Slurry Erosion Wear Behavior of Stainless Steel SS-410 Coated with WC-12co by Detonation Gun Process

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***Abstract*- In the current investigation, cermet coating Tungsten carbide (WC-12Co) was deposited on hydro turbine stainless steel SS-410 by Detonation gun (D-gun) thermal spraying process. Subsequently, the slurry erosion behavior of the coated and bare steels was investigated using a Jet Type Erosion Test Rig. Silica sand was used as the abrasive media. Effects of concentration (ppm), particle sizes, jet velocity and impact angle on the slurry erosion behavior of coated and bare steels under different experimental conditions was studied. The weight of each specimen was measured before and after experimentation using electronic weighing machine. The analysis of slurry erosion behavior of samples was done by using Taguchi's methodology. The average weight reduction due to slurry erosion of coated samples is reduced by 70% from uncoated samples.**

Keywords: Erosion, Wear, Detonation gun process

I. INTRODUCTION

Erosion corrosion is a severe and complex degradation process in which mechanical and electrochemical events interact, causing material loss and component failure. The total material loss results from the sum of the individual contributions of mechanical and electrochemical degradation components and an additional term knows as synergistic or additive effect [1, 2]. Erosion and corrosion of materials cost a very high economic loss to every country. Slurry erosion is a serious problem in a number of Indian hydro power stations especially those located in Himalayan region. Therefore, due to heavy economic losses associated with slurry erosion, this problem has attracted the attention of the researchers worldwide [3]. Slurry erosion occurring as a result of high-velocity impact of hard and angular abrasive particles carried by water is a very common problem faced by the most of the hydropower plants. This problem becomes more severe during monsoon season for hydropower plants situated in the Himalayan region in India and often leads to shutdown [4, 5].
Thermal spray techniques are versatile means of developing a wide variety of coatings to enhance the performance and durability of engineering components exposed to the above said form of wear [6, 7]. Detonation gun (D-gun) spray process is a thermal spray coating process which gives an extremely good adhesive strength, low porosity, coating surface with compressive residual stresses, low oxide contents, and high inter splat strength [8, 9]. The D-gun spray process involves the entrainment of powdered materials with the high-velocity combustion products of a detonation wave as it propagates through a water-cooled barrel. The two-phase mixture of molten particles and detonation products exits the barrel and impinges against a target substrate, where the hot particles bond in overlaying platelets [10]. The evaluation of slurry erosion under actual service conditions is often a difficult task, because of interactive effects of different parameters, such as slurry concentration, velocity, and properties of abrasive medium on wear rate. Accelerated erosion testing of materials can be performed by increasing load, velocity, and other operational parameters in a laboratory test rig where real contact conditions can be simulated [11].

The aim of the current work is to investigate the slurry erosion behavior of D-gun-sprayed WC-12Co coatings on SS-410 steel under the hydro accelerated conditions by means of a jet erosion test rig, to explore the possibility of use of this coating system in actual hydraulic turbines.

II. EXPERIMENTATION

A. Substrate Material

SS-410 stainless steel, which is commonly used in hydropower plants, was selected as a substrate material for the research work These steels received in as cast form were machined and samples of size 15mm*15mm*5mm were prepared. The chemical composition of SS-410 in weight % is 0.15 C, 1 2.0 Si, 1.0 Mn, 0.45 Cr, 0.3 Ni, 18-20 P, 8-12 S and remaining Fe.

B. Coating Deposition

The WC-12Co powder was deposited onto hydro turbine steel using the commercially available detonation gun facility at SVX Powder M surface Engineering Private Limited, Noida, India. The thickness of coating is approximate 200 microns. Before the coating deposition, the polished steel samples were grit blasted using alumina particles of grit size 80.

C. Erodent

For testing purpose, silica sand particles were used as a erodent because silica sand is very hard. Silica sand of three particle sizes (BSS NO. 30, 45, 60) was taken.

