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Parametric Experimental Analysis of Erosion Wear on Mild Steel Material –Response Surface Methodology

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Abstract

Analyze erosion of Mild Steel material on jet erosion tester for slurry transportation system. In this work Mild Steel material will be experimentally investigated under varying velocity of jet, position of angle with respect to constant time duration using jet type erosion wear tester. The wear damage will estimate by means of weight loss techniques. In many application like, techniques of mining, food processing, power generation and other sectors erosion problem is serious in transportation of slurry. Erosion is a critical parameter for design, selection and operation of the hydraulic transportation system. Engineering interest is to estimate the service life of equipment subjected to slurry erosion & to investigate their efficiency. We will select different material used in pipes & pumps and will check it on jet erosion tester and will analyses it on software, results will be compared with theoretical results.
Keyword- Erosion Wear, Process Parameter, RS Method, Optimization Analysis

I. INTRODUCTION

Erosion is one of the most common problems encountered in industries like thermal power plants, hydropower plants, mining industries, food processing industries etc. in which solid liquid mixture is transported through pumps and pipes. 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 apart. Corrosion and erosion are the main causes of wear. Corrosion is caused by chemical reaction of material with its environment. Erosion wear is due to exposure to moving liquids and gases, which may or may not contain hard particulate. 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.

A. Literature Review

Noelmar Pereira Abbade was to analyse the erosion of API 5L X65 pipe steel on Jet impingement tests with sand–water slurry were used. The erosion rate increased with angle of attack until 30° and later decreased until 90°. The micro texture of the eroded surfaces, at angles of attack of 30° and 90°, were similar for both conditions. The flux of impact in the erosion tests was a silica sand–water mixture at 3 wt% concentration. The silica sand had specific rounded shape and size range of 149–297 μm. The slurry erosion tests were performed at flow velocity of 4.5 m s-1, angles of attack of 15°, 30°, 60° and 90°, and at room temperature. The jet impingement consisted of a pump, nozzle and sample holder. The distance from specimen surface to nozzle end was 25 mm, the inner diameter of exit was 6 mm and the water flow sucked the silica sand directly at the nozzle. [1] A.Neville and N.Kapur measured the erosion rate and testing was carried out using stainless steel 316L by a jet of sand and water. A jet impingement test rig used to analyse erosion conditions has been built at the University of Leeds, comprising a centrifugal pump, a set of nozzles, sample holders and a holding tank, experimental setup of the experimental rig, together with the nozzle arrangement, which is used to study the behaviour of various materials. The facility enables the dependence of different input conditions such as the nominal impact angle, sand concentration and flow velocity on the erosion rate to be studied.[2] K. Shimizu conducted experiment on erosion wear tests. For the purpose of this, mild steel (SS400) and ductile iron (FDI) was prepared and Steel grits were impacted against target materials at different incident angles. The size of test piece was of 50mm×50mm×10mm .The results showed that the wear losses varied markedly as a function of the impact angles, and that the maximum wear occurred at specific angles. Maximum wear occurred at 20–30◦ for mild steel, and 60◦ for ductile iron. In the case of both mild steel and ductile cast iron, it was found that the impact angles play a very important and valid role in the erosion process. [3]

B. Design of Experiments

Response Surface Methodology explores the relationships between several explanatory variables and one or more response variables. The method was introduced by G. E. P. Box and K. B. Wilson in 1951. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response. Box and Wilson suggest using a second-degree polynomial model to do this. They acknowledge that this model is only an approximation, but use it because such a model is easy to estimate and apply, even when little is known about the process. Response surface methodology uses statistical models, and therefore practitioners need to be aware that even the best statistical model is an approximation to reality. In practice, both the models and the parameter values are unknown, and subject to uncertainty on top of ignorance. Of course, an estimated optimum point need not be optimum in reality, because of the errors of the estimates and of the inadequacies of the model.
Nonetheless, response surface methodology has an effective track-record of helping researchers improve products and services.

C. Experimental Details

1) Raw Material

The material as mild steel are selected for parametric study of the erosion wear rate with different parameters velocity, impact angle and slurry concentration.

