Slurry Erosion Wear Characteristics of Pump Material Installed in Tapi River Basin of North Maharashtra Region

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***Abstract*— In the present study, slurry erosion wear characteristics of Pump material (Dapora pumping station) has been investigated. The wear specimens were prepared using the impeller material gun metal bronze IS318. The effect of impact on the erosion rate using Indian standard sand were conducted. It is observed that the maximum erosion wear occurs at 45° impact angle which is a typical behaviour of ductile material. Also the erosion wear increases with increasing the impact particle velocity. SEM images of the worn out specimens reveal that the ploughing and cutting mechanisms are dominant at shallow impact angles while at normal impact angle material is removed by indentation craters.**

***Index Terms*—Gun metal bronze IS 318, impeller, Slurry Erosion wear; Slurry Pot tester.**

I. INTRODUCTION

Wear is defined as the progressive volume loss of material from a target surface. It may occur due to corrosion, abrasion or erosion. Slurry erosion is caused by the interaction of solid particles suspended in a liquid and a surface which experiences loss of mass by the repeated impacts of particles. According to Fig.1the erosion wear has classified as a solid particle erosion, liquid impingement erosion and cavitation erosion. Solid particle erosion is the loss of material that results from repeated impact of solid particles suspended in the flowing fluid, at any target surface [1].

The slurry erosion is a complex phenomenon and it is not yet fully understood because it is influenced by many factors, which act simultaneously. Figure 2 shows these factors which include flow field parameters, target material properties and erodent particle characteristics. Among these parameters, the impingement angle and microstructure of the target material play an important role on the material removal process. The impact angle is defined as the angle between the target surface and the direction of impact velocity of the solid particle (see Figure 4). It is generally agreed that the rate of mass loss due to erosion is a function of impact angle of particles [2,3] the variation of the wear with impact angle is different for ductile and brittle materials as shown in Fig.3. For ductile materials, the maximum erosion usually occurs around 20-30° impact angle where as in brittle materials, the maximum erosion occurs at normal (90°) impact angle. The impact velocity has dominant effect on the material removal rate. [4, 5]The erosion rate is generally related to the particle velocity using power law relationship in which the power index for velocity varied in the range of 2-4.

In the present work, The Pump at “Dapora Pumping Sation” at Village Dapora, District Jalgaon was dismantled and the

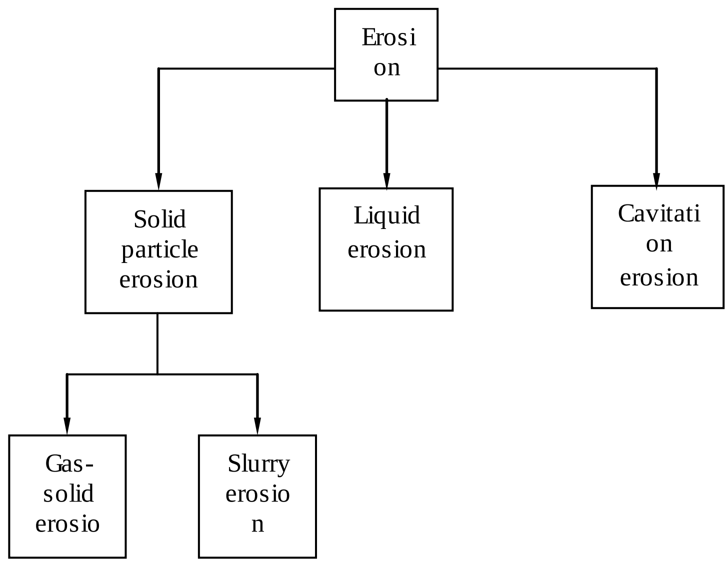


Fig. 1: Types of erosion wear

impeller (Figs. 4) of the pump was examined with necked eyes to identify the probable cause of wear and its type.From the preliminary examination, it was observed that the impeller of

the pump was worm out due to parallel flow wear and the casing was due to erosion wear. It was observed that the material from edges of the diffuser vanes of the impeller was worn out and deformed due to solid particles loading.