D. Slurry-Erosion Testing

Slurry-Erosion Testing was done on a jet type slurry erosion test rig. It is a recirculating-type rig as shown in Figure 2.1.The measured quantities of water and sand are mixed in the tank to obtain the required concentrations of the slurry. The pyramidal-shaped tank does not provide any space for the sand particles to sediment as shown in Figure 2.1. In pyramidal shape tanks, the particles are easily facilitated to flow under gravity. The centrifugal pump used for slurry transportation is driven by a 7.5 H.P./1440 rpm electric motor. Slurry from the tank, sucked through a 100-mm G.I. pipe with the help of a pump, is delivered to the nozzle through 25-mm pipe with a set of control valves. Using these valves, the amount of slurry to pass through the 8-mm nozzle can be controlled easily. An electromagnetic- type flow meter is placed upstream to the nozzle to measure the amount of slurry passing through the nozzle. By using continuity expression, the relation between the velocity of the jet and the discharge indicated by flow meter was established. The holder used to hold the sample has been designed in such a manner to facilitate the variation of impact angle between the slurry jet and sample surface within an accuracy of ±1 deg. Using this specimen holder, it is possible to mount the sample at a desired impact angle ranging from 15 deg to 90 deg. The standoff distance between the nozzle and the specimen was kept fixed at 90 mm for all tests.

To measure the amount of erosion, the weight loss of the samples was measured using a precision weighing balance with 0.1 mg accuracy. All the samples were cleaned carefully with acetone prior to each weight measurement.

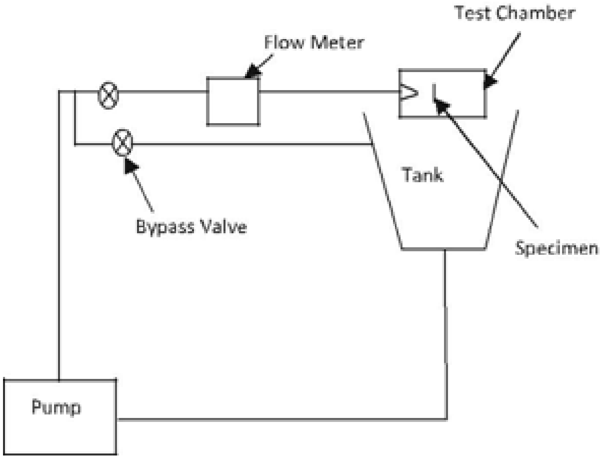

Fig. 2.1. Slurry erosion test rig developed for the current experimentation

E. Design of Experiment

The design of the experiment is a powerful tool that helps in interpreting more meaningful results with the minimum number of experiments using statistical methods for the analysis of data. It also helps in modeling and analyzing the influence of control factors on the performance output. The most important stage in the design of experiment lies in the selection of the control factors. The literature on the slurry erosion behavior of different materials reveals that operating parameters, viz., impact velocity, impingement angle, particle size, and slurry concentration, influence the erosion rate of materials largely. The effect of these four parameters was studied using the L9 (34) orthogonal array of Taguchi's methodology. In the conventional full factorial experimental design, it would have required 34 = 81 runs to study the effect of four factors each at three levels, whereas Taguchi's experiment approach reduces it to only 9 runs. This provides a greater edge in terms of the experimental time and cost. The operating conditions under which erosion tests were carried out have been presented in Table I. Two samples were tested at each combination of factors given by the orthogonal array L9 illustrated in Table II. Each test was run for 60 minutes with weight measurements taken at an interval of every 15 minutes. The analysis of variance (ANOVA) of the results was conducted using ‘‘smaller is better’’ quality characteristics. Randomization of the runs was ensured.

Table I Operating Conditions

Control Factor	Levels			
	I	II	III	
Velocity	15	30	45	m/sec
Impact Angle	30	45	90	deg
Concentration	5000	12000	30000	ppm
Particle Size(BSS no.)	30	45	60	BSS

Run No.	Velocity (m/sec)	ImpactAngle (deg)	Concentration (ppm)	PS (BSS)	Response
1	1(15)	1(30)	1(5000)	30	R1
2	1(15)	2(45)	2(12000)	45	R2
3	1(15)	3(90)	3(30000)	60	R3
4	2(30)	1(30)	2(12000)	60	R4
5	2(30)	2(45)	3(30000)	30	R5
6	2(30)	3(90)	1(5000)	45	R6
7	3(45)	1(30)	3(30000)	45	R7
8	3(45)	2(45)	1(5000)	60	R8
9	3(45)	3(90)	2(12000)	30	R9

Table II Orthogonal array L9

III. RESULTS AND DISCUSSION

For each run of coated and uncoated specimens the weight loss pattern curves were shown below. Along X-axis time was taken and along Y-axis weight of specimen was taken. Graphs from figure no. 3.1 to 3.9 show weight loss pattern curves for uncoated material and graphs from figure no. 3.10 to 3.18 show weight loss pattern for coated material.

