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REVIEW

Bearing problems' effects on the dynamic performance of pumping stations

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Abstract Egypt has a limited water resource and depends mainly on the Nile to satisfy its demands where agriculture consumes more than 80% of the water resources. There are more than 2000 pumping stations in Egypt of different systems operating under different conditions. Pumping stations are subjected to mechanical, electrical, and structural problems affecting behavior, efficiency, safety, and reliability of these stations. These stations are a part of probably the largest network of its kind as the entire volume of water flowing down the Nile (over 55.5 billion cubic meters) has to be pumped twice, once for irrigation and then back from the field to the drains.

Pumping stations use large number of bearings with different types and applications. These bearings have a clear effect on the performance and efficiency of the pumps. Pump bearings in the arid regions are greatly affected by temperature, water quality, lubricants, and maintenance operations. This research focuses on analysis of damaged rolling element bearings of pumping system. The objective of the research is to enhance and control dynamic performance of pumping stations by avoiding damage and failure of bearings. The research proves that damaged bearings generate periodic, non-periodic, and transient forces causing high amplitude of vibration at high frequencies and increasing energy consumption. Bearing faults increase vibration level 85%, where power consumption increases 14% and pump efficiency decreases 18%. It is very important to take care of bearings during installation, alignment, balancing, and maintenance to assure safe and efficient pump operation for long period. As pump efficiency decreases, water power decreases and/or consumed power increases affecting water distribution and management system. Bearing faults break pumping system for long period affecting irrigation system. Optimum operation of pumping stations helps to save and manage water requirement for development and extension projects in arid regions. The

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measurements are performed on full scale model in the field, which proves reliable results on similar pumping stations.

Contents

1. Introduction

Rolling element bearings are among the most common components to be found in industrial rotating machinery. They are found in industries from agriculture to aerospace, in equipment as diverse paper mill to the space shuttle main engine turbo machinery [5]. A bearing is a mechanical device designed to reduce friction in a part of a machine where another part turns or slides. There are four types of bearings, plain bearings, ball bearings, roller bearings, and thrust bearings. Bearings are among the most important components in the vast majority of machines and exacting demands are made upon their carrying capacity and reliability. Bearings used in pumping stations must be able to support the hydraulic loads imposed on the impeller, the mass of the impeller and shaft, as well as the loads from the drive system. Bearings must also keep the axial movement and lateral deflection of the shaft within acceptable limits to maximize the service life of the shaft seal. Bearings have great influence on the performance and operating efficiency, whereas bearing faults are considered a distinct indicator of decreasing pump performance and increasing the vibration leading to failure and breakdown [7].

Most pumping plants use rolling element bearings which are designed to operate for high speed and high performance conditions. Rolling element bearings are manufactured under very stringent quality control standards. Under ideal operating conditions, bearing can last through many years of continuous use. Operating conditions are rarely ideal, so most bearings never achieve their potential as far as useful life is concerned. The life of a rolling element bearing depends on the conditions under which it is manufactured, the care exercised in storing and handling it, installation practice, load conditions, and the operating environment. Due to the fact that a rolling element bearing restricts rotor motion, forces generated by the rotor are transferred through the rolling elements to the bearing's outer ring which is fitted to the bearing housing. Because of this transmission, a direct measurement at the bearing outer ring or casing (housing) is the primary accepted method for monitoring machines with rolling element bearings. Another characteristic that is a unique and normal to rolling element bearings is the generation of vibrations at specific bearing-related frequencies. These frequencies are generated by the bearing based on the bearing's geometry, number of rolling elements, and the speed at which the shaft is rotating.

Without the help of a good predictive maintenance program, vibration problems associated with bearings of critical machines can be difficult to understand and analyze. Good design, good maintenance of a pump, prime mover and piping results in a longer component life, reducing operating costs through lower maintenance costs, lower power costs, and best operating efficiency for the pumping system. A method has been developed to accurately identify the presence, type, and magnitude of defects within rolling element bearings from enveloped random vibration spectra. Envelope spectrum proves a good tool for diagnosing bearing problems [1]. In most practical cases, a failing bearing will have several defects. In this case, components of all the defect types are added linearly in the envelope spectrum [3]. Vibration analysis has been used as a condition monitoring tool for bearing fault detection and diagnosis, probably ever since the first use of bearings when the symptoms were ''something sounds strange'' [5].

Electrical energy to drive a pump represents the major factor in the whole life operating cost of the pump system. The total operating cost includes 87% to power consumption, 8% to maintenance and only 5% to the equipment. With this high cost of power consumption, it is important to avoid any operating conditions that affect pump performance and to improve the operation profitability of the pump. Pumping stations in Egypt consume 1700 GW h per year costing more than 300 millions Egyptian pounds. This high rate of energy consumption could be reduced through different aspects [2].

2. Failure causes of rolling element bearings

Rolling element bearings generally consist of two rings, an inner and an outer ring, between which a set of balls or rollers rotate in raceways. Under normal operating conditions of balanced load and good alignment, fatigue failure begins with a small fissure, located between the surface of the raceway and the rolling elements, which gradually propagate to the surface,