Composition	*Tensile Strength*	*Yield Strength*	*% Elongaton*	*Nature*
Mild Steel (0.1C,0,8Mn, 0.04S, 0.04Ph)	*440 MPa*	*370 MPa*	*15*	*Ductile*

Table 1: Mechanical Properties

2) Sand Particle Composition

Sieve analysis and hydrometer analysis are the two methods used for determination of the distribution of particle size. Hydrometer analysis is used for finer particles, which are below 75 microns whereas sieve analysis is performed to determine the particle size of coarse particles i.e. particle size greater than 75 microns.

Fig. 1: Standard sieve and sand

3) Experimental Setup

The test rig consists of a centrifugal pump, conical tank, nozzle, specimen holder, valves. Electric motor of 0.5 HP is used to drive Centrifugal pump has a capacity of max pressure 13.5 bar at a discharge of 75 L/min. Slurry available in conical tank as can be seen in Figure 2, is sucked through a 38 mm pipe with help of pump and delivered to the nozzle through 25 mm pipe having control valves located upstream.

Slurry is re-circulated during test. The main valve between delivery side and nozzle is used to control the flow rate of the slurry. The rectangular tapered tank having 560×560 mm at top which converges to 38×38 mm at the bottom through a length of 600 mm was used to store the slurry.

Slurry flowing through the pump at high pressure is converted into high velocity stream while passing through the converging section of the 40 mm long nozzle having diameter of 8 mm. The standoff distance between the nozzle and specimen can be varied from 25mm to 90mm. After striking the specimen slurry falls back into the tank.

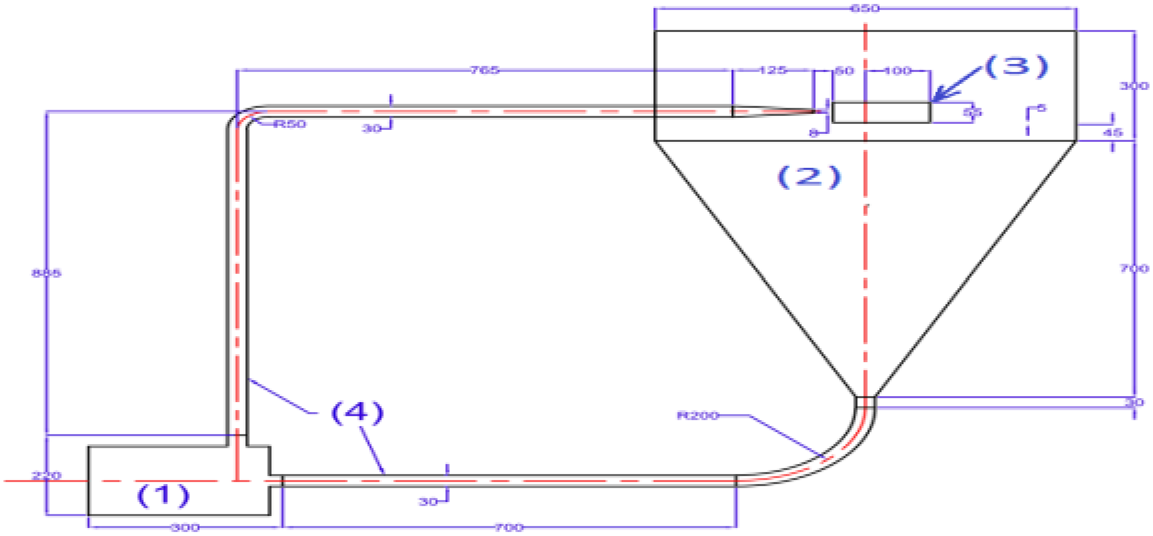

Fig. 2: Schematic diagram of jet erosion tester

4) Specimen Fixture

There are three grooves at 90°, 60° and 30° in fixture. Two blocks are of mirror image of each other. These blocks are fixed such that they are facing each other. Block is made from wood material. It is clamped with metal strip by screw and metal strip is welded with hopper.

