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CONSTRUCTION OF SLURRY JET EROSION TESTER AND THE EFFECT OF PARTICLE SIZE ON SLURRY EROSION

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ABSTRACT

A Jet erosion tester is designed and used to study the relative erosion behavior of high chromium white cast iron (ASTM 532A) at specific concentration of silica sand as an abrasive material, 45° impact angle and two size of abrasive particles. A slurry pot was used which contains two propellers rotated at the speed required for uniform distribution. The test specimens are mounted on test fixture which is fixed and has a provision to move in different angular position to find out the wear for different angles. Two different experiments are conducted preliminarily by using silica sand as abrasive with particle size of 400-600 μm and 600-800 μm. Impact angle of 45° and solid abrasives of 20% wt. concentration are used as fixed parameters for 10 hours. It was found that the erosion resistance decreases with increasing the abrasive particle size.

KEYWORDS: Jet Erosion tester, Slurry erosion, High chromium white irons.

1. INTRODUCTION

Slurry erosion is caused by the interaction of a liquid suspension of solid particles and a target which experiences loss of material by the repeated impact of suspension particles. These parts of a system in which erosion is taking place are connected through the flow field which has a strong bearing on the rate of material loss from the eroding body and hence the time to failure of engineering parts in service (Clark, 1992, ASM, 1992).

Slurry erosion has long been a serious problem in a variety of applications; including the mineral processing, cement manufacturing, slurry pumping, pulp, and paper manufacturing industries (Pearce, 2002, Llewellyn et al., 2004, Zhi et al., 2008), since it is one of the main sources of failure in many industrial applications. Therefore, there is an urgent need to solve this problem or at least minimize its effects. The slurry erosion is a complex phenomenon and it is not yet fully understood because it is influenced by many factors, which act simultaneously. These factors 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 (More et al., 2014).

1.1. Parameters Affecting on Erosion Wear

1.1.1. Impact Angle

Impact angle is defined as the angle between the target surface and the direction of striking velocity of the solid particle. The variation of erosion wear with the impact angle depends on the characteristics of the target surface material namely brittle or ductile type (Clark, 2002). The maximum erosion occurs at 20-30 degrees' impact angles for ductile materials. Whereas, the maximum erosion wear occurs at 90 degrees' impact angle in case of brittle materials (Desale et al., 2009, Thakur et al., 2015).

1.1.2. Velocity of Solid Particles

Velocity of solid particle play very important role in the erosion process and is directly proportional to the erosion rate. As the velocity increases there is significant increase in erosion rate, cause more erosion loss than a particle with less velocity (Thakur et al., 2015).

1.1.3. Hardness

Hardness is the characteristic of a solid material expressing its resistance to permanent deformation. Surface hardness as well as hardness of solid particles has profound effect on the erosion wear mechanism. Hardness ratio has been defined as the ratio of hardness of target material to the hardness of solid particles (Wang et al., 2011).

1.1.4. Particle Size and Shape

Particle size and shape is also one of the prominent parameter, which affect erosion wear. Many investigators have considered solid particle size important to erosion. The erosion wear increases with increase in particle size (Thakur et al., 2015). The effect of particle shape on the erosion is not very well established due to difficulties in defining the different shape features (Wang et al., 2011). Generally, roundness factor is taken into consideration (Thakur et al., 2015, Gandhi et al., 1999).

1.1.5. Solid Concentration

Concentration is amount of solid particles by weight or by volume in the fluid. As concentration of particle increases more particles strike the surface of impeller which increase the erosion rate, the concentration of slurries can vary from 2% to 50% depending upon the type of slurry. However, at very high concentrations particle interaction increases and this decreases the striking velocity of particle on the surface (Sharma and Kumar, 2008).

The present study has been undertaken to evaluate erosion wear of high chromium white cast iron using slurry jet erosion tester. Silica sand water mixture has been used to investigate the effect of particle size of silica on the weight loss due to multi-sized particulate slurries. Experiments on erosion of high chromium white cast iron in sand–water mixture has been carried out to find suitability of the device for wear evaluation.