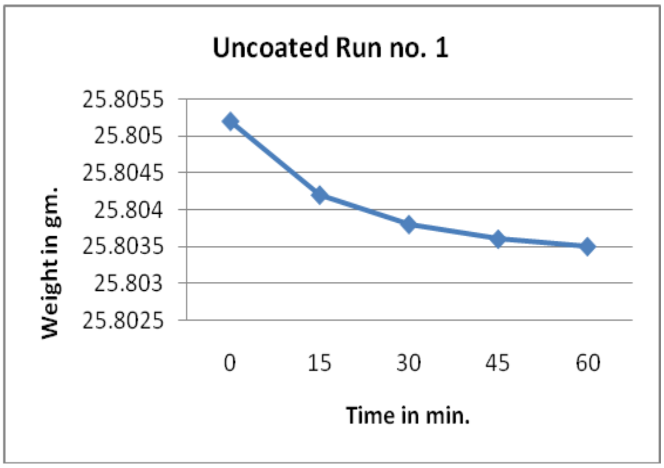

Figure no. 3.1:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 1

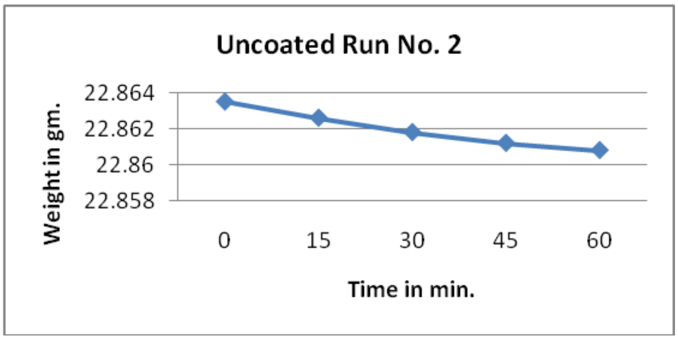

Figure no. 3.2:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 2

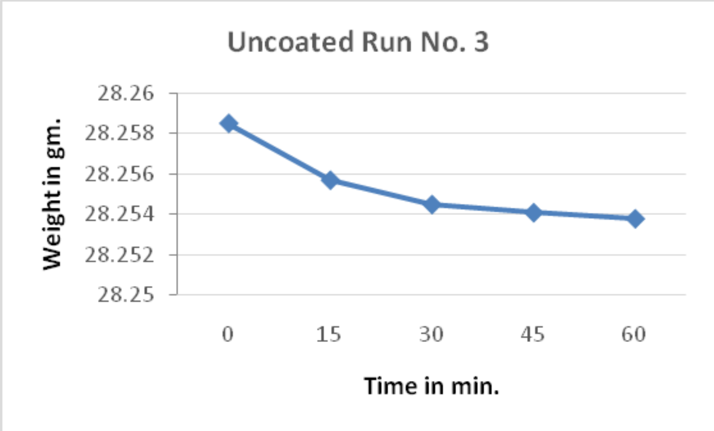

Figure no. 3.3:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 3

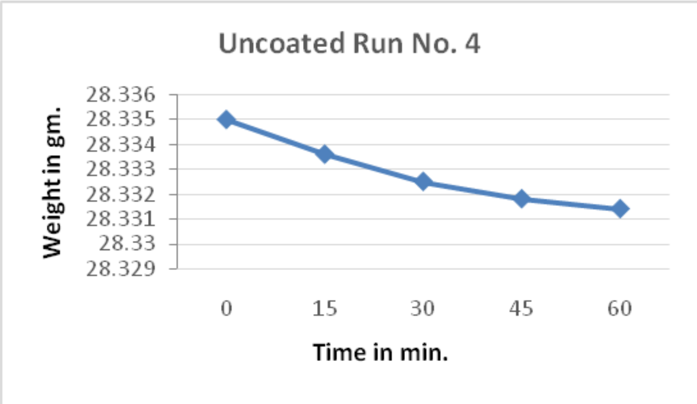

Figure no. 3.4:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 4

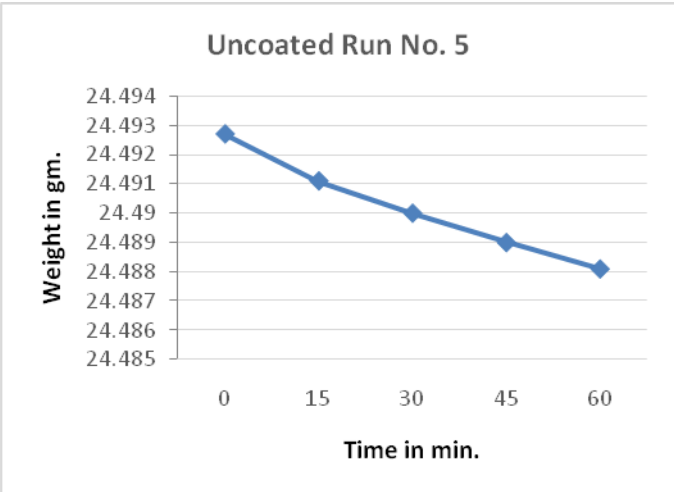

Figure no. 3.5:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 5