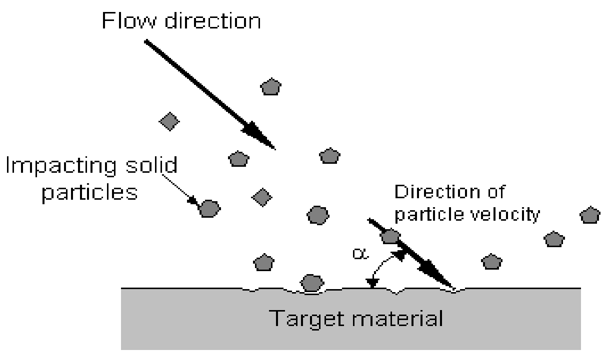


Fig. 2: Erosion wear by solid particles impact

Fig.4: Worthington 5 stage pump impeller (Dapora Pumping Station Jalgaon)

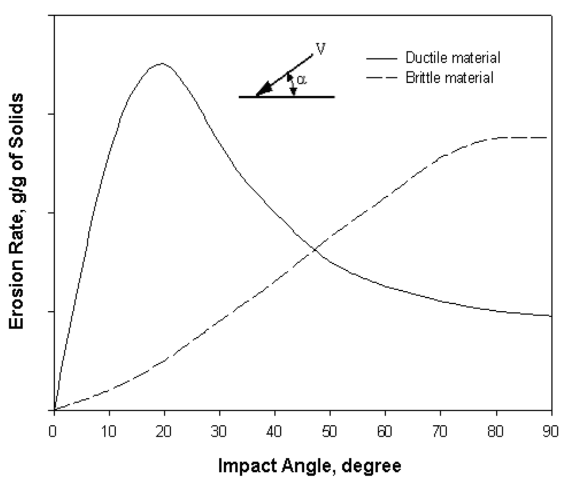


Fig. 3: Variation of erosion wear with impact angle

II. EXPERIMENTAL PROGRAM

2.1. Experimental setup

A slurry pot test rig developed by Desale et al. 2005[6] is used in the present work. Figure 5 shows the schematic diagram of the pot tester with dimensional details. The AISI SS304L cylindrical pot of diameter of 240 mm and height of 155 mm is used to fabricate the slurry pot tester. Four baffles of size 10 mm x 25 mm x 155 mm are provided at wall of cylindrical pot at equal distance to break the vortex motion produced due to rotation of the propeller. At the bottom of the pot, a drain hole of 20 mm diameter is provided to drain the solid-liquid mixture after the experiment**.** A 12 mm thick transparent acrylic sheet is provided to cover the pot which allowed visual observations. The shaft is held in position by bearings assembly placed at a distance over the cover of the cylindrical pot. The shaft is coupled to the shaft of AC motor with Love jaw coupling as shown in Fig. 5, a hole of 11 mm diameter with oil-seal is provided at the bottom of the pot to insert a shaft for rotating the propeller. A PBT-4 propeller is mounted on this shaft for kept slurry in suspension at a distance of 24 mm above the bottom and is rotated by a0.66 kW DC motor. A shaft is also inserted from the top of the tank through the transparent sheet to rotate the wear specimens at desired speeds by a separate 1.1185 kW, 2 Amp AC motor. At lower end of the shaft, a brass sleeve of 30 mm length and 25 mm diameter is provided with provision for fixing two horizontal arms to hold two test fixtures.

