Mechanical Systems and Signal Processing 25 (2011) 3102–3115

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

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

Study of start-up vibration response for oil whirl, oil whip and dry whip

Chen-Chao Fan [a], Jhe-Wei Syu [a], Min-Chun Pan [a,b,*], Wen-Chang Tsao [a]

[a] Department of Mechanical Engineering, National Central University, Taiwan, ROC
[b] Graduate Institute of Biomedical Engineering, National Central University, No. 300, Jhongda Road, Jhongli City, Taoyuan County 32001, Taiwan, ROC

ARTICLE INFO

Article history:
Received 1 September 2010
Received in revised form
28 March 2011
Accepted 19 April 2011
Available online 17 May 2011

Keywords:
Hilbert–Huang Transform
Rub
Whip
Whirl

ABSTRACT

Oil whip induces self-excited vibration in fluid-handling machines and causes self-excited reverse precessional full annular rub, known as "dry whip", which is a secondary phenomenon resulting from a primary cause, that is, "coexistence of oil whip and dry whip". For predicting these instabilities, the clues are hidden in start-up vibration signals of these kinds of machines. This paper presents a method for predicting these kinds of instabilities. First, a Hilbert spectrum combining a full spectrum, which is named the "full Hilbert spectrum", is developed to reveal the whole process. Next, the transient position of a shaft centerline combining an acceptance region is introduced to predict instability at an early stage. The results presented in this study amply demonstrate the transition from stability to instability and the behavior of fluid-induced instability and rub in rotor systems. By this finding, bearing designers can completely understand these instability phenomena existing in fluid-handling machines. As a result, the control parameter for designing controllable bearings can be obtained and the instability problems can be resolved. Consequently, these findings are worth noting.

1. Introduction

Oil whip [1,2] caused by fluid-induced instability is one problem and dry whip induced by rub is another. These kinds of instabilities are serious malfunctions in rotating machinery and may cause a machine catastrophic failure if they occur simultaneously. The oil whip and dry whip involve several major physical phenomena, such as the third bearing effect, friction, impacting, and changes in the system stiffness. The normal operation of machines is affected in such a situation because these instabilities occur repeatedly with constant frequency and amplitude. Moreover, the occurrence of rubbing has two major causes: one is that the oil whip induces instability in a rotating machine and the other is that the desire to increase the efficiency of machines with fluid-film bearings leads to minimize the clearance of seals. However, experiments in this study showed that the coexistence of oil whip and dry whip with almost constant frequency and amplitude occurred in an experimental setup attached with a seal. Though there are some rotor-stator related studies focusing on establishing the symptoms of rotor rub, the transition from stability, oil whirl, oil whip, synchronous precessional full annular rub to the coexistence of oil whip and dry whip were not noticed until recent studies. For observing rub, the full spectrum plot is a good tool but it is insufficient and inappropriate for interpreting nonlinear and non-stationary signals. Therefore, researchers around the world have started using some advanced signal processing techniques, such as the Hilbert–Huang transform (HHT), Wavelets, etc. These tools characterize vibration signals in time–frequency energy representations. HHT developed by Huang and Shen [3,4] is a new method and evolved as a powerful tool for analyzing nonlinear and non-stationary signals.

* Corresponding author at: Department of Mechanical Engineering, National Central University, No. 300, Jhongda Road, Jhongli City, Taoyuan County 32001, Taiwan, ROC. Tel.: +886 3 4267312; fax: +886 3 4254501.
E-mail address: pan_minc@cc.ncu.edu.tw (M.-C. Pan).

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doi:10.1016/j.ymssp.2011.04.012