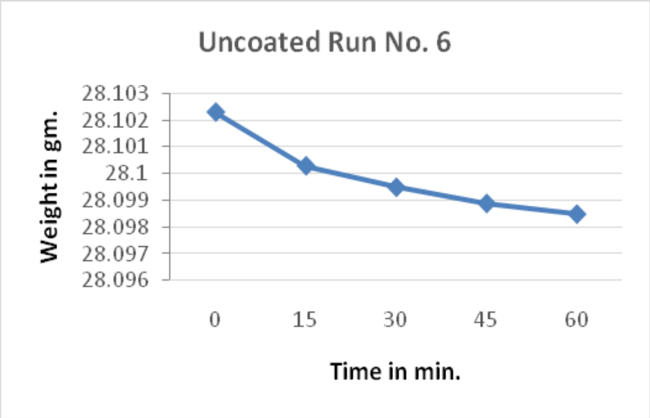

Figure no. 3.6:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 2

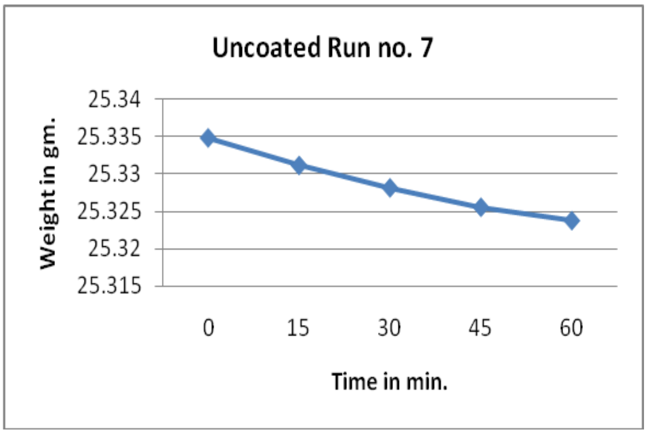

Figure no. 3.7:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 7

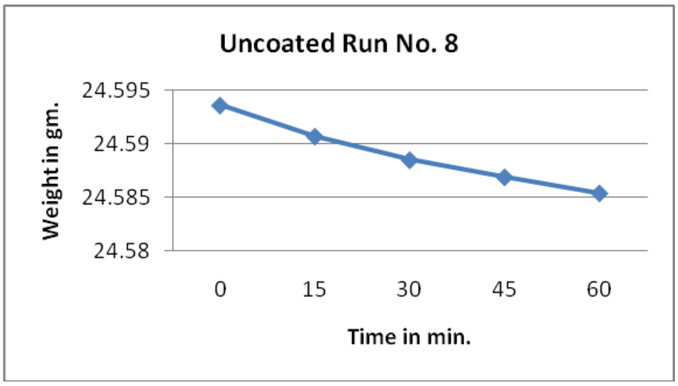

Figure no. 3.8:-Variation of weight change with time in min. for uncoated SS-410 steel for Run no. 8

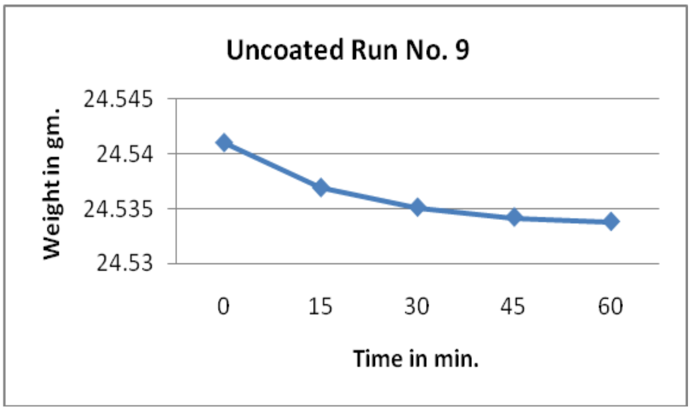

Figure no. 3.9:-Variation of weight change with time in min. for uncoated SS-410 steel for or Run no. 9