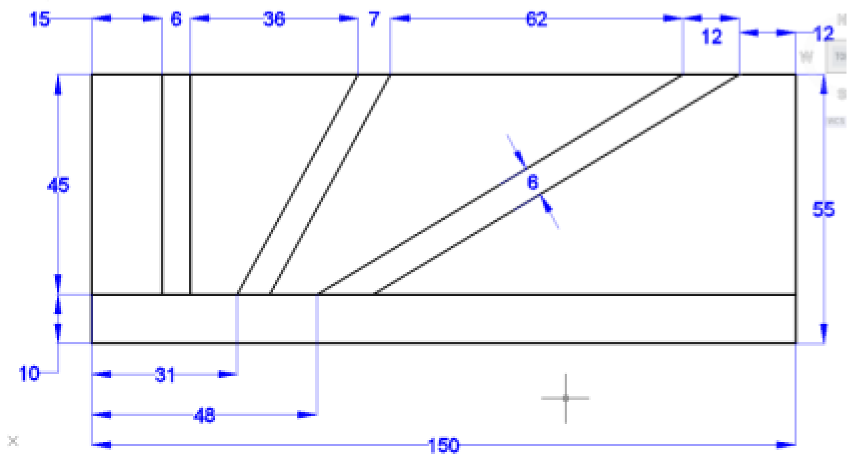

Fig. 3: Specimen fixture

D. Results and Discussions

According to the design of experiments tests were conducted with Impact angle (30^0, 60^0, 90^0), Flow velocity (11.3, 11.95, 12.6 m/s), Slurry Concentration (10%, 20% and 30%) for 1 hour.

In design of experiment the results are analysed to achieve one or more of the following objectives:

1) To establish the best or the optimum condition for a product or a process.
2) To estimate the contribution of individual factors.
3) To estimate the response under the optimum conditions.

1) Estimated Regression Coefficients for Weight Loss

Term	*Coef*	*SE Coef*	*T*	*P*
Constant	*46.9967*	*0.4641*	*101.254*	*0.000*
Impact Angle θ	*-11.2*	*0.3799*	*-29.478*	*0.000*
Flow Velocity V	*14.8*	*0.3799*	*38.953*	*0.000*
Slurry Concentration Θ_{sl}	*8.1*	*0.3799*	*21.319*	*0.000*
*Impact Angle*Impact Angle*	*0.5196*	*0.7333*	*0.079*	*0.499*
*Flow velocity * Flow velocity*	*-2.4804*	*0.7333*	*-3.382*	*0.010*
Slurry Concentration Slurry Concentration*	*0.0196*	*0.7333*	*0.027*	*0.979*
Impact Angle Flow Velocity*	*-1.375*	*0.4248*	*-3.237*	*0.012*
Impact Angle Slurry Concentration*	*0.875*	*0.4248*	*2.06*	*0.073*

*Flow Velocity *Slurry Concentration*	*1.375*	*0.4248*	*3.237*	*0.012*
R- Sq = 99.72 %	*R-sq(pred) = 96.18%*		*R-sq(adj) = 99.35%*	

Table 2: Estimated Regression Coefficients

2) Effect of Velocity on Erosion Wear

To evaluate the effect of velocity on erosion wear, tests were conducted at three different levels of velocity (high, medium and low velocity). The effect of velocity can be calculated by measuring the weight loss at each level of velocity. The effect of velocity on erosion wear is shown in figure 4.

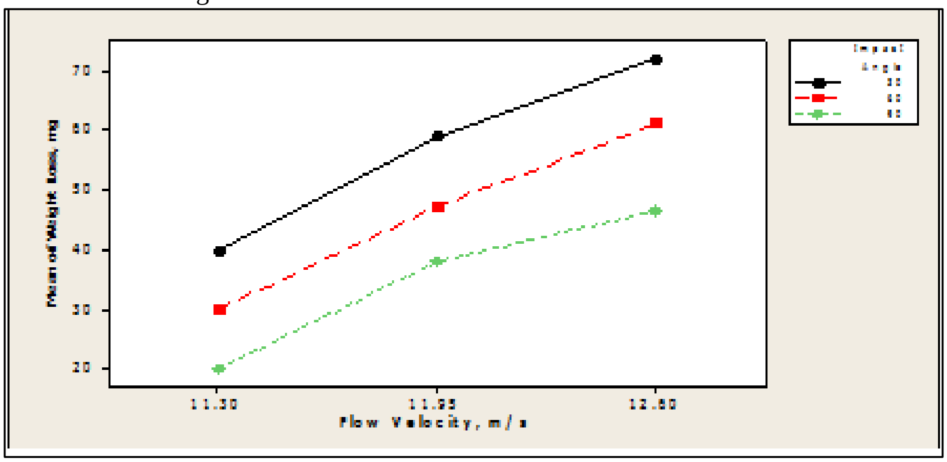

Fig. 4: Effect of velocity on weight loss

It is clear from figure 4 that loss material increases with increase in velocity. The trend of effect of velocity is same at different angles. With increase in velocity, the kinetic energy of solid particle of slurry increases and thus more energy is available with erodent to deform and remove the material.

