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Erosion investigations by means of a centrifugal accelerator erosion tester

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ABSTRACT

The determination and quantification of hydroabrasion due to the presence of solid particles entrained in the liquid flows is of a great importance in industrial equipment design and maintenance. A centrifugal accelerator erosion tester was designed to investigate the particle dynamics and erosion of different materials under various operating conditions. The tester consisted of a rotating disc to accelerate the slurry flow, gear box and a motor, target holders and a slurry pump to provide a controlled continuous feed of the suspension. The specimen samples were located around the disc on adjustable sample holders. In the present study, a series of experimental tests were carried out to study the effects of disc rotational velocity and feed volumetric flow on the flow impingement angle with the sample plates. The velocity magnitude and angle of slurry flow discharging from the tubes inside the rotating disc could be predicted with respect to the forces affecting the particles. The experimental data were then used to validate the CFD simulation results. The erosion of three various ferrous alloys, an aluminum alloy and a polymer (Hawiflex) were investigated experimentally by variation of influencing parameters. The increase in erosion depth and pileup height by increasing the solid concentration was observed, using a stationary roughness measurement device.

1. Introduction

Erosion occurring in equipment handling liquid–solid mixtures e.g. in pipeline parts, pumps, hydroturbines, heat exchangers, hydrocyclones and in various industrial applications results in operational failure and maintenance costs [1]. Material loss by liquid flows occurs in practice in two ways, one is the erosion by a cavitating liquid and the another is the erosion by solid particles entrained in liquid flow known as slurry erosion. In slurries, the material removal from the equipment components is mainly caused by the solid particles and the material loss due to corrosion is of relatively minor importance.

In order to experimentally evaluate the erosion rates of various industrial materials and also to investigate the effects of different influencing parameters on the erosion rate, erosion testers can be used as discussed elsewhere e.g. by Azimian and Bart [1]. However, less information on particle dynamics and erosion of materials in a centrifugal accelerator erosion tester is available [2,3]. Deng et al. [4] performed detailed experiments to investigate the effects of solid particle dynamics on the erosion by blowing the particles with air into a centrifugal accelerator erosion tester. Burnett [5] also found that particle dynamics in the tester had significant effects on the erosion results. He developed a mathematical model whose predictions of the particle velocity vector were confirmed by experimental measurements. The hydroabrasion process by an erosion experimental tester has already been simulated with CFD tools in various cases such as the erosion due to a slurry jet, in elbows and T-junctions [6,7] and in slurry tank erosion tester [1]. Wang et al. [8] conducted detailed experimental tests to validate the CFD simulation results of erosion in slurry jet flows. In addition, they used algebraic empirical models to compare the predicted weight loss with the measured ones. Gnanavelu [9] presented an integrated methodology which couples standard laboratory tests with computational simulations to predict material wear rates due to erosion in various equipments. Parsi et al. [10] provided a comprehensive review of the literature concerning solid particle erosion modeling for oil and gas wells and pipelines applications. They surveyed various empirical and mechanistic erosion prediction models and discussed the CFD-based erosion modeling. To our best knowledge, CFD modeling of a centrifugal accelerator erosion tester and validation of results has not been done previously in the literature. In the present study, a centrifugal accelerator erosion tester was designed and commissioned to investigate the particle dynamics and to quantify hydroabrasion of materials caused by the slurry flow. The flow through the tester was simulated with CFD and the results were compared and validated with experimental data.

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2. Experimental setup

Fig. 1 illustrates a schematic view of the experimental tester and Fig. 2a shows the details of the experimental setup used to reproduce erosion conditions typical of those found in industry. The closed loop experimental tester consists of a conical slurry tank, a detachable digital flow meter (KROHNE, OPTIFLUX 5300), rotating disc with eight internal tubes, a motor and gear box for obtaining a wide range of rotational velocities, adjustable sample holders for various impact angles, a heat exchanger to keep the flow temperature constant, pipes and bypass connections. It is possible to adjust the distance between nozzle and the surface of samples (stand-off distance) and also the impingement angle. The tester enables to study the effects of various influencing and input conditions on erosion such as sand concentration, impact flow velocity, impingement angle, flow temperature, sample specimen material properties, etc. Prior to start each test, the conical tank was filled with 60 l water and the flow meter was attached at its position as shown in Fig. 1. The flow meter was used to adjust the desired feed volumetric flow for the experiments. In order not to damage the flow meter due to the passing abrasive particles, the flow meter was used only at the beginning of each test without the presence of solid particles. The flow meter was connected to a frequency converter, which can guarantee a constant volumetric flow of the mixture flow by controlling the energy input of the pump. Afterwards, the pump was shot down and without changing any settings, the flow meter was detached. As the pump was again started, the desired amount of solid phase for a specified concentration was added gradually to the water in the tank and the test was started.