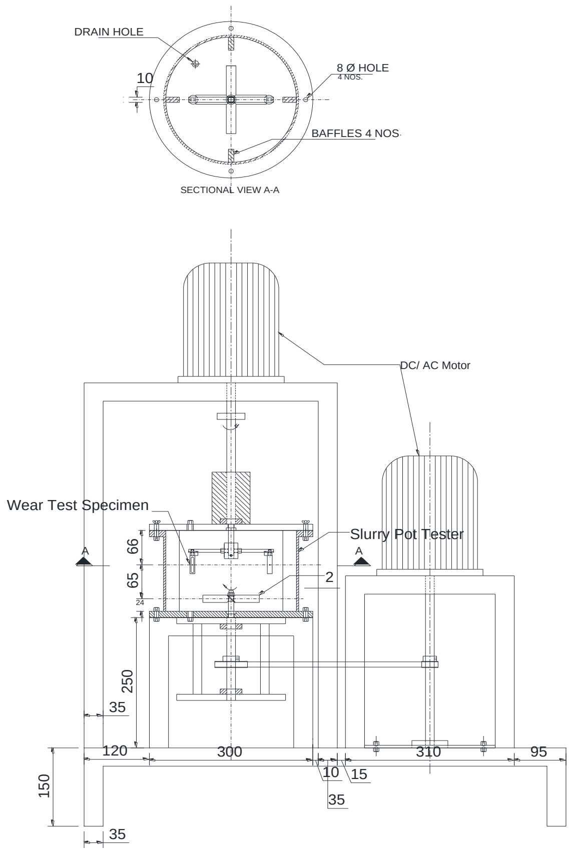


Fig.5: Schematic diagram of Slurry pot tester

2.2 PROPERTIES OF MATERIALS USED

2.2.1 Particle size distribution

The particles are present in the different size ranges so the distribution of the particle size is essential. The distribution of the particle size is obtained by the dry sieve analysis method It is not possible to collect the identical size particles of the solid material so they are sieved by the successive sieves are designed by the mean sieve size. The Sand of average particle size 256μm is collected in between 300 μm & 212 μm Indian standard sieves. The Quartz (IS Sand) is used for the present work, the physical properties are given in Table I.
In the present study, the impeller made of gun metal bronze is used as a substrate material and the Quartz (IS Sand) with water is used as an erodent material.

TABLE I
Physical Properties of Erodent Used

Solid particle	Chemical Formula	Colour	Sp. Gravity (Kg/m^3)	Hardness (VHN)	Particle Shape
Quartz (IS Sand)	SiO_2	Whitish	2652	1100	Blocky

2.2.2 Target material properties

In the present study, the impeller made of gun metal bronze is used as a target material. As discussed in the introduction the impeller is brought from Dapora pumping station (Jalgaon) and it is observed that, the edges of diffuser vanes of the impeller were worn out and deformed, due to solid particles loading. The vanes of the impeller were cut and used to prepare the wear test specimens with the help of water jet cutting machine. The chemical composition of material has been determined by using the optical emission spectrometer and given in TABLE II.

TABLE II
Elemental Composition of the Target Material

Target Material	Elemental composition (wt. %)							
	Cu	Sn	Pb	Zn	Al	Ni	Sb	Fe
Bronze IS 318	85.50	5.25	4.26	4.25	0.003	0.43	0.15	0.10

TABLE III
Range of parameters for the investigation of erosion behavior of Substrates.

Target Material	Impact Angle (°)	Particle size	Solid concentration (% by wt.)	Velocity (m/s)	Slurry type	Test Device
Bronze IS 318	15,30, 45,60, 75, 90	256 μm	10%	3.5,4, 4.5,5, 5.5,6, 6.5,7, 7.5,8	Quartz with tap water	Slurry pot tester

2.2.3 Range of parameters

The erosion wear behaviour was investigated using the specimens made of pump material (Bronze IS 318). The slurry of 10 % by weight concentration was prepared by mixing the 256μm size Quartz (IS Sand) and the tap water. The range of the parameters for the testing is listed in the TABLE III. The experiments were performed at 4.5 m/s velocity in the range of 15^0-90^0 impact angle which in the step of 15^0. Additionally, the experiments at different velocities 4.5- 8 m/s were conducted at 45^0 impact angle.

2.3 EXPERIMENTAL PROCEDURE

Fresh wear specimens are taken for each experiment and are polished with #2000 emery paper before conducting any wear test to keep identical initial condition for each experiment. The wear specimens are cleaned with tap water, rinsed in acetone and dried with hot air blower before and after each test.

