Measurement 116 (2018) 575–585

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

The dynamic parameters correlation assessment of the textile machine high-speed bearings in changed technological conditions

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ARTICLE INFO

Keywords:
Vibrodiagnostics
Trending
Dynamic imbalance

ABSTRACT

The paper describes the correlation of the changed manufacturing and technological conditions of the spinning device applicable in the textile industry with the change of the dynamic parameters of the spinning rotor bearings. Special ball bearings for textile machines are designed for high rotational speeds and relatively low loads. They are characterized by high dimensional accuracy and reliable running, which guarantees their great utility value. In the diagnostics of the spinning machine spindle high-speed bearings, absolute vibrations were measured according to the recommendation of STN ISO 10816-3 norm. The conducted experiments focused primarily on the assessment of the impact of the unstable technological process on the change of the monitored dynamic parameters. The measurements showed a statistical increase of the measured dynamic parameters by 50% when the spinning machine spindle rotor speed was increased by 15%. The measured vibration values showed that technological instability (rotor clogging by fiber during combing and subsequent braking and speed deceleration, a signal from a damaged drive belt, variable dynamic imbalance of the rotor, and at the same time an uneven bowl wear caused by the fiber friction) had a noticeable impact.

1. Introduction

Rolling bearings are important parts of machines, mechanisms, and devices that enable them to operate reliably and provide for the safe and long-term functioning of the technical systems without friction and enormous wear. On the other hand, roller bearing damage is an important and significant phenomenon that can lead to the failure of machines, mechanisms, and equipment in all industrial areas where they are used. The analyses of the breakdown causes, their possible consequences, and their removal create conditions for ensuring the quality and reliability of rolling bearings during their technical life. Similarly to other machine components, even in the case of roller bearings, there may be a variety of causes of premature damage and failure of the bearing. It is necessary to differentiate between bearing durability, determined by wear due to the application of load at operating speed, and bearing lifetime, which is a period of the bearing serviceability before it is for various reasons decommissioned. The life of the bearing is affected, for example, by improper installation, misalignment of bearings, by manufacturing defaults in the production of connecting parts, by improper handling of bearings, by impurities deposited in bearings, or by poor lubrication. When damage or other deficiencies occur in bearings, it is important to determine the cause so that measures can be taken to prevent further damage [1,2].

The research into bearing damage includes the knowledge of metallurgy, tribology, operating environment, and consideration of the load applied. In some cases, even a single event may cause malfunctioning. Sometimes it requires a combination of several complex events and circumstances, in addition supported by a faulty human decision, adverse environmental conditions, demanding operating conditions, and improper maintenance to make such an event occur. All of this contributes to premature failure of bearings. Ultimately, this leads to a disastrous breakdown of the rotating component or of a component moving in a reciprocal manner, and to additional damage to the associated mechanisms. Due to the high cost of production losses and due to the time constraints that the service department experiences, the reality check calls for a maximally simplified and effective problem-solving process [1,3].

The main problem of diagnostics is the determination of critical locations in which a suitable electrical output sensor can measure the change in the physical variable characteristic of the fault, its origin, and development. The measured change of one or more physical variables can serve as a means of determining a reliable criterion that would characterize the origin and development of the fault up to the moment of the breakdown, as well as the time period during which the object can be used and the time point when it has to be dismantled and repaired (Fig. 1). In practice, it is not always possible to monitor all the

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https://doi.org/10.1016/j.measurement.2017.11.052
Received 5 September 2017; Received in revised form 23 November 2017; Accepted 25 November 2017

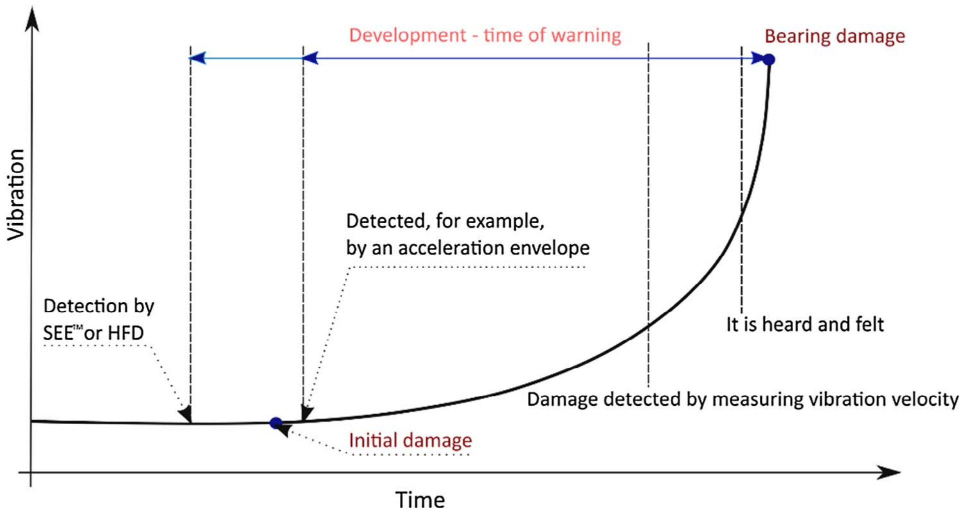

Fig. 1. Bearing damage evolution – the trend of measured rolling bearings vibrations [3]