2. EXPERIMENTAL PROCEDURE

2.1. Construction of Jet Erosion Tester

Initially an experiment on high chromium white cast iron (ASTM A532-ClassIII A) (HCWI) in sand-water mixture has been carried out to find suitability of the device for erosion evaluation. The photograph and schematic diagram for the jet erosion tester are shown in Fig. 1 and Fig. 2, they show that the test rig consists of important part namely as slurry pot, this pot has 110-liter capacity. The function of this pot is to prepare homogeneous mixture of sand and water for different particle sizes of silica sand and 20% wt. concentrations of silica sand as an abrasive. To prepare the homogeneous mixtures of different combinations the pot has a stirrer which is to be rotated by A.C. motor has maximum capacity of 1420 rpm. This test rig also contains a centrifugal pump of 2Hp capacity (2.5 bar) made by DONGYIN (Pumps CPM200/2). This pump sucks the slurry from slurry pot and supply the high pressure slurry to the converging section of the nozzle made according to ASTM standard G76 of 5 mm diameter and 124 mm long where its pressure energy is converted into the velocity of fluid.

Fig. 1. Photograph of jet erosion tester.

There is one control valve also attached to control the mass flow rate of the mixture. It also has a specimen holder (Fixture), which has an arrangement to moves in different angular positions. One plastic chamber is also attached to rig which is helped to restrict the spreading of mixture into the work environment. This chamber collects the mixture after impacting on the specimen and drops it back into the slurry pot to recirculate the mixture. The main part of the test rig is the frame structure which supports or holds the whole assembly and stirrer motor.

2.2. Particle Size Distribution

Measurement of abrasive particle size distribution is essential to establish the variation in the particles in the solid sample and the percentage of particles present in different size ranges. For the coarser particles, sieve analysis can be used to determine the abrasive particle size distribution. This distribution has been obtained by dry sieve analysis method. A representative sample of the abrasives is taken and sieving is done with a set of sieves. Special care is taken to ensure that the sample is properly dried.

The abrasive used was silica sand, AFS 20-40 (U.S. sieve size), from local market (Iraqi sand). To collect identical size particles of the solid material, the particles were sieved using required sieves sizes. The particles collected from successive sieves are two different particle size in the range of (400-600) µm and (600 to 800) µm. Fig. 3 shows the shape and size of silica sand.

For the present study (HCWI) is used as a target material. And its chemical composition is given in Table 1. These types of cast irons are generally used in slurry pumps, brick dies, several mine drilling equipment's, rock machining equipment's and the similar areas (Çetinkaya, 2006).

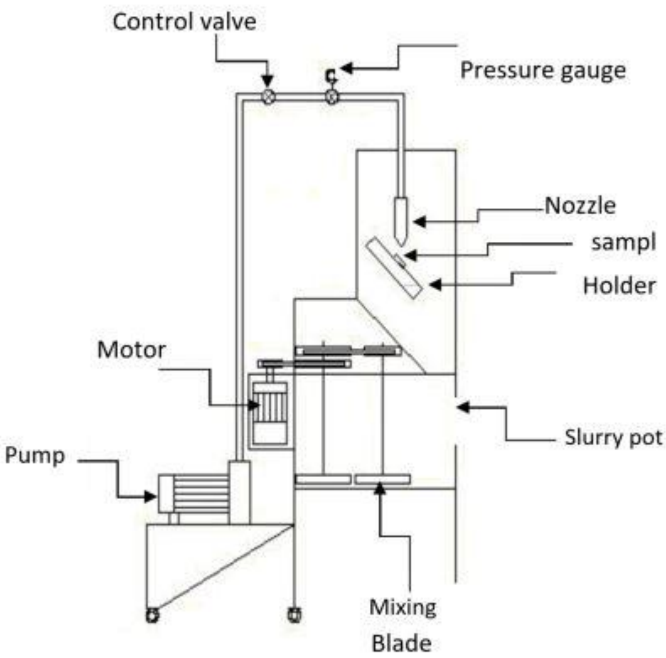


Fig. 2. Schematic diagram of jet erosion tester.

