Model-based prognostics of gear health using stochastic dynamical models

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ABSTRACT

In this paper we present a statistical approach to estimating the time in which an operating gear will reach a critical stage. The approach relies on measured vibration signals. From these signals features are first extracted and then their evolution over time is predicted. This is done based on a dynamic model that relates hidden degradation phenomena to measured outputs. The Expectation–Maximization algorithm is used to estimate the parameters of the underlying state-space model on line. The time to reach the safety alarm threshold is determined by estimating the distribution of the remaining useful life using the estimated linear model. The results obtained on a pilot test bed are presented.

1. Introduction

The on line condition monitoring of rotational machinery has become an almost indispensable part of modern control and supervision systems. In many industrial environments operators and maintenance personnel rely heavily on various prognostics and health management (PHM) systems. These systems can provide crucial information about the current health of installed devices, predict the remaining useful life of the components and diagnose a fault in case that it occurs. While the techniques addressing different diagnostic issues and condition-monitoring techniques have received a lot of attention in the past four decades [1,2], progress in the area of prognosis is relatively recent. In this paper, we present an algorithm for an efficient, robust and easy-to-deploy model-based prediction of the remaining useful life (RUL) of a gear system, based on vibration signals processed by means of the Hilbert transform (HT) [3,4]. The system can be used to predict the damage propagation trend and provide a safety alarm before the fault reaches critical levels.

The dynamics of gear-damage propagation is inherently a stochastic process, with stochastic components that result either from the stochastic nature of the damage propagation or are introduced into the signal through the measurement process. Therefore, the distribution of the remaining useful life must be estimated by propagating the distribution of the current system state, using a model of the damage-evolution process. Additionally, when a new measurement is obtained, the underlying process model can be updated and a new distribution of the system state is estimated, effectively resulting in an updated prediction. After this, the updated distribution of the RUL can be estimated using the updated model and the distribution of the system state. The estimation of the RUL is thus an iterative procedure that can employ different techniques for propagating the probability distribution over time.

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