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A review of gear fault diagnosis using various condition indicators

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Abstract

Plentiful work has been done for condition monitoring (CI) and fault diagnosis of fixed-axis gearboxes. However, still it is found that articles citing condition indicators for fault diagnosis of gearboxes are less in quantity, in academic journals, conference proceedings and technical reports. The specialty of condition indicators is to provide accurate information regarding the condition of various components at different levels of damage (initial, heavy or growing). Here, these indicators are addressed domain-wise and their characteristics are stated. The objective of this paper is to review and encapsulate this literature to provide a wide and good reference for researchers to be utilized. The structure of a fixed-axis gearbox is briefly introduced. The unique behaviors and fault characteristics of fixed-axis gearbox is recognized and studied. Investigations on the basis of statistical indicators are also summarized based on the adopted methodologies. Lastly, open problems are stated and further research prospects pointed out.

Keywords: Fixed-axis gearboxes; fault diagnosis;condition indicators; gear fault;signal processing;

1. Introduction

Over more than two decade, huge emphasis is given to research on vibration based fault diagnosis methodologies [1]-[4] that are applied to vibration signals acquired from gearboxes via transducers mounted on gearbox casing. The output of these techniques is to identify changes in the signal caused due to damaged parts. Modulations appear within gearbox, because gearboxes mostly operate under rough working environment. Their basic components, for ex. gears and bearings, are subject to damage modes such as fatigue crack, pitting, scaling [5],[6]. Even a small failure could lead to a catastrophe, therefore condition monitoring and fault diagnosis systems should be planted in a

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machine to raise alarm thereby avoiding accidents and generate cost savings. Most of the studies focus on fixed-axes gearboxes in which all gears rotate around their own fixed centres. Also, information of fault has been finding out by the use of statistical analysis of vibration signal [7]. Compared to vibration based techniques, studies on condition indicators (CI) for fault diagnosis of gearboxes are limited. In 2005, Samuel and Pines [8]and in 2014 Lei et al. [9], thoroughly reviewed vibration based diagnostic techniques for a planetary gearbox, while a review specifically focusing on statistical indicators for fault diagnosis of gearboxes has not been reported yet on the basis of authors' literature search. This paper aims to encapsulate and survey the research and development of CI for fault diagnosis of gearboxes. It is to blend the individual pieces of work on this topic in context to gearboxes. An attempt has been made to provide a broad reference for researchers and helping them to develop advanced research topics in this area.

The plot of the paper is organized as follows. Section 2, briefly explains fixed-axis gearboxes, characteristic frequency and statistical measurement for fault detection. Section3 reviews the publications on CIs according to the used methodologies. Section 4 provides a summary of publications and pointing out CIs w.r.t. appearing fault. Section 5 describes prospects and identifies future research areas. Concluding remarks are drawn in Section 6.

2. Brief overview of fixed-axis gearboxes and condition indicators

2.1. Gearbox behavior

All the gears in the gearbox mesh at the same time with their respective pinions which results in sliding of each tooth on other thereby generating vibrations. The line diagram of energy (torque) flow in a fixed axes gearbox consisting two meshing pairs is highlighted in fig 1. The blue vectors shows direction of energy flow from input to output shaft. The following points can be noticed when gears are in operation:

- These gear vibrations are governed by the gear mesh frequency and its harmonics, due to the variable stiffness in the meshing process [10].
- For a pair of damaged meshing gears in fixed-axis gearboxes, fault characteristic frequencies and sidebands emerge symmetrically around the meshing frequency and its harmonics in the frequency spectra [11].
- The signal picked up from accelerometers attached on bearing housing contains several type vibrations from meshing gears, shafts, bearings, etc. The useful characteristics may easily be masked in such strong background noise. Therefore, it becomes difficult to extract fault features of low vibrating nature without denoising [12], [13].

Based on the above points it can be stated that vibration signals are compound in nature. Moreover, if a gearbox with multiple meshing pairs then the fault diagnosis will become more complex.

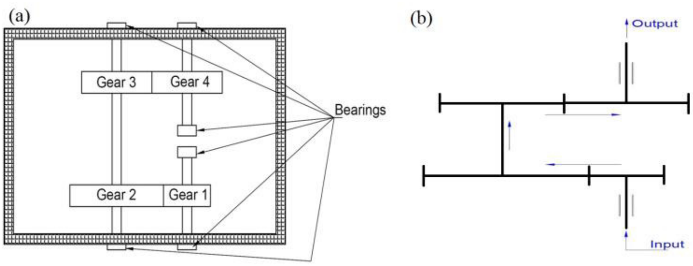

Fig. 1. Torque flow diagram of a fixed axis gearbox having two meshing pairs

2.2. Characteristic frequency evaluation

The distinctive frequencies of a gearbox, comprising gear rotating frequency, meshing frequency and their harmonics are affected by fault. The identification of fault is related to the occurrence of the characteristic frequency which is linked to the given fault. Hence to evaluate the gear mesh frequency of the fixed axis gearbox is important and has been provided here. Let us consider fig1to define the notations,

Z_i – is the number of teeth on gear i ($i = 1,2,3,4$).