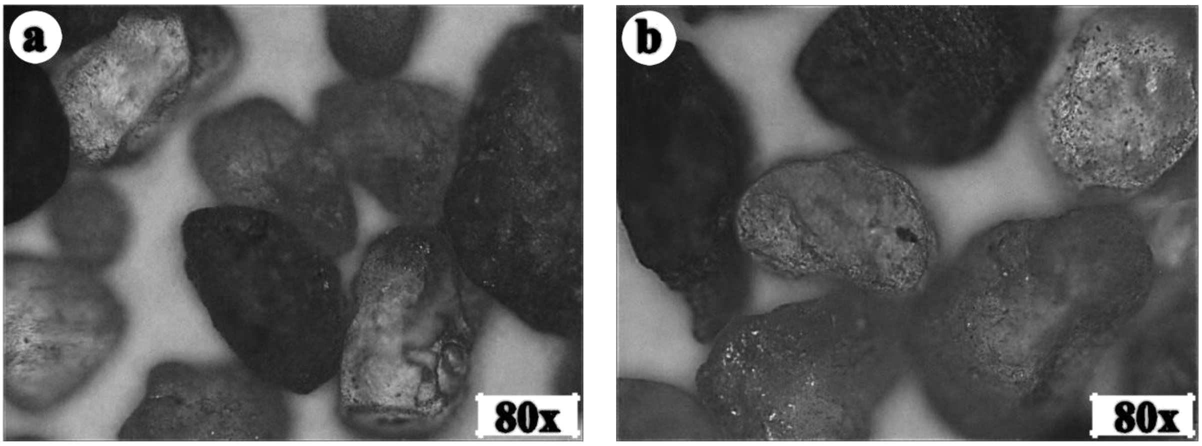


Fig. 3a. Shape and size of (400-600) µm silica sand

Fig. 3b. Shape and size of (600 to 800) silica sand

The range of parameters investigated for preliminary experiments, which are carried out with HCWI using solid-liquid mixtures of selected erodent silica sand of (400-600) µm and (600 to 800) µm particle size is given in Table 3.

Table 1. Chemical composition of target material (HCWI) used in present work.

Target Material	Element Composition (Wt %)							
	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%
High Chromium White Cast Iron	2.5	0.867	0.678	0.035	0.04	27.5	0.1	0.194

Table 2. Range of parameter for preliminary study

Target Material	Impact angle (degree)	Particle Size (µm)	Solid particles	Abrasive/water % by wt.	Time (hour)
High Chromium White Cast Iron	45°	400-600 600-800	Silica Sand	20%	10

2.3. Erosive Wear Testing

Erosive wear specimens were cut with a wire cutting machine to a dimensions of 37.5×20×10 mm and for each experiment were grinded with 220 to 600 grit emery paper before conducting any wear test to keep identical initial condition for each experiment. The wear specimens were cleaned with distilled water, rinsed in acetone and dried with hot air blower before each test. Mass loss of the wear specimen was measured by an electronic balance having least count of 0.1mg. The solid–liquid mixture was prepared by mixing 20% wt. concentration of silica sand with water and at temperature range of 20oC-25°C. The sand was sieved to successive sieves, i.e. (400-600) µm and (600 to 800) µm. A predetermined mass of sand was poured first in the pot and then a known quantity of water was poured through the top of the pot to completely fill the pot. The pot stirrer is then rotated by A.C. motor to achieve the uniform distribution of sand particles in water. The specimens have been fixed on the specimen holder of the erosion device exposed through the nozzle to a jet of the slurry (water & sand) pumped from the pot. The jet cause erosion in the specimen's surface. After each test was completed, specimens were removed immediately, cleaned in acetone and dried with hot air blower, and weight losses were then measured every two hours.

3. RESULT AND DISCUSSION

In order to authenticate the working of the jet erosion tester, a high chromium white cast iron (ASTM A532-ClassIII A) was used to study the erosion wear pattern. Further the erodent specimens were examined using SEM to verify the mechanisms of material removal.

Fig. 4 shows the mass losses with erosion time at angle 45°, concentration of sand 20% and at temperature range of 20oC-25°C. It was observed that the mass loss increases almost linearly with time for the two cases. For fine and coarse silica sand there are remarkable differences in mass loss, showing that there is a lower mass loss upon removal of fine particles from the coarser particles and is in agreement with observations reported by (Stachowiak, 2006).

Further, to identify the erosion mechanisms at different particle size, scanning electron microscope (SEM) studies of worn out surfaces was performed. The SEM micrographs of the wear specimens for 20% solid concentrations, 45° impact angle and different particle size are presented in Fig. 5a and Fig. 5b. It can be seen from the Fig. 5a that the surface featured evident cutting produced by abrasive particles and some ploughing. Material displaced by ploughing is evident along with a large number of pits and shear lips a combination of these types of damage causing deeper grooves and more material pile-up. Fig 5b For the finer particles, it can be seen less visible damage to the surface, surface featured evident more ploughing with lesser pits caused by abrasive particles. These results are agreeing with what find by (Chung, 2014).