3) Effect of Impact Angle on Erosion Wear

Impact angle has a significant effect on erosion wear and mechanism of erosion. Figure 5 shows the effect of impact angle on erosion.

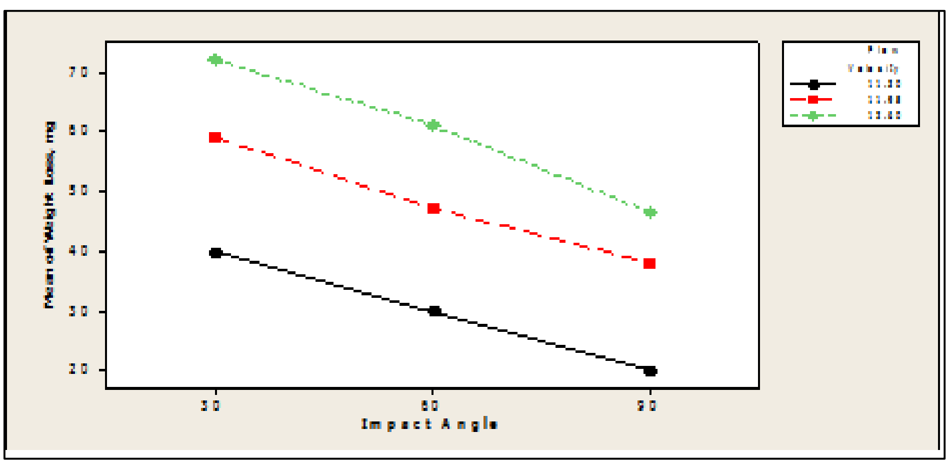

Fig. 5: Effect of Impact Angle on Erosion Wear

It is observed that the maximum weight loss is at angle of 300 and minimum at 900. Same trend is followed at all levels of mass flow rate. At lower angle tangential component of velocity causes the erosion and at higher angle normal component is responsible for the erosion.

4) Effect of Slurry Concentration on Erosion Wear

To evaluate the effect of slurry concentration on erosion wear, tests were conducted at three different levels of concentration (10%, 20% and 30%). The effect of slurry concentration can be calculated by measuring the weight loss at each level of concentration which effect on erosion wear is shown in figure 6.

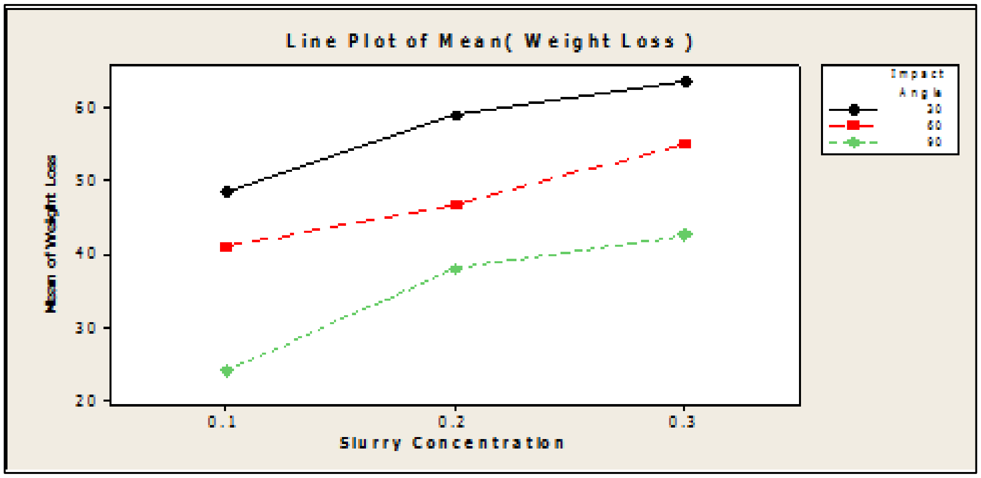

Fig. 6: Effect of Slurry Concentration on Erosion Wear

5) Main Effect Plot for Weight Loss

A main effects plot is a plot of the means of the response variable for each level of a factor. It gives a general idea of which main effects may be important. The Figure 7 shows the locations of the main effects for weight loss.

