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Review

Hydraulic performance and erosive wear of centrifugal slurry pumps - A review

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ABSTRACT

Centrifugal pumps are being extensively used for hydraulic transportation of solids over short and medium distances through pipelines where the requirements of head and discharge are moderate. The performance characteristics and erosion wear of the pump components are the most critical design and selection parameters. An improvement in performance reduces the energy expenditure while the reduction in erosion wear enhances the service life. Efforts have been made to estimate the reduction in water performance of the pump for handling different types of solid particles and to find methods to mitigate it. Different correlations were proposed to estimate the pump performance handling slurry. Regarding the erosion of the pump components, different techniques were used to identify the zones of maximum localized wear and to suggest an approach to reduce it. In the present paper, experimental and numerical studies undertaken in this area have been discussed. For the optimized pump design, selection of the pump material, properties of the solid particles, flow characteristic of the slurry and the concentration of the solids play a significant role. The review summarizes the current state of the art of estimation of pump performance and wear characteristics of the pump. The pump design needs to be optimized for handling slurries based on the drop in performance and expected service life.

Contents

1. Introduction

The hydraulic transportation of solids through the pipeline in the form of slurry has been used widely as an effective and cost saving method of conveying bulk solids. The pumping unit is one of the most important components to the system. The pumps are broadly classified into two main categories namely positive displacement and roto-dynamic. Roto-dynamic pumps are generally used for continuous throughput and possess wider flow passages for smooth flow of solid particles. Centrifugal pump, a type of roto-dynamic pump, is mostly used in a large number of industries for small and medium distances transportation of slurries. The conventional pump design is generally modified to develop a centrifugal slurry pump. The modifications include enlargement of the flow passage to accommodate bigger particles, use of a robust impeller with smaller number of vanes, special sealing arrangements and appropriate wear resistant material to ensure longer life [1]. The performance and wear characteristic of these pumps depend on the properties of solids and its suspension. The performance and wear characteristics of these pumps are generally investigated

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using laboratory test rigs. The actual field behavior of these pumps is then predicted based on these experiments. Most of the experimental works reported in the literature to evaluate these characteristics had a test rig arrangement similar to one shown in Fig. 1.

This paper discusses some of important experimental and numerical works on the performance and wear estimation of centrifugal slurry pumps to gain an insight into the present state of knowledge.

2. Experimental studies on performance evaluation of centrifugal slurry pump

The performance of the centrifugal slurry pump plays an important role in the trouble-free and economical transportation of solid-liquid mixtures in the hydraulic transportation system. The performance of these pumps with water gets reduced with the presence of suspended solids as shown in Fig. 2. To determine the performance of these pumps with slurry, either experiments are performed with actual slurry or available correlations are used to predict it [2]. Correlations were generally developed to estimate the additional parameters defined as under.

$$\text{Head ratio (HR)} = \frac{\text{Head developed by slurry at a given flow rate (m)}}{\text{Head developed by water at the same flow rate (m)}}$$

$$\text{Power ratio (PR)} = \frac{\text{Input power drawn by slurry at a given flow rate (kW)}}{\text{Input power drawn by water at the same flow rate (kW)}}$$

$$\text{Efficiency ratio (ER)} = \frac{\text{Efficiency of the pump for slurry at a given flow rate}}{\text{Efficiency of the pump for water at the same flow rate}}$$

The head reduction factor (K_H) is defined as 1-HR and the reduction factor for efficiency (K_η) is defined as 1-ER.

