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Erosion Behaviour of Stainless Steel Grade-316

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***Abstract*:** *Erosion of the hydro turbine steels is a serious issue, especially for the hydro power plants situated on the rivers. In the current investigation, slurry erosion performance of stainless steel (Grade-316), which is commonly used in hydro-turbine power plants has been studied. Silica sand is used as the abrasive media in the test apparatus.Three parametershave been selected to study the performance of stainless steel, which majorly observed under practical conditions. The effect of slurry concentration (ppm), average size of slurry particles (µm) and rotational speed (rpm) on the slurry erosion behaviour of selected material was investigated under different experimental conditions.*

Keywords:- *turbine , steel grade -316,* Slurry erosion, *TAGUCHI*

OBJECTIVE

Parametric studies of slurry erosion of hydro turbine steel by using Taguchi methodology for orthogonal array.

I. INTRODUCTION

Erosion corrosion is a degradation of material surface due to mechanical action, often by impinging liquid, abrasion by slurry, particles suspended in fast flowing liquid or gas, bubbles or droplets, cavitation, etc. The mechanism can be described as follows:

- Mechanical erosion of the material, or protective (or passive) oxide layer on its surface,
- Enhanced corrosion of the material, if the corrosion rate of the material depends on the thickness of the oxide layer.

The mechanism of erosion corrosion, the materials affected by it, and the conditions when it occurs is generally different from that of flow-accelerated corrosion, although the last one is sometimes classified as a sub-type of erosion corrosion.

In the following experimentation, stainless steel Grade-316 is selected for the erosion under selected parameters. Slurry erosion occurs when a solid–liquid mixture, specifically known as slurry, causes wear. This is common phenomenon in hydro turbine underwater parts and many other related industrial situations. Slurry erosion is a complex process consisting of interaction of three co-existing phases, namely carrier liquid, hard solid particles and the metallic surface in many ways. Major factors effecting erosive wear rate are: - the hardness, shape, size and concentration of erosive particles; the angle of impingement; the fluid flow exposure conditions (laminar, turbulent) and the physical (surface roughness), chemical and mechanical properties (toughness, hardness, etc.) of the targeting material.

Purpose of this experiment is to study the utility of stainless steel Grade-316 as the material for Hydro-Turbines.

Material selected: Stainless steel (Grade-316)
Chemical Formula: Fe, <0.03% C, 16-18.5% Cr, 10-14% Ni, 2-3% Mo, <2% Mn, <1% Si, <0.045% P, <0.03%S.

Mechanical properties:

Table 1

Grade	Tensile Str (MPa) min	Yield Str 0.2% Proof (MPa) min	Elong (% in 50mm) min	Hardness	
				Rockwell B (HR B) max	Brinell (HB) max
316	515	205	40	95	217
316L	485	170	40	95	217
316H	515	205	40	95	217

Physical properties:

Table 2

Grade	Density (kg/m^3)	Elastic Modulus (GPa)	Mean Co-eff of Thermal Expansion (µm/m/°C)			Thermal Conductivity (W/m.K)		Specific Heat 0-100°C (J/kg.K)	Elec Resistivity (nΩ.m)
			0-100°C	0-315°C	0-538°C	At 100°C	At 500°C		
316/L/H	8000	193	15.9	16.2	17.5	16.3	21.5	500	740

Profile of Specimen: Hollow cylindrical (Length=10mm, Outer diameter = 10mm, inner diameter = 6mm).

Fig. 1 Stainless Steel – Grade-316

Erodent: For bringing the testing conditions as close as possible to the actual hydropower plants, the sand particles used as erodent were of silica sand.
Silica sand used for experimentation consists of particles having different sizes. Sizes used for experimentation are as follows: 100µm, 300µm, 500µm.
Slurry for slurry-erosion testing is prepared by suitable concentration of different sizes of erodent particles in 25 litersof water.

Size- 500µm

Size- 300µm

Size- 100µm

II. EXPERIMENTATION

Slurry erosion testing

A high-speed test rig was (DUCOM TR401) was used to study the erosion behavior of steel specimens. The test rig consists of various components: Jack, Jack top frame, Slurry chamber, Specimen, Supporting frame, Rotor, Spindle assembly, Slurry tank, Valve for slurry drain out, Stirrer motor.
In order to perform investigation different levels being selected as shown in table 3

Table 3

Parameters selected	*Level 1*	*Level 2*	*Level 3*
Erodent size	**100µm**	**300 µm**	**500 µm**
Concentration	**10000ppm**	**20000ppm**	**30000ppm**
Speed	**1000 rpm**	**2000 rpm**	**3000rpm**

Before the beginning of erosion test cycle, the slurry with specified erodent particle size is prepared in