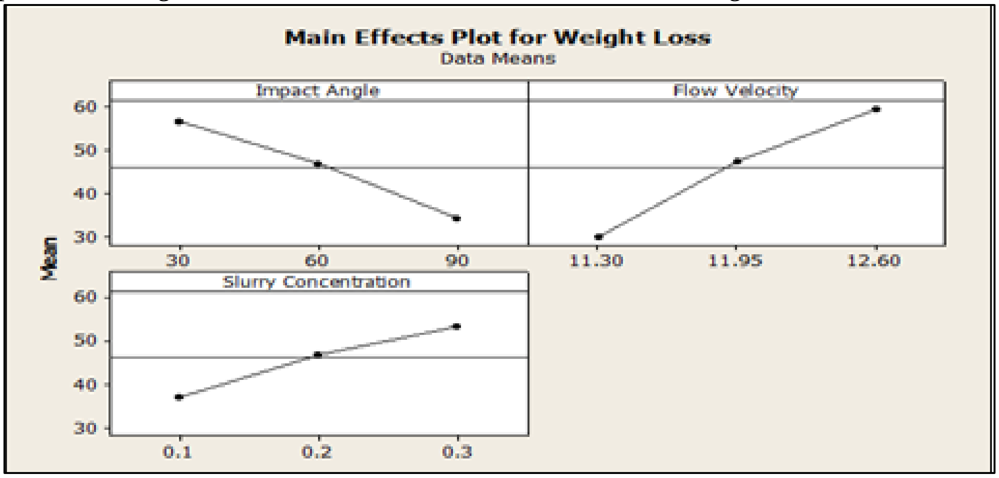

Fig. 7: Main effect plot for weight loss

6) Interaction Plot for Weight Loss

An Interaction Plot for Weight Loss is a plot of the means of the response variable for each level of a factor.

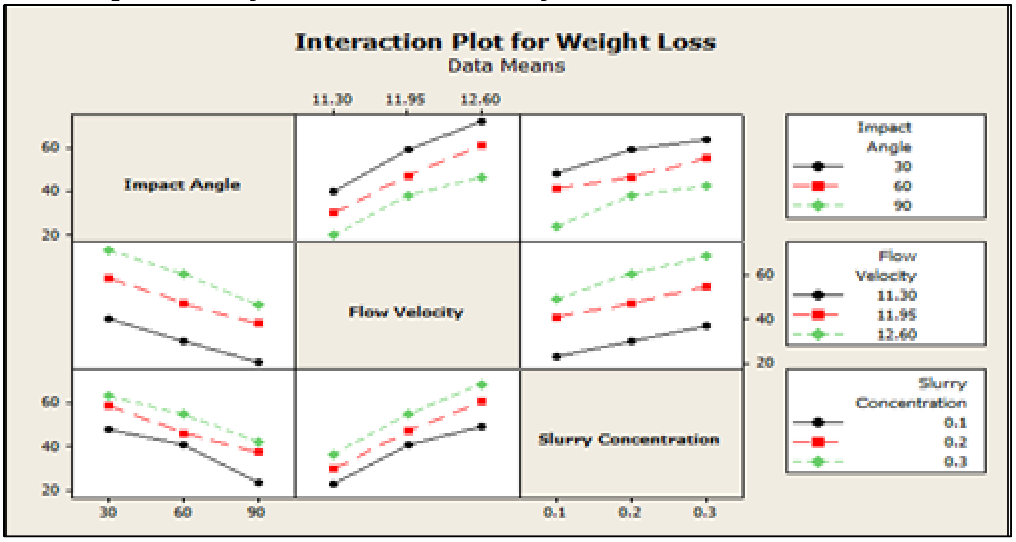

Fig. 8: Interaction plot for weight loss

7) Response Optimization

Response Optimization is used to help identification of the factor settings that optimize a single response or a set of responses. The objective of response surface methodology is not only to examine the response over the entire factor, but also to focus the region of interest where the response reaches its optimum value.