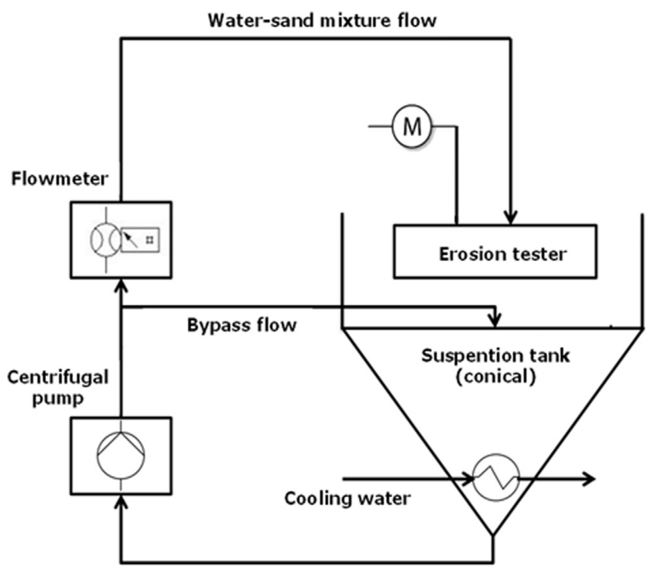

Fig. 1. Schematic of the closed loop experimental tester.

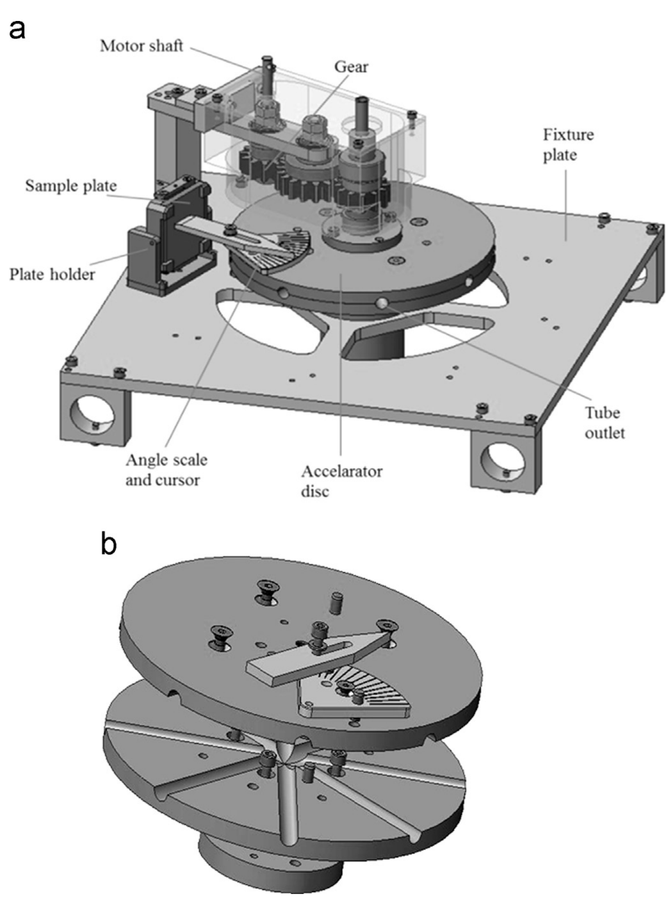

Fig. 2. (a) CAD view of the centrifugal accelerator erosion tester. (b) Two hardened discs with 8 internal tubes for the slurry flow.

The advantage of such a tester is that several sample materials can be tested simultaneously under identical or even different conditions. Characterization and determination of the erosion resistance of different materials in a short time is possible here [11]. The heart of the experimental tester is a disc that has eight acceleration tubes as depicted in Fig. 2b in detail. The disc material is stainless steel 1.4122 (hardened and tempered) and is made from two half discs. This material was hardened to a hardness of 55 HRC with a vacuum hardening method. A grinding process was also performed on the half discs to increase their wear resistance. The water–sand mixture was continuously pumped with a slurry pump into the central inlet pipe of the rotating disc. The mixture was accelerated through radial channels by centrifugal force due to the rotational velocity provided through the gear box. The gear box is connected to a motor through a shaft. As shown in Fig. 3a the gears installation (frontal gearwheels 1.4305 with hub) was in a way to get relatively wide range of rotational velocities by substituting the gears.

The mixture flow ejected with a velocity defined by the velocity of the disc periphery. The target samples were concentric with the disc on a ring. Various angles of particle impingement could be reached by varying the adjustment of each target holder as presented in Fig. 3b. The target sample as depicted could be fixed on the target holder and could be substituted with various materials, which were interesting for erosion tests. The effects of influencing parameters such as particle velocity, particle concentration, size and type of the abrasive solid particles, etc., could be investigated on the erosion rate of sample specimens. A slurry centrifugal (panzer) pump of the Habermann Company was used to pump the suspension flows with high solid phase concentrations.

In the experimental tests, the disc rotated at a constant speed and the slurry flow was fed through a pipe into the center of the disc. By rotation of the rotating disc, the medium was accelerated to a certain speed in the acceleration tubes. The phenomenon of the centrifugal force caused the medium to leave the accelerating tube while rotating in a certain angle and was splashed to the stationary samples adjusted around the disk. The samples could be then examined for wear after a certain test period by precise weighing. In this type of tester, the erosion rate by the slurry flow could be controlled by the speed of the rotating disc's motor as well. In contrast, the velocity of medium was controlled only by the feed velocity in other types of erosion testers such as slurry jet erosion tester.

High speed camera from VDS-Vosskühler Company (model HCC-1000) providing a $1k \times 1k$ resolution, with high light