Mechanical Systems and Signal Processing 99 (2018) 169–196

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

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

Review

A review on data-driven fault severity assessment in rolling bearings

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ARTICLE INFO

Article history:
Received 24 January 2017
Received in revised form 9 June 2017
Accepted 10 June 2017

Keywords:
Rolling bearings
Fault severity
Fault assessment
Fault size
Quantitative diagnosis

ABSTRACT

Health condition monitoring of rotating machinery is a crucial task to guarantee reliability in industrial processes. In particular, bearings are mechanical components used in most rotating devices and they represent the main source of faults in such equipments; reason for which research activities on detecting and diagnosing their faults have increased. Fault detection aims at identifying whether the device is or not in a fault condition, and diagnosis is commonly oriented towards identifying the fault mode of the device, after detection. An important step after fault detection and diagnosis is the analysis of the magnitude or the degradation level of the fault, because this represents a support to the decision-making process in condition based-maintenance. However, no extensive works are devoted to analyse this problem, or some works tackle it from the fault diagnosis point of view. In a rough manner, fault severity is associated with the magnitude of the fault. In bearings, fault severity can be related to the physical size of fault or a general degradation of the component. Due to literature regarding the severity assessment of bearing damages is limited, this paper aims at discussing the recent methods and techniques used to achieve the fault severity evaluation in the main components of the rolling bearings, such as inner race, outer race, and ball. The review is mainly focused on data-driven approaches such as signal processing for extracting the proper fault signatures associated with the damage degradation, and learning approaches that are used to identify degradation patterns with regards to health conditions. Finally, new challenges are highlighted in order to develop new contributions in this field.

Contents

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http://dx.doi.org/10.1016/j.ymssp.2017.06.012
0888-3270/

1. Introduction

Health condition monitoring (HCM) of rotating machinery is a crucial task to guarantee reliability in industrial processes. It is oriented towards detecting the presence of fault situations such as the identification of healthy and faulty state, and diagnosis of the type of faults, using available models and signals, such as vibration and acoustic emissions [1–4]. Bearings are mechanical components used frequently in most rotating devices and they represent the main source of faults in such equipment; bearing faults can constitute the 44% of the total number of faults in some devices [5]. In a rough manner, a rolling bearing, also known as rolling-element bearing, has four main components: (i) the ball, also called roller or rolling element, (ii) the inner race, (iii) the outer race, and (iv) the cage, which provides equal spacing between balls for preventing internal strikes; damages or faults can appear on these components, as illustrated in Fig. 1, or even appear as a generalized damage of the whole device. There are also other standardized forms of roller elements such as cylindrical rollers, tapered rollers, needles, and barrel rollers, but they are not within the scope of the present study. The selected papers in this review tackle the fault severity assessment mainly for the inner race, outer race, and ball.

Basically, bearing faults are classified as (i) single point defect, (ii) multiple point defect, and (iii) generalized roughness; also called “distributed faults”. The single point defect is defined as a single, localized defect on a relatively intact bearing surface. A single point defect will cause certain characteristic fault frequencies which appear in the vibration, current, sound, or acoustic emission signals. These frequencies are predictable and depend on the surface of the bearing containing the fault point, i.e., inner race, outer race, ball, and cage [6]; therefore, there is one characteristic fault frequency associated with each of the four components of the bearing. A detailed analysis of the single inner race defect is given in [7]. Examples of single point defects are cracks, pits or holes, and spalls. Cracks and holes, on the inner and outer race, occur if the bearings are used for a long time. These faults are severe and many research papers have discussed the single point defect. As claimed in [8], cracks on inner and outer races are the most frequent faults, with 90% of all faults in rolling bearings, while cracks in balls or cages represent 10%. Spalling or pitting is the main manifestation of fault development in a bearing during the earlier stages [9].

In spite of the name, a bearing can possess multiple single-point defects, which consist of several, perhaps overlapping, single point defects. In such a case, the spectra of the vibration signal differ from those expected from the single point defect. For instance, spectral lines can occur at the same frequencies expected for single point defects, but the relative amplitudes of the components may change considerably, and perhaps, their harmonics are not necessarily the largest components. A detailed description of these type of faults is given in [10].