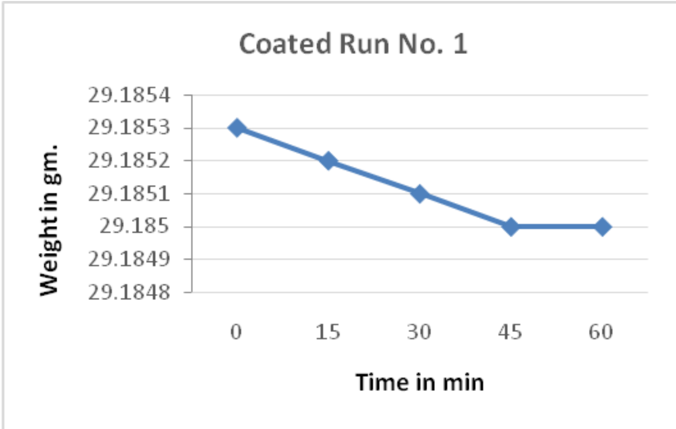

Figure no. 3.10:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 1

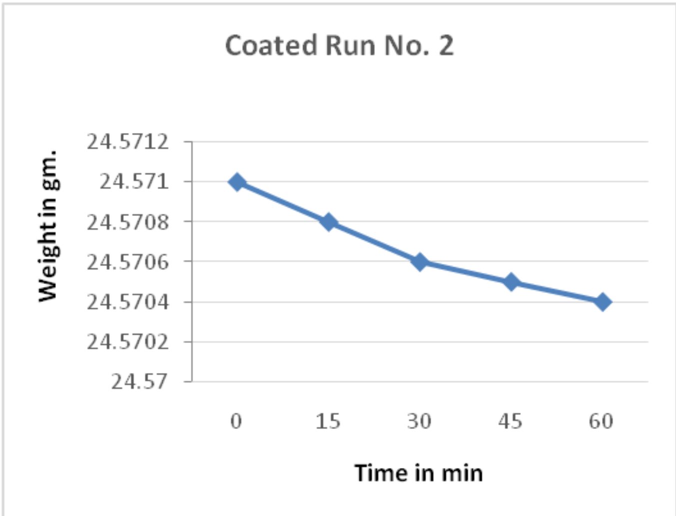

Figure no. 3.11:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 2

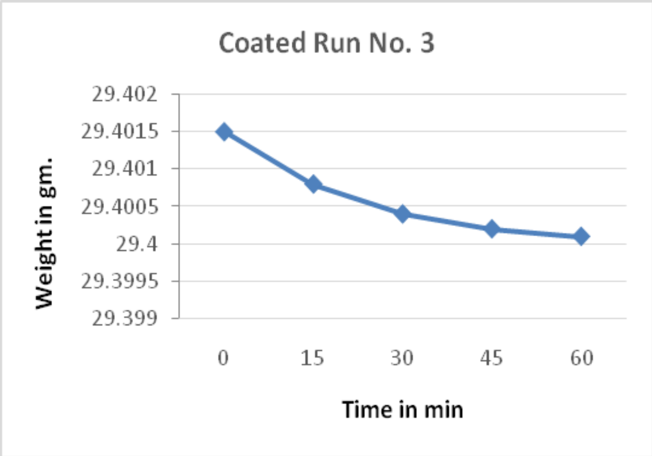

Figure no. 3.12:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 3

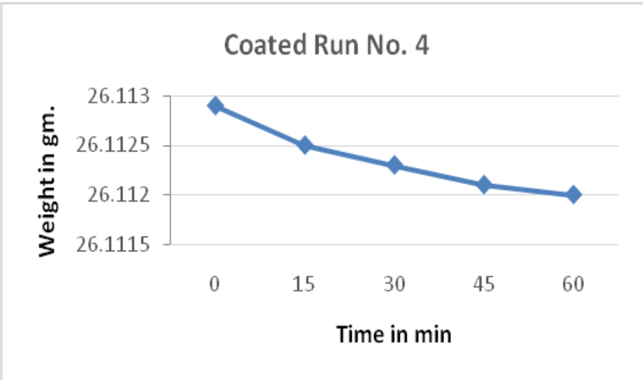

Figure no. 3.13:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 4

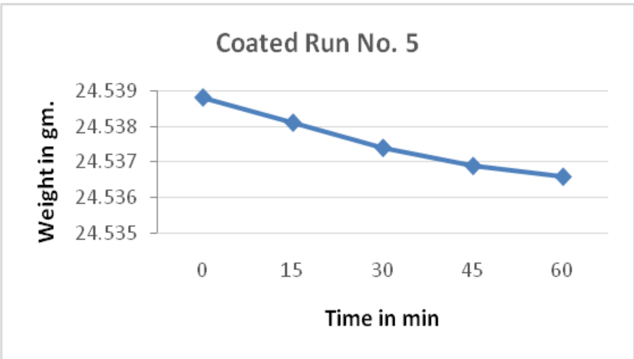

Figure no. 3.14:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 5

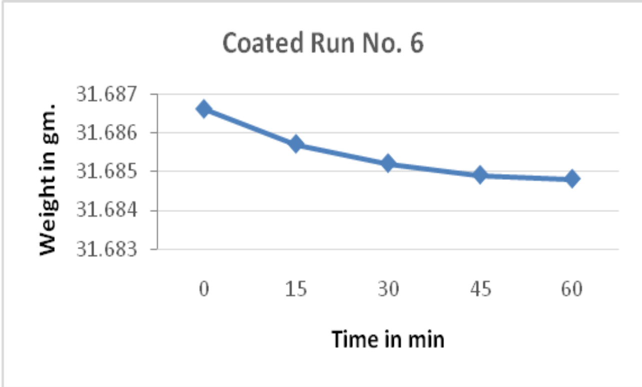

Figure no. 3.15:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 6

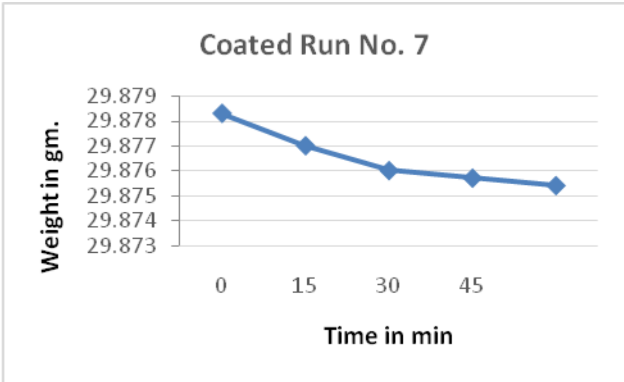

Figure no. 3.16:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 7

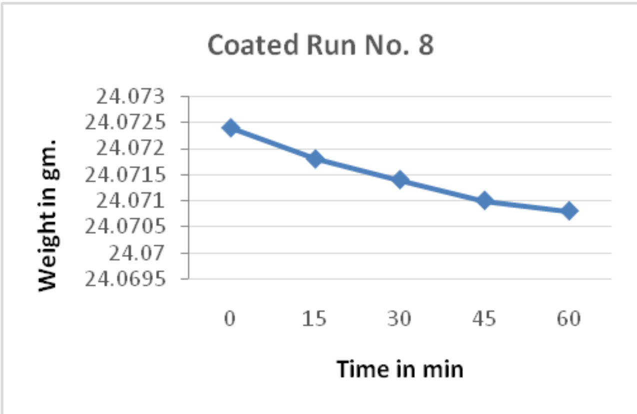

