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Low angle scouring erosion behaviour of elastomeric materials

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ABSTRACT

Elastomers are a particularly important class of material, finding increasing utilization in applications such as piping and tubular components; pumps; valves and cyclones; where considerable resistance to low angle scouring erosion is critical. Assessment of elastomers at impingement angles >10° has been readily available using various slurry jet devices, however, there is a clear need for a suitable method for evaluating these materials under conditions of high velocity, low angle (<10°) impingement.

Based on this requirement, a new specimen holder was developed for the Coriolis slurry erosion tester. This rig has previously been shown to provide a convenient and repeatable method for evaluating the scouring erosion resistance of a variety of hard materials [1]; however, until recently the capability to assess elastomeric materials was hindered by the distortion of specimens when the holding force was applied. The new holder alleviates this problem and ensures improved control of the slurry flow over the specimen surface thus producing consistent and reproducible erosion scars, which can be used for determining the expected wear of elastomers under conditions of low angle erosion.

The current work examines the scouring erosion resistance and mechanisms of material removal for selected elastomers and compares data with that of various white irons, steels, cermets and overlays. The influence of erodent type on the resulting wear mechanisms has also been examined. Results have enabled correlations to be made between scouring erosion attack resistance, hardness and material type.

1. Introduction

The capability to withstand high velocity, low angle impingement by solids-bearing slurries is a critical requirement for materials used in a variety of industrial applications such as pipes, valves, nozzles, cyclones and pumps. Examples of catastrophic component failure as a result of slurry erosion can be seen in Fig. 1.

Elastomers are a particularly important class of material, which offer the potential for increasing utilization in such applications. Several authors have shown that elastomers provide enhanced erosion protection under certain conditions when compared to metals or ceramics [2–4]. This is primarily due to characteristics such as a low elastic modulus and high elastic energy limit which result in a high deformation capacity and high rebound resilience for this type of material [5].

Impingement angle is one of the major influences on erosion involving hard solids-bearing slurries and despite test systems such as the slurry jet erosion rig providing data for higher angle impacts, they do not have the capability of assessing materials at angles less than 10°. Suitable methods for comparing scouring erosion resistant materials and for supporting the development of improved elastomeric products have not been readily available. As a consequence there is a lack of related performance data even though this class of material is of great interest and has been successfully implemented as a replacement material for more traditional metallic materials in applications where such wear mechanisms are prevalent [6–8].

The Coriolis test assesses material resistance to particle impacts of less than 10° and has been shown to provide a convenient and reproducible technique [1,9–12] for assessing material performance under scouring erosion conditions and data obtained have correlated well with field trials [13,14]. The rig possess the ability to assess a material under both elastic and plastic particle impacts [15], which is related to the normal impact velocities of the particles on the test surface compared to the critical velocity required for plastic deformation [16]. This results in a more discriminatory test.

The intention of this work was to expand the capabilities of the Coriolis rig to enable the repeatable and reliable assessment of elastomeric materials in order to increase the current limited knowledge and data available regarding the comparative behaviour and degradation mechanisms of elastomers under conditions of low-angle scouring erosion.

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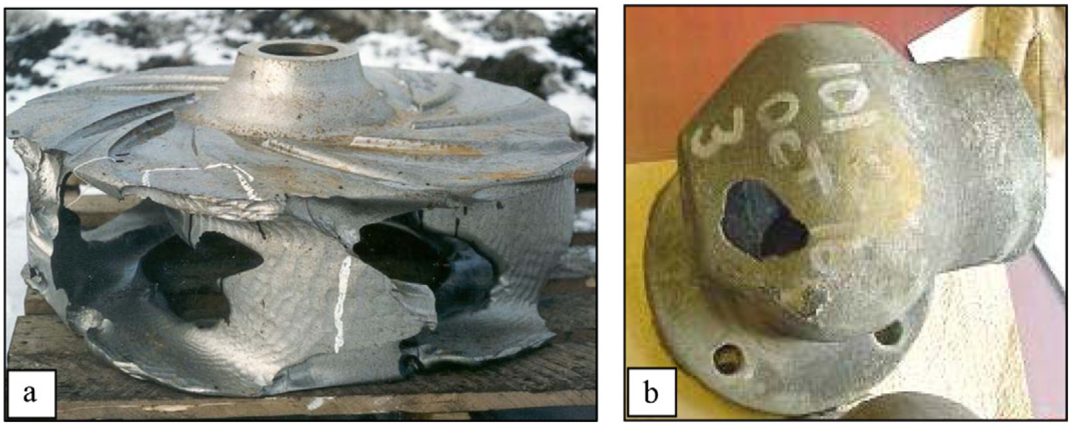

Fig. 1. Examples of slurry erosion in a) a pump impeller and b) nozzle.

