Chapter 10
Degradation Based Condition Classification and Prediction in Rotating Machinery Prognostics

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ABSTRACT
A transition stage exists during the equipment degradation, which is between the normal condition and the failure condition. The transition stage presents small changes and may not cause significant function loss. However, the transition stage contains the degradation information of the equipment, which is beneficial for the condition classification and prediction in prognostics. The degradation based condition classification and prediction of rotating machinery are studied in this chapter. The normal, abnormal, and failure conditions are defined through anomaly determination of the transition stage. The condition classification methods are analyzed with the degradation conditions. Then the probability of failure occurrence is discussed in the transition stage. Finally, considering the degradation processes in rotating machinery, the condition classification and prediction are carried out with the field data.

INTRODUCTION
Due to the increasing requirements of the equipment reliability in reality, prognostics has attracted more attention in recent researches. Different from diagnostics, prognostics concentrates more on the possibility of fault occurrence and the remaining useful life of the equipment (Byington, Roemer, and Galie, 2002). The prognostic methods are usually based on the assumption that failures are caused by the component’s aging and degradation. And the parameters indicating the degradation are available with the failure onset extraction of the continuously monitored data in mechanical system.
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Condition classification and prediction are two important aspects in prognostics, where the equipment’s conditions include normal, abnormal and faulty states (Jiang, and Liu, 2011). Usually, the normal state is defined with the condition when the equipment is firstly installed or after maintenance. The failure condition is determined when the equipment is greatly affected by the component failure such as efficiency reduction, vibration increment and so on. The abnormal state is defined when the equipment is operating in some kind of abnormality but the failure has not been observed. The abnormal state is a transition stage in life cycle of the equipment, and it’s beneficial for the prognostics as the degradation information is included in the transition stage.

This chapter analyzes the degradation based condition classification and prediction approaches in prognostics. The remaining sections are organized as follows. The basic concepts of condition classification and prediction in prognostics are firstly discussed. Then the anomaly is defined to detect the degradation of the equipment. Finally, the condition classification and prediction are discussed based on the degradation processes.

BACKGROUND

Model-driven and data-driven methods are two important approaches taken by prognostics (Heng, Zhang, Tan, and Mathew, 2009; Byington, and Stoelting, 2004; Goebe, Saha, and Saxena, 2008). Model-driven prognostics is established by the mathematical model of the physical component or statistical model of the certain failure mode. Consequently, model-driven prognostics presents higher accuracy but with a specific application range. Data-driven prognostics is implemented by analyzing the monitoring data as well as the history data (Schwabacher, and Goebel, 2007). Extensive adaptability characteristic makes the data-driven prognostics with lower accuracy as fault mechanism is not considered. Other prognostics methods are also studied in many cases where evolutionary prognostics is a promising approach to predict the equipment’s fault onset and indicate the possibility of the failure (Roemer, Byington, Kacprzynski, and Vachtsevanos, 2006), and it is data-based.

The conditions in condition monitoring are usually classified into normal, and various faulty types. Yang (2005) used condition classification to study the healthy and faulty states in a small reciprocating compressor. One normal condition and four faulty conditions of the roller bearing were classified in (Jack, and Nandi, 2002). In fault diagnostics, 14 faulty types of the turbo pump were classified by Yuan, and Chu (2006), while normal states and abnormal states were not considered. Kinds of condition classification methods are studied including the linear and nonlinear classifiers. S. J. Sixon consider the five common classifiers: Euclidean distance to centroids, linear discriminant analysis, quadratic discriminant analysis, learning vector quantization and support vector machines (Dixon, and Brereton, 2009), with the results that the accuracy of the classifiers depends on the structure of the data set.

In machine operation processes, once the machine departs from the normal state, there exists a transition state between the normal state and the failure condition. Usually the intermittent state has little effect on the equipment, and may not cause significant functional loss. However, the intermittent states contain the information of equipment degradation. And estimating the abnormal state between the normal and failure conditions is essential in prognostics.

The prediction of the failure time and the probability of the failure occurrence are usually considered in prognostics. Time series forecasting is widely applied in predicting the failure time. Based on the past observations of the same variable, the forecasting model is established to describe the underlying relationship of the data,
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