Experiment No. 1

Parameters Selected: 1. Erodent Size = 100 µm 2. Concentration = 10000 ppm 3. Speed = 1000 rpm

Table -4

Specimen	Ext. Diameter	Length	Initial Wt.	Weight in gms after				
Stainless Steel	(in mm)	(in mm)	(in gms)	15 mins	30 mins	45 mins	60 mins	75 mins
Grade 316	9.96	9.51	3.2277	3.2261	3.2257	3.2246	3.2224	3.2212

Table -5

Specimen	Surface Area	Cumulative weight loss in gms after				
Stainless Steel	(in mm^2)	15 mins	30 mins	45 mins	60 mins	75 mins
Grade 316	297.6900	0.0016	0.002	0.0031	0.0053	0.0065

Table -6

Specimen	Surface Area	Cumulative Specific weight loss (wt. loss/Surface Area) in gms/m^2 after				
Stainless Steel	(in mm^2)	15 mins	30 mins	45 mins	60 mins	75 mins
Grade 316	297.6900	5.374718667	6.718398334	10.41351742	17.80375558	21.83479458

Table -1.4

Specimen	Cumulative specific wt. loss rate (wt. loss/ (surface area * time)) in gms/m^2-min after				
Stainless Steel	15 mins	30 mins	45 mins	60 mins	75 mins
Grade 316	0.358314578	0.223946611	0.231411498	0.29672926	0.291130594

25 liters of water. A typical erosion test cycle began with the mounting of cylindrical specimen to the rotor assembly and then filling of the slurry chamber with the slurry. Care was taken to prevent over-tightening of clamping screws, which could induce compressive stresses in the specimen. After completing of the erosion testing cycle, specimens were removed from the rotor assembly, gently brushed and cleaned with acetone in order to remove attached particles if any.

Initial weight of the specimen and weight of the specimen after every 15 minutes is recorded with the help precision microbalance having an accuracy of 0.1mg. In this way the loss in mass of the test specimen is recorded. As erosion is a surface phenomenon, so the peripheral surface area of each specimen was calculated by measuring the length and external diameter with the help of digital micrometer having an accuracy of 0.01mm. Specific mass loss was calculated using the following relationship:-

Specific mass loss = mass loss (g) × 10^6 / peripheral surface area (m^2)

To determine the effect of the chosen parameters, slurry erosion tests have being planned using Taguchi methodology. Taguchi method consists of a plan of experiments with the objective of acquiring data in a controlled way, executing the experiments and analyzing data, in order to obtain information about the behavior of a given process.The results have been plotted as cumulative erosion (specific mass loss in g/m^2) versus time of exposure (hours) in order to ascertain the kinetics of slurry erosion behavior of stainless steel (Grade-316). Results obtained after experimentation using Taguchi methodology for orthogonal array was plotted graphically. Two graphs is prepared for each experiment:-

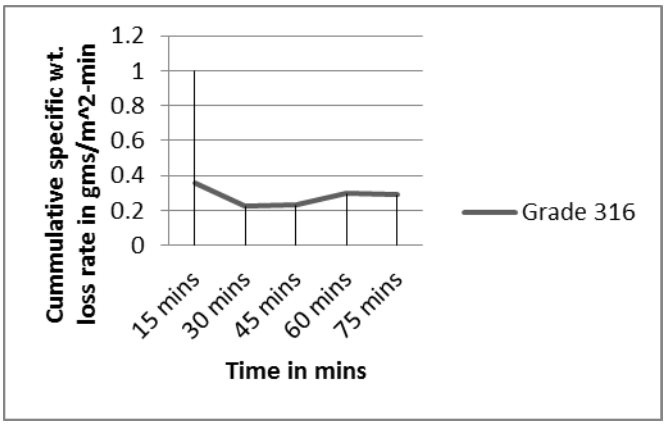
- Cumulative specific weight loss in g/m^2 versus time in minutes.
- Cumulative specific weight loss rate in g/m^2-min versus time in minutes.

Taguchi Methodology For Orthogonal Array

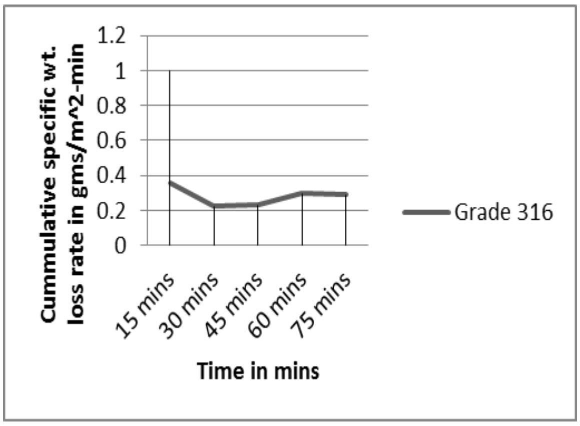
Table 4

S.NO.	Erodent size(in μm)	Concentration (ppm)	Speed (rpm)
Experiment no:-1	100	10,000	1000
Experiment no:2	300	10.000	2000
Experiment no:3	500	10,000	3000
Experiment no:4	100	20,000	2000
Experiment no:5	300	20,000	3000
Experiment no:6	500	20,000	1000
Experiment no:7	100	30,000	3000
Experiment no:8	300	30,000	1000
Experiment no:9	500	30,000	2000