To prepare the solid-liquid mixture, a predetermined mass of solid particles was weighing on weighing balance and poured first in the pot then it was closed by tightening the acrylic cover. The known quantity of water was then poured through the hole at the top of the cover to completely fill the pot. The propeller shaft is rotated in down-pumping mode at the desired suspension speed to achieve nearly uniform distribution of solid particles in water. The speed of each shaft is measured by using a non-contact type tachometer. The assembly of the test fixture was mounted on upper shaft, which is to be rotated at desired test speed [7].The speed of shaft is controlled by using VFD controller. Mass loss of the wear specimen is measured by an electronic balance (Make: Merck, Model No. SI234DE) having least count of 0.1 mg. The average mass loss of two wear specimens is used to evaluate the erosion rate according to the relationship proposed by [8] which is as below;

$$Ew = \frac{W_L}{\rho_S \times A_{SP} \times Cv \times V_{SP} \times T \times Sin\alpha} \quad (1)$$

$$Cv = \frac{Cw}{\rho_S - (\rho_S - 1) \times Cw} \quad (2)$$

Where,

E_w is erosion rate in g/g, W_L is average mass loss in g, ρ_s is solid particle density Kg/m^3, Asp is area of test specimen in m^2, C_v is the solids volumetric concentration, V_{sp} is the velocity of test specimen m/s, T is Experimental time in min, α is impact angle in degree and C_w is solids concentration by weight.

III. RESULT AND DISCUSSION

The effect of impact angle on the erosion wear rate of impeller material is presented systematically. Also, the effect of velocity on erosion wear rate is discussed in detail along with the material removal mechanisms.

3.1.1 Variation of the wear with orientation angle

The variation of erosion rate with orientation angle of wear specimen is presented graphically in Fig. 6 for the gun metal bronze IS 318 (impeller material) with quartz particulate mixtures. The variation of erosion wear with the impact angle depends on the characteristics of target material namely, brittle or ductile type. It can be seen from Figs. 6 that the erosion rate of gun metal bronze IS 318 increases with increase in the orientation angle up to 45° showing maximum value as 9.284 x 10^{-8} g/g with quartz as erodent. Further increase in orientation angle results in continuous decrease in the wear rate till 90° angle. Many investigators [6, 8, 9, 10, 11, 12, 13, 14 and 15] have also reported similar variation of erosion wear with impact angle for ductile materials. However, different angle for the maximum wear has been reported by different investigators, which can be attributed to the variations in the materials used, test rig and experimental conditions.

To investigate the material removal mechanisms, SEM micrographs of worn out specimens have been examined. The SEM micrographs of worn out surfaces of gun metal bronze IS 318 at 45° impact angle due to particulate mixtures of quartz is shown in Figs. 7 (a). It is observed from Fig. 7 (a) that the blocky shape quartz particles remove the target material due to deformation, ploughing and displacing the material in the flow direction. However at the impact angle of 90°, it can be seen that the platelet mechanism disappeared showing only indentations at the surface (Fig. 7 b). The impacting particles at normal impact angle develop indentation with piling of the material over the adjacent crater, which may get flattened by further impact of particles. This indicates that at the impact angle of 90°, all the particles are striking the target surface with normal impact angle only.

TABLE IV

Result of erosion wear test at different impact angle on Substrates.

Sr. No.	Impact Angle(°)	Average Mass loss (x 10^{-8} g)	Erosion Wear (x 10^{-8} g/g)
1	15	0.0031	4.794
2	30	0.0102	8.166
3	45	0.0164	9.284
4	60	0.01165	5.385
5	75	0.00575	2.382
6	90	0.0045	1.801