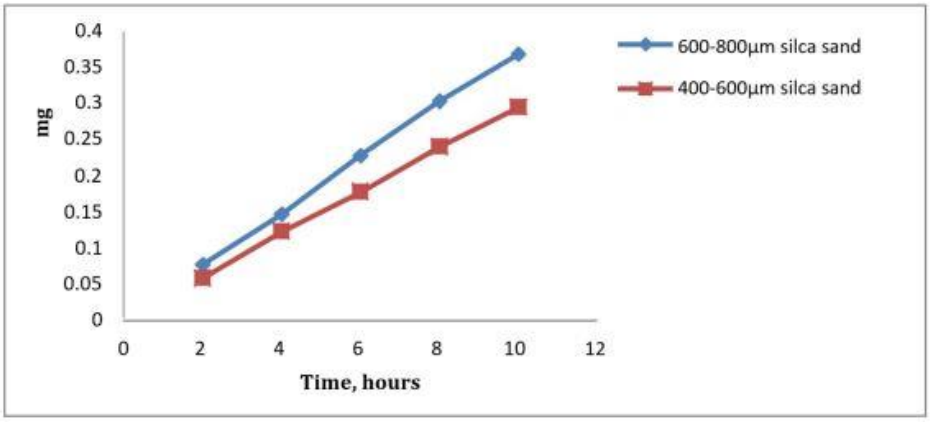
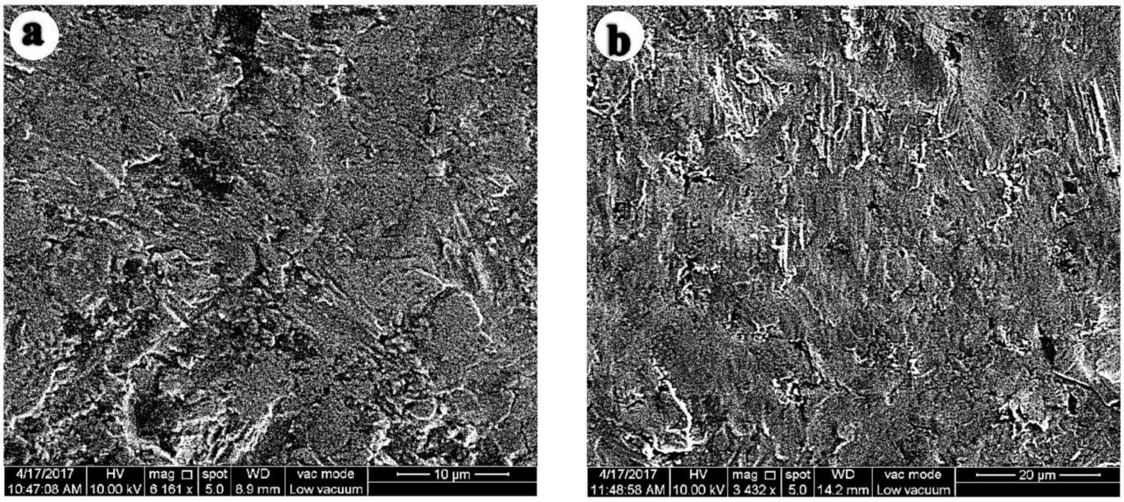


Fig. 4. Erosion wear data determined by using jet erosion tester, 20%wt. concentration for 10 hrs at angle 45^{o}.



(a) At particle size (600-800) µm. **(b) At particle size (400 to 600) µm.**

Fig. 5 SEM micrographs of worn out surfaces of HCWI at (impact angle = 45°, weight concentration = 20%, test temperature = 20-25°C).

4. CONCLUSIONS

Arrangements in the Jet Erosion Tester have been made to evaluate the effect of 45° impact angle, concentration, particle size etc. on erosion wear. This design of jet erosion tester is intended to conduct erosive wear tests at 20%wt. solid concentrations to simulate the wear conditions for mineral and mining industries, cement industries etc. and may provide more realistic results.

The contribution of jet erosion wear for high chromium white cast iron are find out in the form weight loss for the different particle size and same conditions 45° impact angle, 20% solid concentration of sand and 10 hours as testing time. By the observations, it is found that at different particle size for the same working condition the weight loss occurs is higher for coarser particle.

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