Figure no. 3.17:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 8

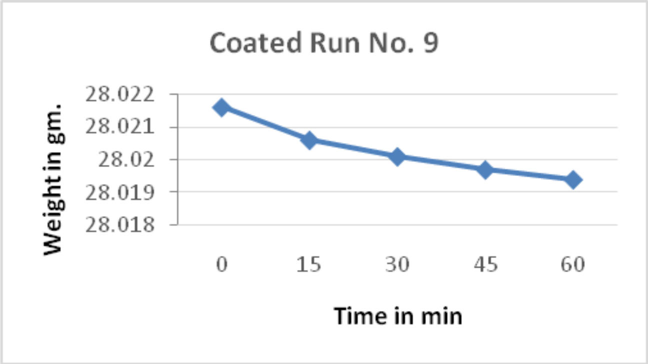

Figure no. 3.18:-Variation of weight change with time in min. for coated SS-410 steel for Run no. 9

From these graphs it was observed that there was decrease in erosion rate of coated specimens than the uncoated specimens. The total average reduced weight of uncoated specimens due to slurry erosion during experiments is 0.011525gm and that of coated specimens is 0.00345gm .The slurry erosion of coated samples is reduced by 70% from uncoated samples. The effect of four parameters on slurry erosion rate of both coated and uncoated specimens is given below:

A. Effect of velocity

The rate of slurry erosion depend upon the velocity of impinging particles in water. The weight loss pattern curve for both uncoated and coated material is given below.