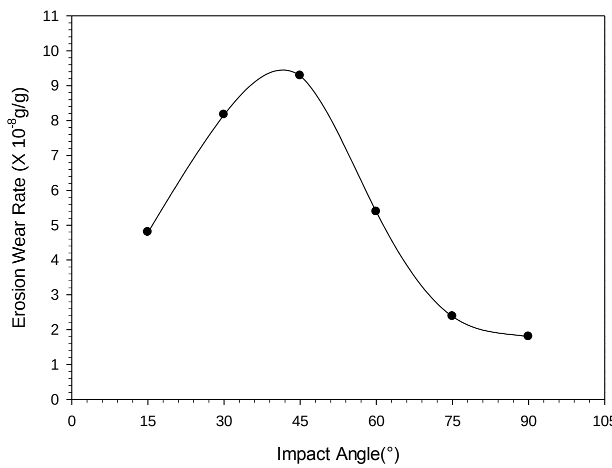
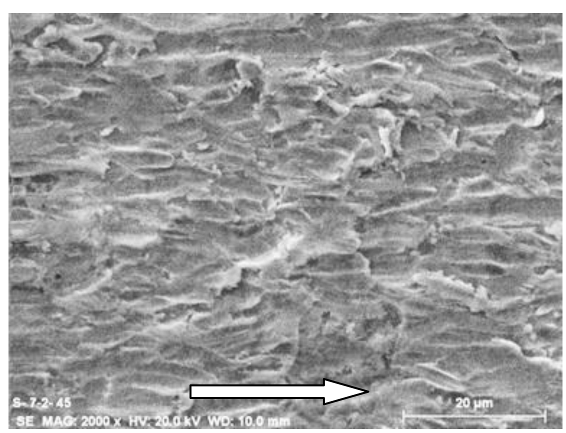
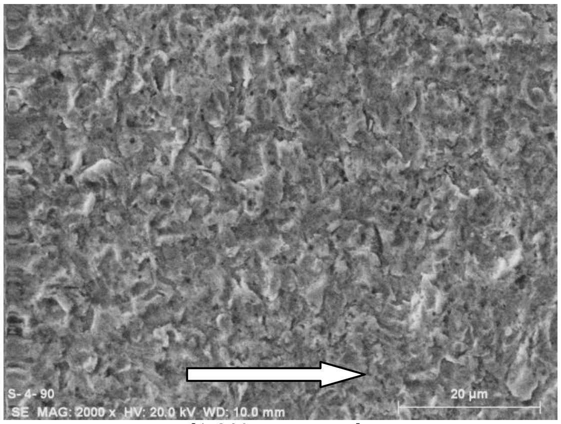


Fig.6: Effect of Impact angle on erosion wear rate



a) 45° impact angle



b) 90° impact angle

Fig. 7: SEM micrographs of worn out surfaces of gun metal bronze IS 318 at different impact angles (particle size: 256 µm , Cw = 10 % by wt. and Velocity = 4.5 m/s)

3.1.2 Effect of Velocity

To investigate the effect of velocity on erosion rate, experiments were further conducted at 3.5 - 8 m/s velocities (given in Table III) with gun metal bronze IS 318 as target material and quartz particles as erodents at 45° impact angle. The average mass loss values at higher velocities for particles size of 256µm at 10% weight concentration of sand-water mixture are given in Table V at 45° impact angle. The variation of erosion rate at these velocities with respect to impact angle is presented in Fig. 8. It is seen that the erosion rate is significantly higher for higher velocities. The erosion rate increases with increasing the velocity and the average slope for velocity is seen to be 2.34. The exponent of velocity is generally found to lie in the range of 2 to 3 depending on the slurry properties and the target material. [8, 16, 17, 18, 19] In order to analyze the material removal mechanism, the worn out surfaces at 3.5 m/s, 6 m/s and 8 m/s velocities for 45° impact angle were examined using scanning electron microscope and the micrographs are shown in Fig. 9 (a-c). It has been already discussed that the material removal is contributed by the platelet formation at 4.5 m/s velocity and 45° orientation angle (see Fig. 7 (a)). The impacting quartz particles deform the surface by ploughing, displacing the material and forming a rim over the adjacent crater in the particle flow direction without formation of new surface. However, at higher velocities 6 m/s and 8 m/s, the material is also removed by micro cutting along with the platelets formation (Fig. 9 (b and c)).

TABLE V

Mass loss and erosion wear rates of gun metal bronze IS 318 at different velocities and at 45° Impact angle.