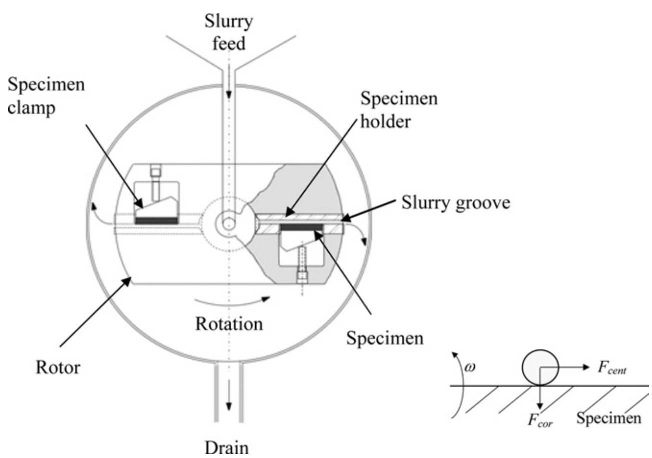

Fig. 2. Schematic of Coriolis rig and diagram showing forces acting on erosive particles.

As such, Coriolis erosion evaluation has been carried out on two natural rubbers and a polyurethane material and the results compared with a range of materials commonly subjected to scouring erosion attack mechanisms.

2. Experimental details

2.1. Erosion testing

The Coriolis rig is designed to simulate the flow of hard, solids-bearing slurries in applications such as pumps, nozzles, pipelines etc., by utilizing centrifugal forces and Coriolis accelerations to rapidly pass aqueous erosive slurry across a test surface. The test enables the interactions of particles with sample surfaces to be assessed and hence provides a means for calculating the erosion resistance of a material under specific conditions.

As can be seen in Fig. 2, the Coriolis rig consists of a diametrically grooved rotor, which revolves at a preselected speed (in this case 5000 rpm). The slurry is pre-mixed before it is fed into the centre of the rotor at a constant rate of 60 ml/s. The considerable centrifugal force (F_{cent}) subsequently causes it to be expelled along the slurry grooves and Coriolis forces (F_{cor}), act to force the slurry against the sample surfaces thereby causing low angle attack. The velocity with which the slurry traverses across the sample surface increases depending on the distance from the centre of rotation, with the average velocity ranging from 14–24 ms^{-1} across the length of a standard coupon.

The standard slurry used for Coriolis assessments consists of water and 10 wt.% AFS 50–70 silica sand, which has a semi-rounded morphology and a particle size range of 275–415 μm. The type of erosive employed is key to determining the wear mechanisms which occur during testing. The semi-rounded shape of the silica erosive (see Fig. 3a) typically produces evidence of microploughing and plastic material deformation and its mean particle size is comparable to that of the quartz constituent of many mineral processing slurries causing scouring erosion.

Due to the typically high resistance of elastomers to slurry erosion, a more angular erosive was also employed to provide a more aggressive environment and hence a more discriminatory test method. The 80 mesh SiC erosive chosen possesses a particle size range of 205–365 μm and more importantly exhibits an angular morphology (see Fig. 3b). This combination promotes a cutting action as the particles impact the surface of the coupons, thereby resulting in higher levels of material removal.

The standard coupons for high hardness materials are rectangular in shape with sharp edges and a fine ground test surface. These are located in diametrically opposing positions, using the highly resistant WC-based specimen clamps. In the case of elastomers/polymers, clamping of the specimens is not such a simple concept. Due to the reduced rigidity of these materials, once a load is applied to a sample they are prone to distortion. This subsequently results in uneven contact between the sample surface and the slurry grooves, along which the slurry flows during the test.

As a result of these issues, new specimen holders were designed and manufactured to ensure even and consistent contact between the elastomer test surface and the slurry grooves. The new holders accommodate precisely moulded coupons (27 × 5 × 3 mm) exposing only the large test surface and restricting all other movement, thus preventing distortion due to loading and allowing comparisons to be made between the erosion resistances of different material categories.

2.2. Examination of erosion scars

As materials examined using the Coriolis rig often possess very different densities and/or contain dissimilar constituents with different densities (e.g. Cr white irons), rather than comparing the wear rates using mass loss, a non-contacting laser profilometry system (Viking, Solarius Development, Sunnyvale, CA) was implemented to measure the volume loss of the erosion scars. The vertical resolution of the system is 0.1 μm, whilst the spatial resolution is approximately 30 μm for all acquired maps. An example of a typical erosion scar is shown in Fig. 4.