

# Chapter 93

## Application of Artificial Intelligence to Gearbox Fault Diagnosis: A Review

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### ABSTRACT

*Gearboxes are employed in a wide variety of applications, ranging from small domestic appliances to the rather gigantic power plants and marine propulsion systems. Gearbox failure may not only result in significant financial losses resulting from downtime of machinery but may also place human life at risk. Gearbox failure in transmission systems of warships and single engine aircraft, beside other military applications, is unacceptable. The criticality of the gearbox in rotary machines has resulted in enormous effort on the part of researchers to develop new and efficient methods of diagnosing faults in gearboxes so that timely rectification can be undertaken before catastrophic failure occurs. Artificial intelligence (AI) has been a significant milestone in automated gearbox fault diagnosis (GFD). This chapter reviews over a decade of research efforts on fault diagnosis of gearboxes with AI techniques. Some of areas of AI in GFD which still merit attention have been identified and discussed at the end of the chapter.*

### INTRODUCTION

Gearboxes find their applications in diverse areas ranging from automobiles to large power plants. The implications of gearbox failure may vary from unexpected downtime of machinery to loss of human life, hence, the need to develop an online monitoring system to detect incipient gearbox failures.

Artificial intelligence (AI), an area of computer science, has shown promising results towards the development of efficient and automated fault diagnosis methods for gearboxes. Some of the AI tech-

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niques include expert systems, artificial neural networks (ANNs), support vector machines (SVMs), fuzzy inference systems (FIS) and genetic algorithms (GAs).

This chapter reviews over a decade of research efforts in the application of AI techniques to fault diagnosis of gearboxes and attempts to identify those areas in the field that may still demand further research. Indeed, the literature on this subject is enormous and diverse; a review on all of the available literature would be voluminous and omission of some of the published papers would be inevitable. Some of the publications on the application of AI to GFD may also have been published in other languages. Owing to the limitation of language proficiency, non-English publications have not been considered in this chapter.

The following section discusses some of the extensively employed AI classifiers in fault diagnosis of gearboxes. The application of a particular classifier to GFD has been summarized immediately after its brief description and useful references provided where appropriate. The latter part of the chapter discusses some of the open problems in the field of intelligent GFD providing an insight into future research directions.

## **BACKGROUND**

Fault diagnosis of a gearbox is usually accomplished by comparing the vibration or acoustic (sound emission) signals generated by the gearbox under normal and faulty running conditions. Vibration or acoustic signals are collected from the gearbox through one or more accelerometers or microphones placed at suitable locations on or around the gearbox casing. Though a visual analysis of the time-domain vibration or acoustic signal may often reveal the occurrence of a fault, effective gear fault identification is usually achieved by adopting effective signal processing techniques in conjunction with AI. In order to determine the condition of the gearbox, meaningful features need to be extracted from the gearbox signals. The feature extraction stage is usually preceded by some form of signal processing. The extracted features may be time, frequency or time-frequency domain features. In order to obtain a substantial size of the features set capable of determining the condition of a gearbox, vibration or acoustic signals may be acquired under different gear health conditions under various combinations of loads, speeds and lubrication conditions. Sometimes, the signal captured under a given gearbox condition may be segmented into several parts in order to generate a significant number of features.

A gear fault diagnosis system must, as far as possible, be reliable and automated such that a relatively unskilled operator may undertake immediate measures to prevent catastrophic failures without the assistance of a signal analyst. Artificial intelligence in conjunction with signal processing techniques is a step towards automated GFD. The features extracted from the pre-processed vibration or sound emission signals collected under various gearbox health conditions may be fed in the form of feature vectors to one or more AI classifiers with the objective of gearbox fault identification. AI classifiers may be supervised or unsupervised. In the former type, a part of the feature set extracted from the gearbox signals is used for training the classifier while the remaining is reserved to test it for its classification efficiency.

The problem of GFD with AI may then be treated as a pattern classification problem and is preceded by feature extraction with various signal processing techniques and in certain cases, additionally, by feature selection methods. When the size of the feature set is too large, a criterion can be defined to optimize the feature set. Further, when the dimensionality of the feature vectors is very high, certain feature

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