Graph -1



Graphs – 2



Effect of erodent size, concentration and speed at different levels analyzed with the help of

Qualitek 4 software

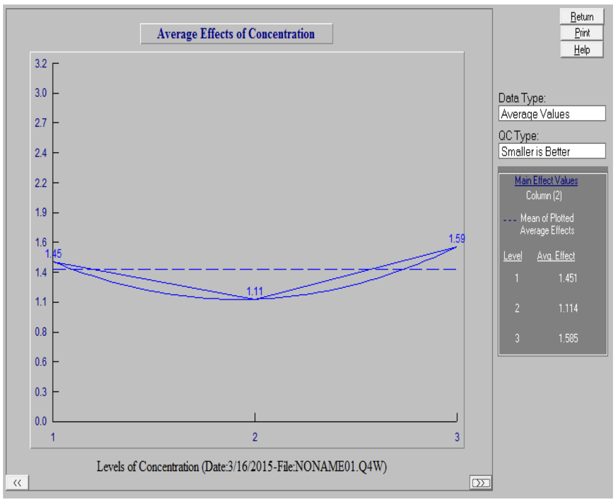


Figure-2 Average Effects of Concentration

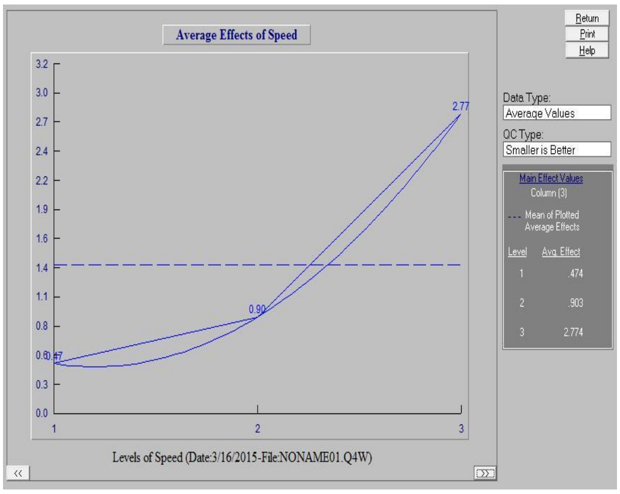


Figure-3 Average Effects of Speed

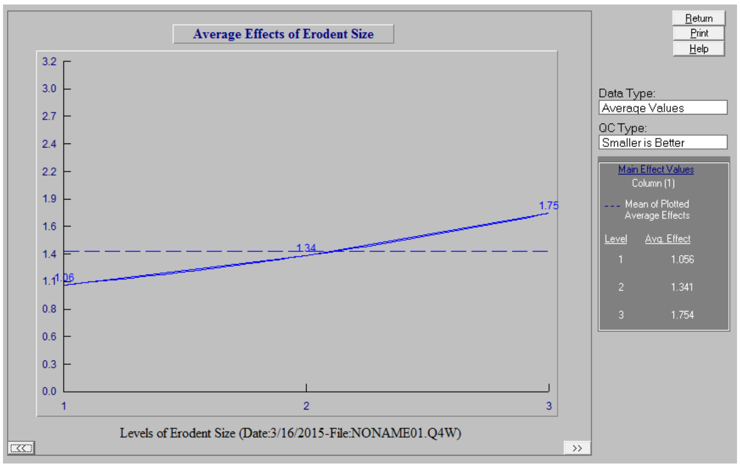


Figure-4 Average Effects of Erodent Size

III. CONCLUSION

- From the above analysis and graphical representation of the Average effects of speed, concentration and erodent size at different levels can be studied.
- Figure – 2 depicts that as the speed of rotation increases from Level 1 to Level 3, there is drastic increases in the erosion of the stainless steel Grade-316.
- Figure – 3 depicts that as the erodent size increases from the level 1 to level 3 , there is increase in the erosion of the stainless steel Grade-316.
- Figure – 4 depicts that as the concentration of slurry increases from the Level 1 to Level 2, erosion of the stainless steel Grade-316 decreases whereas with further increases in the concentration from Level 2 to Level 3, erosion of the stainless steel Grade-316 increases.

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