operating parameters of the device with complex and expensive modern measuring devices. Therefore, even in today's technically advanced times, in some cases, it is advisable and useful to monitor the noise, temperature rise, or vibration, which may indicate a bearing failure. Bearings that are in good condition produce fine humming when in operation. Screeching or grinding sounds indicate that the bearing is not in a good condition. If the bearing operates for a longer time at about 125 °C, its durability is reduced. It is visually checked whether the bearing is sufficiently lubricated, well-sealed or not visibly worn [4,5,6]. Several methods and techniques successfully have been analyzed where the direct influence on performance and tribological properties of the product have been defined [7–9].

As one of the most common mechanical equipment classes, rotation machinery occupies an important role in industrial applications such as manufacturing, metallurgy, energy, and transportation. Due to tough working environments, similar materials, and structural properties, rotation machinery can be subject to malfunctions or failures. This can significantly decrease machinery service performance including manufacturing quality and operation safety and cause machinery to break down, which may lead to serious catastrophes. Accordingly, research into fault diagnosis of rotation machinery has attracted considerable attention by researchers in related domains in recent years. The vibration signals collected from velocity or accelerator sensors located in machinery housing are generally regarded as the foundation of fault diagnostic procedures. However, most existing studies on fault diagnosis of rotation machinery have empirically or experimentally focused on analyzing single sensor signals [10].

In industrials, vibration based diagnosis using accelerometers mounted on the gear/bearing housing has prevailed in the recent decades because it does not interfere with the normal operation of rotating machines [11].

In terms of signal processing, vibration signals are usually employed to analyze the rotating machinery faults because the vibration signals are easy to acquire and highly correlate with the condition of the rotating machinery. However, the vibration signals contain high-dimensional data and are enclosed by a lot of irrelevant and redundant information, which degenerate the accuracy as well as the fault identification time of the diagnostic system. To solve the problem, a proper feature extraction technique which can extract useful information of faults from the vibration signal is desirable. At present, there exist many methods to extract the features of faults from vibration signals, such as Fourier transform, short time Fourier transform, and wavelet transform [12].

The utilization of technological equipment in the textile industry has its particularities mainly due to the presence of chemical and biological factors. In this field, the production process consists of several phases: processing of natural raw materials (cotton, flax, hemp, or sisal hemp), fiber treatment (cleaning, dyeing, bleaching, maceration, suppression, plating, and impregnation), weaving on knitting machines and the final product manufacturing – sewing, knitting. The dust produced in the textile production often contains the residue of chemically treated substances, which is why the dust can be toxic. The development of bearings for spinning machines is closely related to the solutions for the mounting of the most important textile machine elements. Their use is ultimately not limited to textile machines; they can also be utilized in other machinery. Special ball bearings for textile machines are designed for high rotational speeds and relatively low loads. They are characterized by high dimensional accuracy and reliable running, which guarantees their great utility value. These bearings are often supplemented with some other components, e.g. flexible mountings. In some cases, they make complex integrated bearing units that enable technologically and economically more efficient production of textile machines.

Bearings are often confronted with adverse conditions during operation, which can lead to premature damage.

2. The description of the research problem

Based on the partner company's request, we have undertaken the diagnostics of high-speed bearings of the spinning machine applicable in textile production (Fig. 2a). The machine manufacturer and technology buyers demand high operational reliability and high bearing durability.

A spindle of textile machinery, especially of spinning machines, is a shaft, at one end of which is a fixed spinning rotor and the other end is connected to the drive. The shaft is mounted in a special double-row ball bearing, the outer sleeve of which is supported by elastic elements fitted into a carrier body that is attached to the machine frame. At a higher weight of the spinning rotor, the shaft acts as a flexible body, large vibrations are generated and extensive dynamic forces effect the bearings in that they reduce their lifetime.

In this context, the spinning spindle high-speed bearing has undergone diagnostic measurements and assessment during its being in operation. Measurements – dynamic data collection – were performed in two modes of spinning spindle operation: in real machine operation, with roller bearing speed of 120.000 rpm, and through comparing selected spindles at the test station in laboratory conditions at our workplace at the speed of 90,000 rpm.

2.1. The analysis of the methods applied

The measurement and analysis of vibrations has an unmistakable