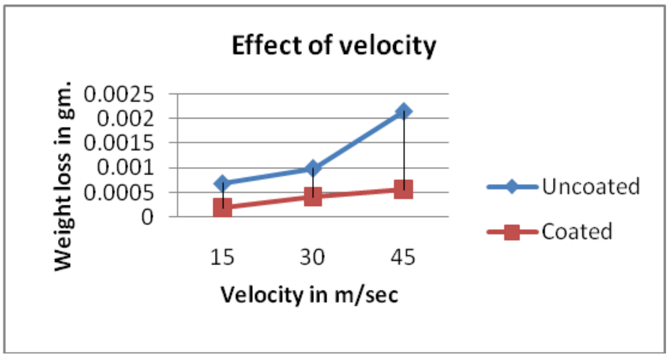

Figure no. 3.19-Variation of loss of weight for coated as well as uncoated SS-410 w.r.t velocity

It was observed that for both specimens with increase in velocity the slurry erosion rate is increased. But the rate of slurry erosion for coated specimens is less than uncoated specimens. It was observed that there is rapid increase in rate of slurry erosion from 15m/s to 30m/s but there is less increase in rate of slurry erosion from 30m/s to45m/s. Because at high speeds the sand particles strike with each other due to which energy of particles is reduced.

B. Effect of impact angle

The rate of slurry erosion depends upon the angle of specimen with the jet of slurry. The weight loss pattern curve for both uncoated and coated material is given below.

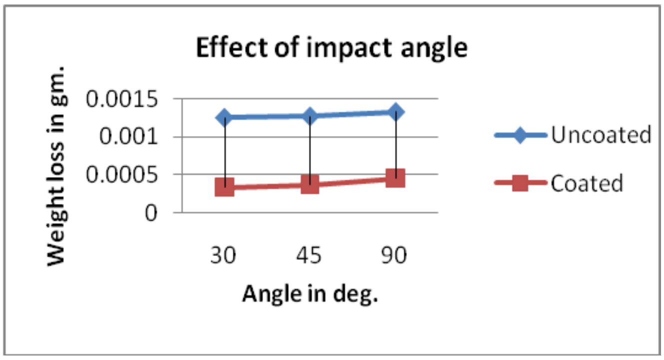

Figure no. 3.20:-Variation of loss of weight for coated as well as uncoated SS-410 w.r.t impact angle

It was observed that highest rate of slurry erosion is at 90 deg because at 90 deg maximum sand particles strikes with the surface of specimen.

C. Effect of concentration

The rate of slurry erosion depends upon the concentration of slurry in the water. The weight loss pattern curve for both uncoated and coated material is given below:

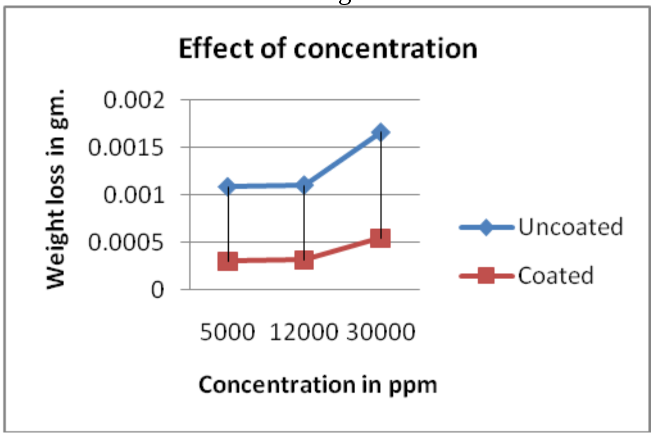

Figure no. 3.21:-Variation of loss of weight for coated as well as uncoated SS-410 w.r.t ppm

It was observed that with inrease in concentration of slurry the rate of slurry erosion is increased. But we see that there is less increase in rate of slurry erosion from 12000ppm to 30000ppm. Because at higher concentrations sand particles collide with each other due to which the energy is reduced and sand particles strike with surface of specimen with less momentum and slurry erosion rate is decreased.

D. Effect of particle size

The rate of slurry erosion depends upon the particle size of the silica sand. The weight loss pattern curve for both uncoated and coated material is given below.