Sr. No.	**Velocity (m/s)**	**Average mass loss ($x10^{-8}$ g)**	**Erosion Wear ($x 10^{-8}$ g/g)**	**Time (Min)**
1	3.5	0.0076	5.5318	60
2	4	0.0112	7.1332	60
3	4.5	0.0164	9.284	60
4	5	0.0127	12.9416	30
5	5.5	0.0160	14.8222	30
6	6	0.02235	18.9793	30
7	6.5	0.01395	21.8698	15
8	7	0.0192	27.9503	15
9	7.5	0.0242	32.8805	15
10	8	0.0192	36.6848	10

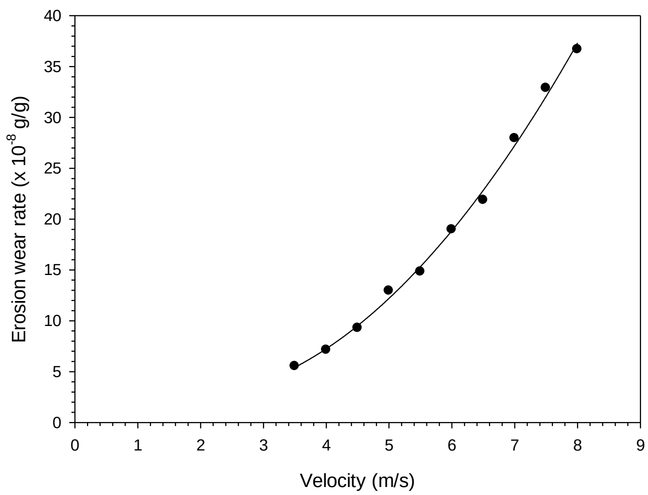
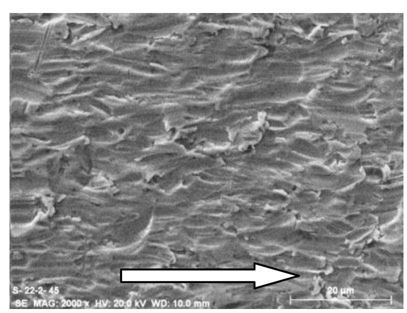
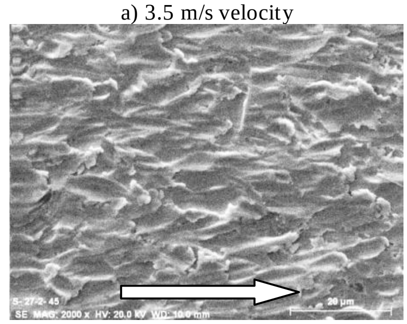


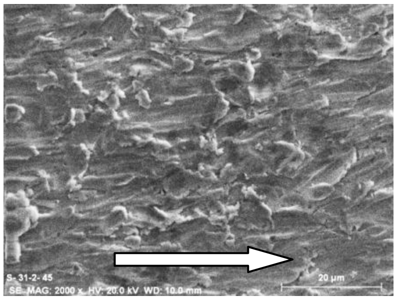
Fig.8: Effect of Velocity on erosion wear rate



a) 3.5 m/s velocity



b) 6 m/s velocity



c) 8 m/s velocity

Fig. 9: SEM micrographs of worn out surfaces of gun metal bronze IS318 with quartz particulate mixture at different velocities (particle size: 256 µm , Cw = 10 % by wt. and impact angle 45° images)

IV. CONCLUDING REMARKS

The impeller made of gun metal bronze IS 318 from Dapora pumping station (Jalgaon) was used for erosion wear testing using slurry pot tester. From the experimental results and the micrographs of the worn out surfaces following broad conclusions can be drawn;

1) The impeller material (gun metal bronze IS 318) shows maximum erosion wear at 45° impact angle and further increasing the impact angles erosion wear decreases and observed minimum at normal impact angle.

2) SEM micrographs of worn out specimens revealed that at 45° impact angle the material is removed due to deformation, ploughing and displacing the material in the flow direction. However, at normal impact angle, the indentation craters are dominant.

3) Increasing the velocity of the erodent increases the erosion rate and the average slope for velocity is observed 2.34. Thus the kinetic energy of the impacting particle is responsible for material removal from the target surface.

4) At 45° impact angle, the impacting quartz particles deform the surface by ploughing, displacing the material while increasing the velocity, the material is also removed by micro cutting along with the platelets formation.

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