Engineering Failure Analysis 18 (2011) 2149–2164

Contents lists available at ScienceDirect

Engineering Failure Analysis

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

Dynamic simulation of spur gear with tooth root crack propagating along tooth width and crack depth

Zaigang Chen, Yimin Shao *

State Key Laboratory of Mechanical Transmission, Chongqing University, Chongqing 400030, China

ARTICLE INFO

Article history:
Received 11 April 2011
Received in revised form 26 June 2011
Accepted 8 July 2011
Available online 22 July 2011

Keywords:
Tooth crack
Propagation
Gear mesh stiffness
Sidebands

ABSTRACT

Gear tooth crack will cause changes in vibration characteristics of gear system, based on which, operating condition of the gear system is always monitored to prevent a presence of serious damage. However, it is also a unsolved puzzle to establish the relationship between tooth crack propagation and vibration features during gear operating process. In this study, an analytical model is proposed to investigate the effect of gear tooth crack on the gear mesh stiffness. Both the tooth crack propagations along tooth width and crack depth are incorporated in this model to simulate gear tooth root crack, especially when it is at very early stage. With this analytical formulation, the mesh stiffness of a spur gear pair with different crack length and depth can be obtained. Afterwards, the effects of gear tooth root crack size on the gear dynamics are simulated and the corresponding changes in statistical indicators – RMS and kurtosis are investigated. The results show that both RMS and kurtosis increase with the growth of tooth crack size for propagation whatever along tooth width and crack length. Frequency spectrum analysis is also carried out to examine the effects of tooth crack. The results show that sidebands caused by the tooth crack are more sensitive than the mesh frequency and its harmonics. The developed analytical model can predict the change of gear mesh stiffness with presence of a gear tooth crack and the corresponding dynamic responses could supply some guidance to the gear condition monitoring and fault diagnosis, especially for the gear tooth crack at early stage.

0. Introduction

Gearboxes are the most important mechanisms in industrial machinery, automotive applications, and our daily lives to transmit power and produce high rotational speed changes and/or change the direction of motion. And due to their growing applications, gearbox health monitoring and early fault detection have been under intensive investigation [1,2].

As is known, gear tooth failure can cause removal and/or plastic deformations on the contacting tooth surfaces or even presence of fatigue crack. And the severity of tooth damage is usually assessed by the reduction of the stiffness [3,4]. There has been a lot of work carried out to investigate gear tooth stiffness with and/or without tooth faults. Finite element models (FEA) [4–8] and analytical methods are the widely used approaches to fulfill the stiffness modeling and calculation. However, FEA models for the tooth stiffness calculation need mesh refinements and are computationally expensive. On the other hand, analytical methods show good results with less computation time compared with FEA models [4,9,10].

Gear mesh stiffness without defects was computed analytically by Weber [9], Cornell [10], while a digitization approach was used by Kasuba and Evans [11]. Yang and Lin [12] used the so-called potential energy method to calculate the total mesh stiffness of a gear pair versus gear rotational position. And their model was further refined by Tian [13] and Wu et al. [1] by

* Corresponding author. Tel.: +86 (0)23 65112520; fax: +86 (0)23 65106195.
E-mail address: ymshao@cqu.edu.cn (Y. Shao).

1350-6307/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.engfailanal.2011.07.006