Mechanism and Machine Theory 115 (2017) 97–113

Contents lists available at ScienceDirect

Mechanism and Machine Theory

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

Research paper

Load sharing analysis and reliability prediction for planetary gear train of helicopter

Ming Li[a,*], Liyang Xie[a], Lijun Ding[b]

[a] School of Mechanical Engineering and Automation, Northeastern University, Shenyang 110819, China
[b] Operation Support Center, Liming Aero Engine Corporation of China, Shenyang 110000, China

ARTICLE INFO

Article history:
Received 12 December 2016
Revised 9 April 2017
Accepted 1 May 2017

Keywords:
Planetary gear train
Load sharing
Reliability prediction
Minimum order statistic
Gear fatigue test

ABSTRACT

Due to inevitable manufacturing and installation errors, there are many problems of unequal load sharing in planetary gear train. In this paper, a model is established to predict the reliability of helicopter planetary gear train under the condition of partial load. Firstly, the structure of gear system and partial load state are analyzed in detail, and the load histories of each gear are transformed into equivalent constant amplitude load spectrums to be as the load input variable for reliability model. At the same time, a tooth bending fatigue test is carried out with specific gears, and the statistical results of test data are as the strength input variable for reliability model. Then, according to partial load characteristics of the gear system, the reliability model is established based on the concept of minimum order statistic. Finally, the bad influence of unequal load sharing on planetary gear train is shown by prediction result and the reliability model is verified through a statistical analysis method of random censored data.

© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

Planetary gear trains are widely used in aviation industry, because they not only have the characters of small volume, light weight, stable running and low noise, but also they have a high bearing capacity and a long service life. In planetary gear trains, if the input power is equally shared among planet gears, the torque on each planet gear will be significantly reduced. At the same time, the radial forces on center gears will be offset each other. This results in a longer service life for gears and a less radial support requirement for bearings. However, if the problem of unequal load sharing from input gear to planet gears is neglected, the superiority of planetary gear train will not be well performed. At present, there are more or less problems of unequal load sharing in some planetary gear mechanisms [1–3]. In fact, due to inevitable manufacturing and installation errors, as well as the deformation of components and other factors, resulting in the load sharing among planet gears will be uneven.

Some scholars have done a lot of research on the unequal load sharing analysis for the planetary gear train. Hidaka et al. [4–6] showed that both experimentally and theoretically, only when at least one center gear was floating the planetary gear train would have a perfect load sharing state. Muller [7] put forward the same theory. Seager et al. [8–11] emphasized the importance of supporting conditions to improve the load sharing. Hayashi et al. [12] showed experimentally that increasing input power could help to improve the load conditions. Kahraman [13,14] proposed a discrete model by which the influence of the carrier pin hole and planet run-out errors on load sharing was studied. Kahraman [14] subsequently presented a load

* Corresponding author.
E-mail address: a15941660820@163.com (M. Li).

http://dx.doi.org/10.1016/j.mechmachtheory.2017.05.001
0094-114X/© 2017 Elsevier Ltd. All rights reserved.

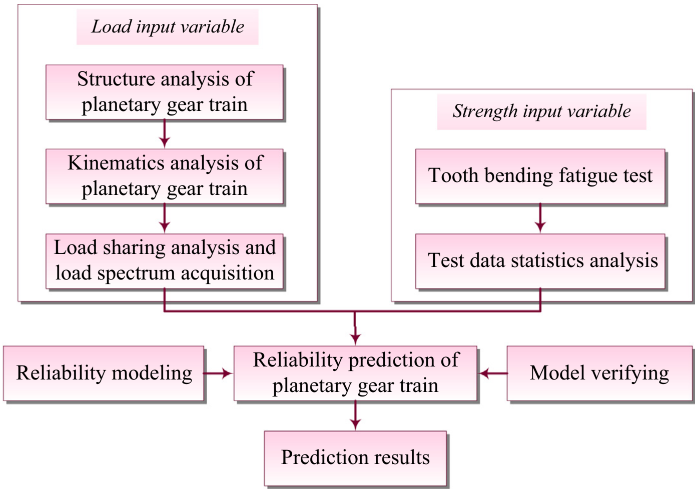

Fig. 1. Reliability prediction flowchart of the planetary gear train.

sharing model to determine the static load sharing among planet gears and validated experimentally the prediction result of the model. Viiavakar et al. [15] continued to study this work by making ring gear flexibilities. Bodas et al. [16] presented a deformable body model of planetary gear train to demonstrate theoretically that adding more planet gears the system would be more sensitive to the manufacturing and assembly errors. Singh [17] used a three-dimensional model to prove a similar conclusion.

Once planetary gear train is biased, the load environment of gear system will be deteriorated, which ultimately affect the reliability of the gear system. Reliability analysis is necessary for gear transmission system, especially for that in aviation field. In view of the reliability analysis and prediction for gear system, domestic and foreign scholars have also carried out some research. Liyang [18] defined a concept of time-domain series system and proposed a special method of reliability modeling for gear train. Yang [19] conducted a work to investigate the applicability of linear cumulative damage rule in gear reliability design. Zhang [20] proposed a random perturbation method for reliability design of gear pairs. Zhang [21] proposed an application of the stress and strength interference theory in reliability calculation of gear transmission. Nejad [22] studied a calculation method for long-term root bending fatigue damage in wind turbines. Li [23] evaluated the reliability of universal gear wind turbine systems using a logic diagram. Guerine [24] researched the dynamic statistical responses for the gear system with uncertain parameters. And Di Zhou [25] considered reliability-based sensitive factors to conduct the reliability analysis for the planetary gear train in shearer mechanism.

Unequal load sharing in the planetary gear train is inevitable, so the influence on reliability of gear system cannot be ignored. In particular, the planetary gear train in aviation field has the outstanding characteristics of high speed and heavy load, and therefore any failure form may lead to a tragedy. In this paper, the unequal load sharing analysis and reliability prediction for planetary gear train of a helicopter are carried out, and Fig. 1 is a flowchart of the study. The concept of minimum order statistic is used to establish a probability life relationship between gear and tooth, and finally to complete the reliability modeling. The model takes the load and strength information of tooth as input variables, simply and effectively predict the reliability of planetary gear train in partial load state. In the process of collecting load spectrum, a series of discrete points are used to represent the load history, which greatly reduces the computational task of the simulation model, so that the attention can be placed on the complete establishment for the simulation model. Complete simulation model can be used to take into account the impact of deformation of various support members on stress, and only then can we better achieve the study of partial load. In addition, for the reliability prediction of gear system, we predict the system reliability based on the life information of specific gear, not as usual, based on the fatigue properties of gear material. Thus effectively avoid the consideration of these factors, such as surface state, size effect, stress concentration, and residual stress. This not only improves the prediction accuracy, but also simplifies the calculation.

2. Planetary gear train

2.1. Introduction of the helicopter reducer

The main rotor reducer of a twin-engine helicopter is shown in Fig. 2. It decelerates through two stages to transfer engine power to propeller. The first stage deceleration is that a large spiral bevel gear meshes at the same time with two small ones to achieve combination of the input power of both sides. The second stage deceleration is completed by a planetary gear train, and finally its output shaft transfers the power to propeller. Rated working conditions of the reducer is that input power on both sides is respectively 200 kW, input speed is 4000 rpm, and internal working temperature is 70°C.

Download English Version:

https://daneshyari.com/en/article/5018741

Download Persian Version:

https://daneshyari.com/article/5018741

Daneshyari.com