For homologous family of pumps, the point to point data of one size pump to another size or change in rotational speed of centrifugal pump can be transferred using affinity laws which are expressed as the dimensionless parameters given below.

$$\text{Specific head } sH = \left(\frac{gH}{N^2D^2}\right)$$

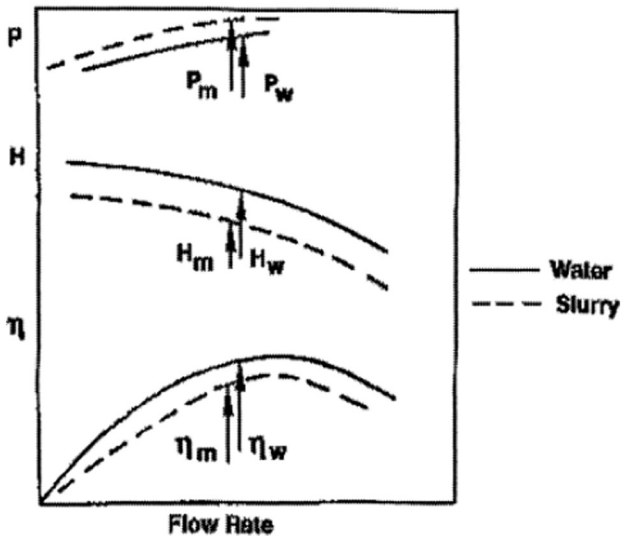

Fig. 2. Effect of slurry on centrifugal slurry pump performance characteristic [2].

$$\text{Specific discharge } sQ = \left(\frac{Q}{ND^3}\right)$$

$$\text{Specific power } sP = \left(\frac{P_{input}}{\rho N^3 D^5}\right)$$

The applicability of these laws to centrifugal slurry pumps is also one of the major concerns of the researchers due to the effect of suspended solid particles and the geometry of these pumps.

The analysis of the effects of solid particles on the pump performance was initiated by Fairbank [3]. He investigated the performance of a 3 in. centrifugal pump handling mud and suspension of two sands of median diameters of 34 μm and 800 μm. He observed that the head developed with slurry is similar to that of with water for very fine size particles, but it reduces for bigger particle sizes. He found that the drop in head-capacity characteristics at constant speed is increased with increase in solid particle concentration and particle size, while the flow rate at maximum efficiency is independent of the

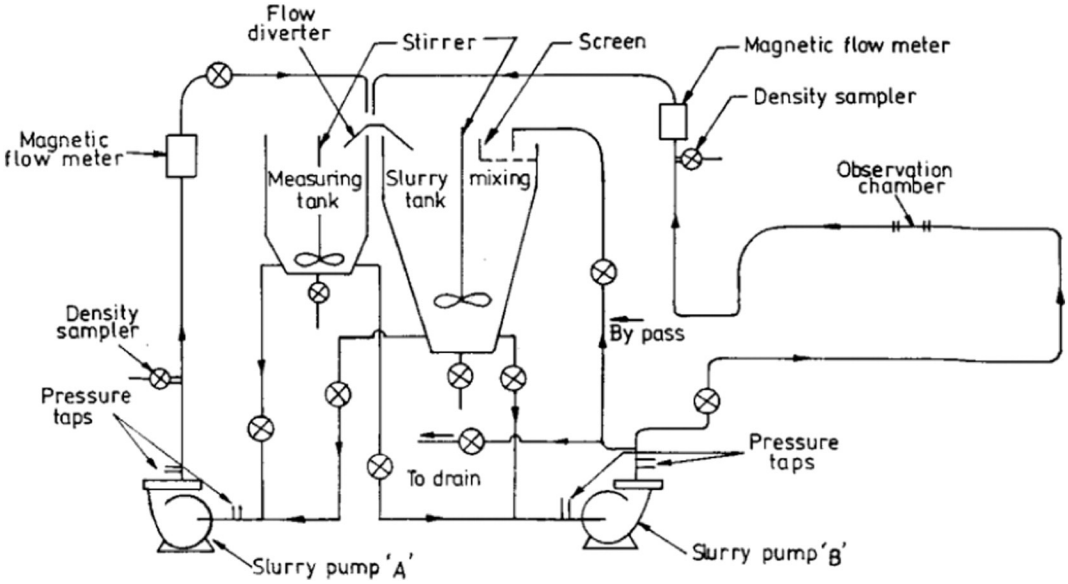

Fig. 1. Schematic diagram of the experimental setup used for pump performance and wear investigation [1].