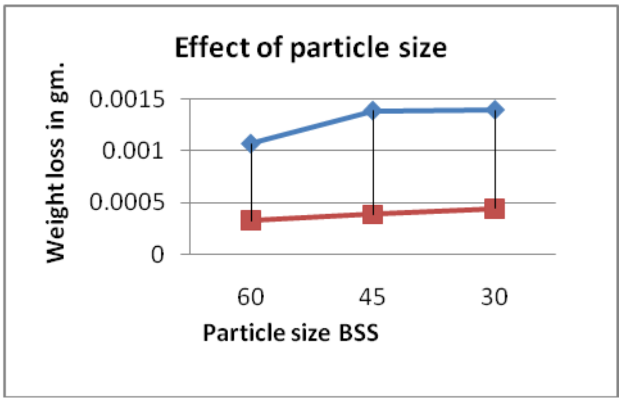

Figure no. 3.22:-Variation of loss of weight for coated as well as uncoated SS-410 w.r.t particle size

It was observed that with increase in particle size , the rate of slurry erosion is increased. We see that the rate of slurry erosion of coated specimens is less than the rate of slurry erosion of uncoated specimens.

IV. CONCLUSIONS

(a) D-gun-sprayed WC-12Co coatings can reduce the erosion rates of the SS-410 steel.

(b) During the slurry erosion of SS-410 steel, slurry concentration and jet velocity were found to more be dominant factors in comparison with average particle size. In the case of D-gun-sprayed WC-12Co coatings, average particle size was found to be more dominant factor in comparison with slurry concentration and jet velocity. Thus, D-gun-sprayed WC-12Co coatings can be used in high-speed hydro turbines and with high concentration slurries.

REFERENCES

[1] H.X. Guo, B.T. Lu, and J.L. Luo, “Interaction of Mechanical and Electrochemical Factors in Erosion-Corrosion of Carbon Steel”, Electrochim. Acta, 2005, 51(2), p 315–323

[2] A. Neville, F. Reza, S. Chiovelli, and T. Revega, “Assessing Metal Matrix Composites for Corrosion and Erosion-Corrosion Application in the Oilsands Industry”, Corrosion, 2006, 62(8), p 657–675

[3] A.P. Harsha and D.K. Bhaskar, Solid Particle Erosion Behaviour of Ferrous and Non-ferrous Materials and Correlation of Erosion Data with Erosion Models, Mater. Des., 2008, 29(9), p 1745-1754

[4] D.P. Sharma and S. Singh, Operational Problems of Water Turbine in U.P.—With Special Reference to Tiloth Power Station, Proceedings of All India Seminar on Metallurgical Problems in Power Projects, 30-31 Oct. 1987 (Lucknow), p 18-35

[5] B. Rajasekaran, S. Ganesh Sundara Raman, S. Joshi, and G. Sundararajan, Influence of Detonation Gun Sprayed Alumina Coating on AA 6063 Samples Under Cyclic Loading With and Without Fretting, Tribol. Int., 2008, 41(4), p 315-322

[6] P.M.J. Vuoristo, K. Niemi, and T. Mantyala, “On the Properties of Detonation Gun Sprayed and Plasma Sprayed Ceramic Coatings, Thermal Spray”, International Advances in Coatings Technology, C.C. Berndt, Ed., ASM International, Metals Park, OH, 1992, p 171-175

[7] B.S.K. Naidu, Developing Silt Consciousness in the Minds of Hydropower Engineers, Proceedings of 1st International Conference on Silting Problems in Hydropower Plants, CBIP, 13-15 Oct.1999 (New Delhi), p 1-36

[8] S.V. Joshi and R. Sivakumar, “Protective Coatings by Plasma Spraying”, Trans. Indian Ceram. Soc., 1991, 50, p 50-59

[9] K.G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, New York, 1988, p 15-48

[10] J. Knapp, “Fine-Particle Slurry Wear Resistance of Selected Tungsten Carbide Thermal Spray Coatings”, Tribol. Int., 1997, 30(3), p 225-234

[11] SanjeevBhandari, Harpreet Singh, Harmesh Kumar, and VikasRastogi (2012),” Slurry Erosion Performance Study of Detonation Gun-Sprayed WC-10Co-4Cr Coatings on CF8M Steel Under Hydro-Accelerated Conditions”, Journal of Thermal Spray Technology, Vol. 21(5), pp. 1054—1064