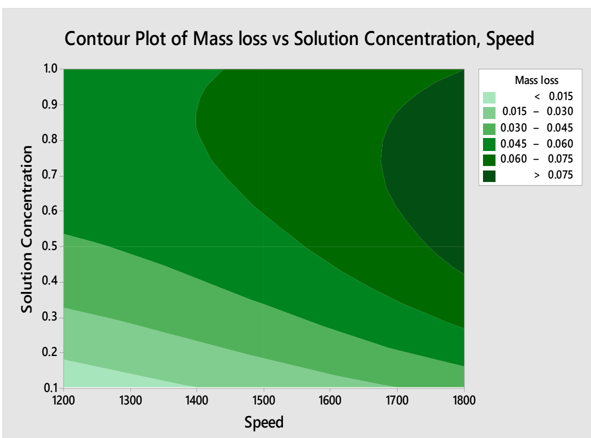
A contour plot is a graphic representation of the relationship among the three numeric variables in two dimensions. Two variables are for X and Y axes, and a third variable Z is for contour levels. The contour level are plotted as curves, the area between the curves can be colour coded to indicate interpolated values. The various contour plot for the three variables are discussed below for both SS 304 and SS 202.

1. Stainless Steel 202

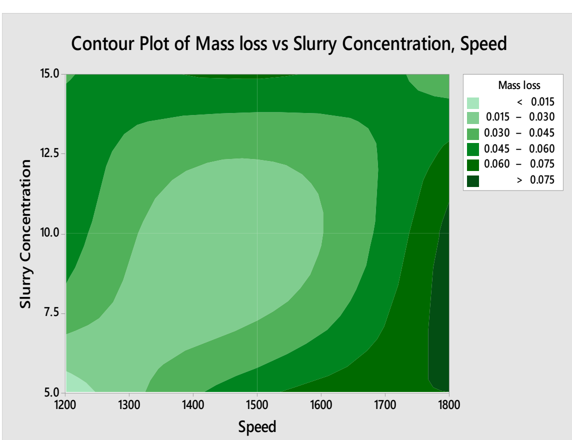
a) Contour plot of mass loss vs Solution concentration and Slurry Concentration.



b) Contour plot of mass loss vs Solution concentration and Speed.

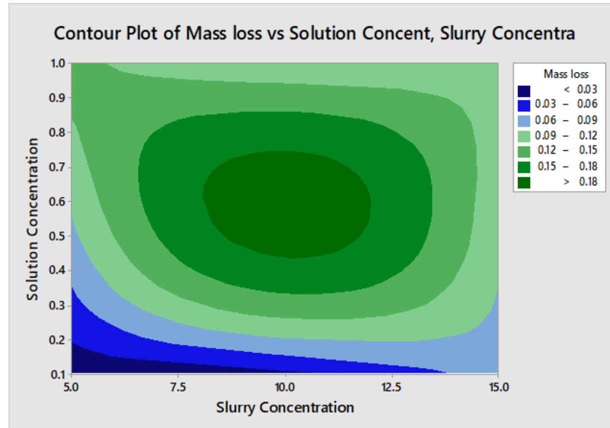


c) Contour plot of mass loss vs Solution concentration and Speed.

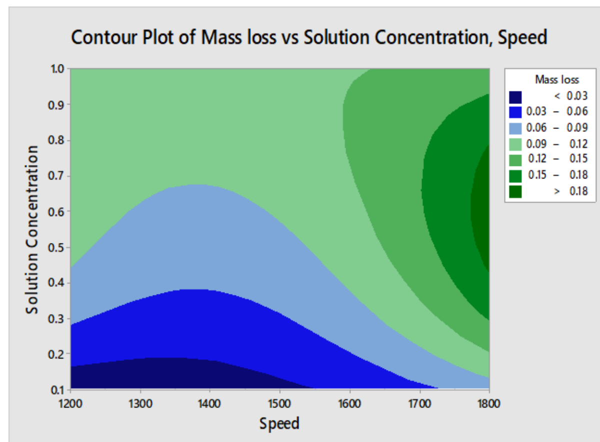


2. Stainless Steel 304

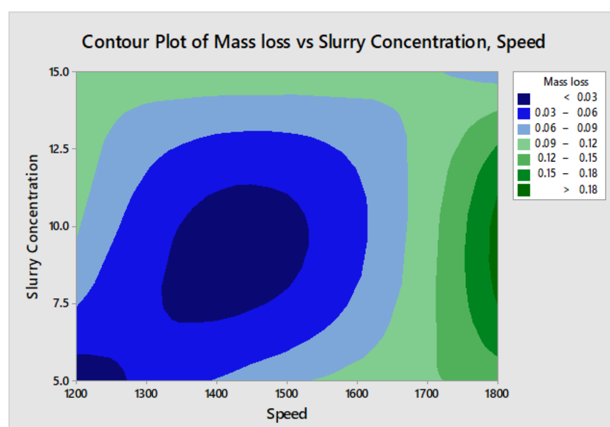
a) Contour plot of mass loss vs Solution concentration and Slurry Concentration.



b) Contour plot of mass loss vs Solution concentration and Speed.



c) Contour plot of mass loss vs Solution concentration and Speed.



E. Effects on the material

The below figure shows the effects of test over the material.

Fig.7.Material after test

IX. CONCLUSION

1. The following conclusion were conducted by varying the factors namely speed, slurry concentration and molarity values in three levels, using Taguchi L9 orthogonal array.
2. The effect of the factors on erosive wear characteristics of SS304 and SS202 were compared and studied.
3. Contour plots for interaction effects of the factors influencing mass loss have been generated using MINITAB 16 statistical analysis software.
4. Interaction effects of speed, slurry concentration and molarity erosion rate have been discussed.

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