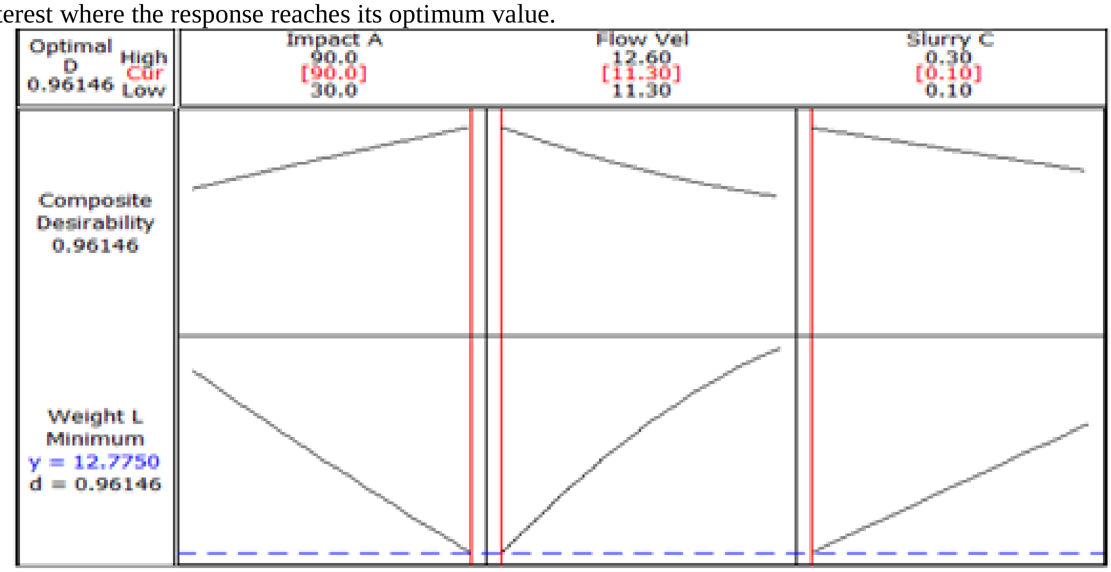

Fig. 9: Optimized Parameters for Weight Loss

Based on the developed response for various output variables optimality search can be obtained. The analysis process for the developed model carried out by using RSM optimization technique i.e. to explore whether all the factors are within their working range or not. The goal is to MINIMIZE the WEIGHT LOSS. As the composite desirability in optimization process is close to 1, it can be conclude that the parameters in process are within their working range. The desirability of optimization has been calculated as 1.000, and all parameters are in working range. The optimum values of weight loss for different parameter presented in table 9

8) Surface Plot for Weight Loss

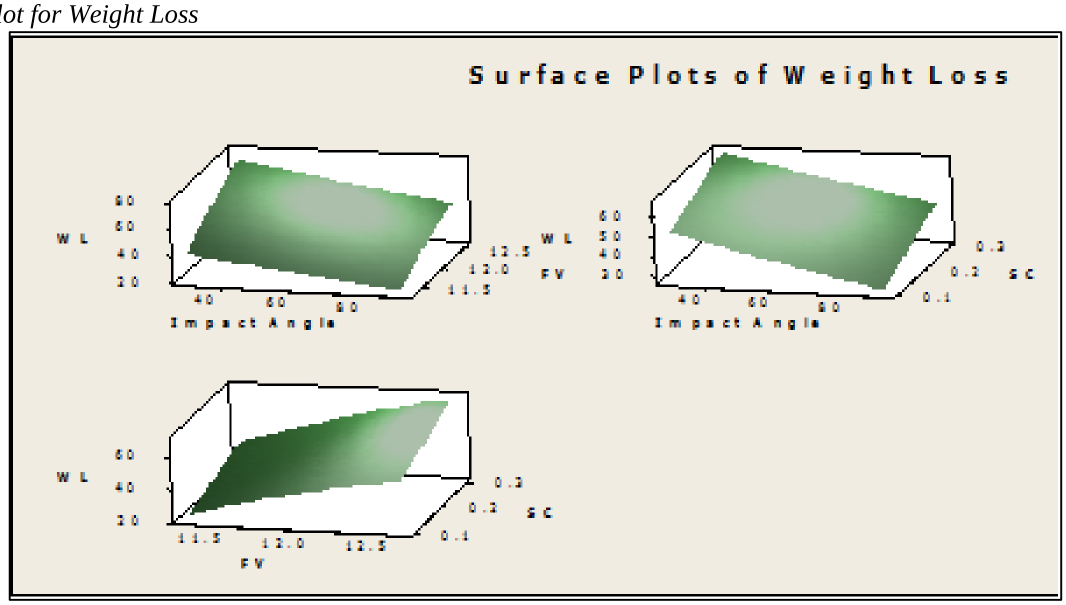

Fig. 10: Surface Plot for Weight Loss

9) Contour Plot for Weight Loss

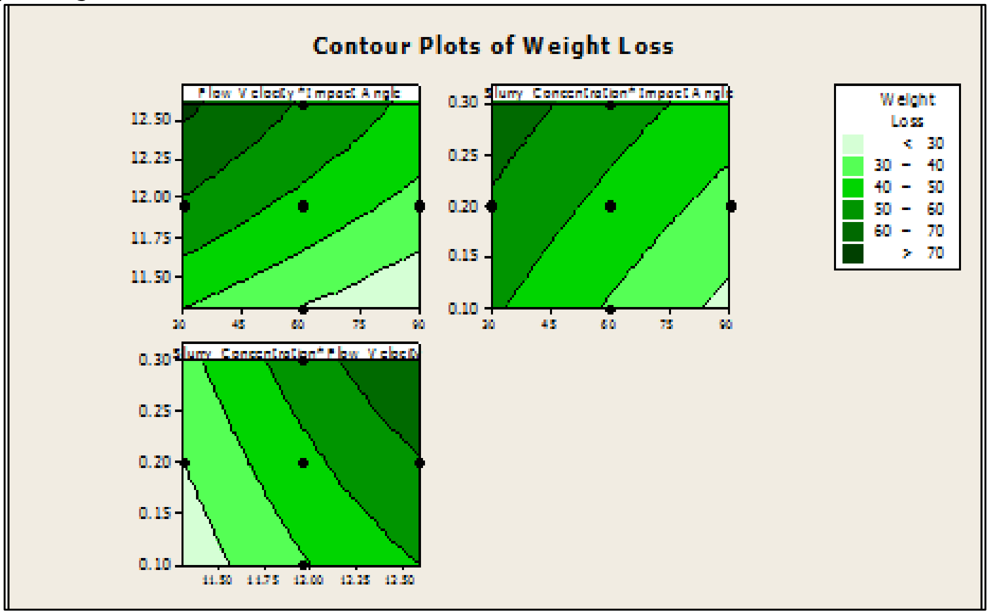

Fig. 11: Contour Plot for Weight Loss

II. CONCLUSION

The erosion rate evaluated with varying the parameters impact angle, velocity of flow of sand slurry and slurry concentration. The erosion wear rates are evaluated in terms of weight loss of material using jet erosion tester. The conclusions of the experimentation result are listed below:

- Erosion wear is a function of velocity of slurry. From Fig 4 maximum wear loss is found at 12.6 m/s and minimum at 11.3 m/s, so as velocity increases erosion wear rate proportionally increases.
- Maximum erosion wear rate is found at impact angle 30̊ and minimum at impact angle 90̊. So as impact angle decreases erosion wear rate proportionally increases.
- Maximum erosion wear rate is found at 30 % wt. of slurry concentration and minimum at 10% wt. slurry concentration. Erosion wears increase with increase in slurry concentration.
- Erosion weight loss is the function of time.
- From the developed model as in table, the optimal process parameter combination, i.e. Impact angle (θ) 90, Flow Velocity (V) 11.30, Slurry Concentration (Øsl) 0.1 was found out to achieve minimum weight loss of 12.8306 mg/hour.

REFERENCES

[1] Noelmar Pereira Abbade and Sergio Crnkovic, "Sand–water slurry erosion of API 5L X65 pipe steel as quenched from intercritical temperature", Tribology International 33 (2000) 811–816.
[2] A.Neville and N.Kapur, "An integrated methodology for predicting material wear rates due to erosion", Wear 267(2009) 1935-1944.
[3] K.Shimizu and T.Noguchi, "FEM analysis of erosion wears", Wear 250(2001) 779-784.
[4] Satish V. Borse, and B.K.Gandhi, "Nominal particle size of multi-sized particulate slurries for evaluation of erosion wear and effect of fine particles", Wear 257(2004) 73-79.
[5] K.Nandkumar and P.Minev, "A phenomenological model for erosion of material in a horizontal slurry pipeline flow", Wear 269(2010) 190-196.