



Stability research of multistage gear transmission system with crack fault

Xin Wang ^{a, b, *}

^a School of Mechanical Engineering, Baoji University of Arts and Sciences, Baoji 721016, China

^b School of Mechanical Engineering, Tianjin Polytechnic University, Tianjin 300387, China



ARTICLE INFO

Article history:

Received 13 September 2017

Received in revised form 21 July 2018

Accepted 23 July 2018

Handling Editor: L.N. Virgin

Keywords:

Multistage gear transmission system

Nonlinear dynamics

Crack fault

Sub-harmonic resonance

ABSTRACT

The sub-harmonic resonance phenomenon exists in multistage gear transmission system. Collision motion leads the sub-harmonic resonance instability, which brings harm to system stability. So investigating instability conditions of sub-harmonic resonance and effects of fault on stability have important significance on controlling system stability. From the point of view of nonlinear dynamics, dimensionless dynamical equations of multistage gear transmission system which contains a two-stage fixed-axis gear and a one-stage planetary gear are established. The bifurcation diagrams of system are obtained. By the changing of Poincaré section analyze the evolution process of sub-harmonic resonance and instability conditions. The changes of sub-harmonic resonance and system stability are studied under fixed-axis gear tooth crack fault state in different clearance. The study has important significance for operational prediction of system.

© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

A reasonable clearance is tolerated in gear design. But with the increase in running time, the faults such as wear, deformation, crack, broken, etc, make system original design parameters changing. It results in the original stable reciprocating impact periodic motion evolved into abnormal vibration which will impact on the stability, safety and service life of system. For multistage gear transmission system, nonlinear vibrations between the gears will be coupled which makes the vibrations more complex. Stability of system after coupling becomes unknown. So it is necessary to further study on system stability. For the study of the stability of multistage gear transmission system, Lin and Parker [1] focused on the instabilities caused by parametric excitation in two-stage gear system. Náprstek [2] uses the research results of the dynamic stability improve the safety and reliability of the engineering system. Yang [3] find that the single stage gear rotor-bearing collision vibration system generates the sub-harmonic bifurcation with the increase of excitation frequency, which makes the system unstable, from the stable periodic motion through the sub-harmonic bifurcation to chaos. Due to the coupling characteristics, the multistage gear transmission system is not stable. The sub-harmonic resonance in the system is affected and changed by the design parameters and the coupling characteristics, which is easy to cause the instability of the system.

From test response signals of the multistage gear transmission system experiment, we found the phenomenon of sub-harmonic resonance. The stability of the system has been impacted. So analyzing the vibration mechanism of sub-harmonic resonance, studying the conditions under which it appears and the changes of motion state of system, and

* School of Mechanical Engineering, Baoji University of Arts and Sciences, Baoji 721016, China.

E-mail address: 46607190@qq.com.

finding the sub-harmonic resonance speed range, has important significance for optimization design, reliability analysis and fault diagnosis of the multistage gear transmission system. The sub-harmonic vibration in test response signals is coupled with many complex vibrations. It is difficult to extract the nonlinear characteristics of sub-harmonic vibration accurately from the coupling signals, and the influence of sub-harmonic vibration to the stability of the system. So it is necessary to do the further nonlinear dynamic stability analysis on system sub-harmonic vibration. The topic of sub-harmonic resonance has been widely discussed during last decades. For example, bifurcation processes of the sub-harmonic resonance of different gears and the influence of parameters to the system were discussed [4–6]. Al-shyyab [7] studied the steady state periodic motion of the two-stage gear system. But the influence of faults on system stability is not considered in most studies.

Crack failure is the most common fault in gear transmission system. In term of the influence of crack on the stability of the system, most of the researches focus on the rotor bearing system with crack fault [8–14]. There are other studies that go on from other perspectives. Obrezanova [15] investigated the stability of a straight two-dimensional dynamically propagating crack to small perturbation of its path. Li [16] presented an effective and convenient method which used the finite element method (FEM) to research the motion stability of the nonlinear rotor-bearing system with cracked faults and other nonlinear force. In literature [17] the lateral vibrations of the beams with two breathing cracks were considered. Two contact parameters were used to describe breathing of the cracks. The continuation technique was applied to analyze numerically the periodic vibrations. The periodic motions, their stability and bifurcations were investigated. It was analyzed the sub-harmonic motions, which originate from the period-doubling bifurcations. Wang [18,19] and Boiangiu [20] studied the conditions, positions and areas of the stable vibrations and the unstable vibrations on a rotor system with a transverse crack quantitatively theoretically. Variable perturbation method had been used to study the stability of bending-torsional coupled vibration of a rotor system with a crack [21].

At present, there is no study on stability of the multistage gear transmission system with fault. When there is a fault in multistage gear transmission system and coupled with sub-harmonic resonance, if the changes of nonlinear dynamic and stability in the system are not clear will make the system stability uncontrollable. The system may be sudden instability. So it is necessary to make clear these nonlinear dynamic changes to control the system stability effectively. The study has important significance for the operation prediction of system with fault.

In this study, dimensionless dynamical equations of system which contains a two-stage fixed-axis gear and a one-stage planetary gear are established based on the test rig of the multistage gear transmission system. By studying the bifurcation characteristics under different clearance, the rotational speed range of the sub-harmonic resonance is found. Using Poincaré section analyses the evolution process, instability condition, and the influence of fixed-axis gear tooth crack to the sub-harmonic resonance and stability of the system.

2. Torsional dynamic model of the multistage gear transmission system

The system studied in this paper is a test rig of the multistage gear transmission system which contains a two-stage fixed-axis gear and a one-stage planetary, as showed in Fig. 1.

where spur gears 1, 2 compose the 1st stage fixed-axis gear for the input, spur gears 3, 4 compose the 2nd stage fixed-axis gear, the planet carrier is for the output. The torsional dynamic model is established by using the lumped mass method as showed in Fig. 2. The model does not consider the transverse vibration displacement of gears. Gear parameters are simulated with a spring and a damper.

where, $\theta_s, \theta_c, \theta_{pn}, \theta_1, \theta_2, \theta_3, \theta_4$ represent the angular displacement of sun gear, planet carrier, planetary gear n ($n = 1, 2, 3, 4$), spur gears 1, 2, 3, 4, respectively. Throughout this paper, the subscripts $s, c, pn, r, 1, 2, 3, 4$ denote sun gear, planet carrier, planetary, ring gear and spur gears 1, 2, 3, 4. Quantities $r_s, r_c, r_{pn}, r_1, r_2, r_3, r_4$ are the base circle radius of gears. Quantities $K_{spn}(t)$,

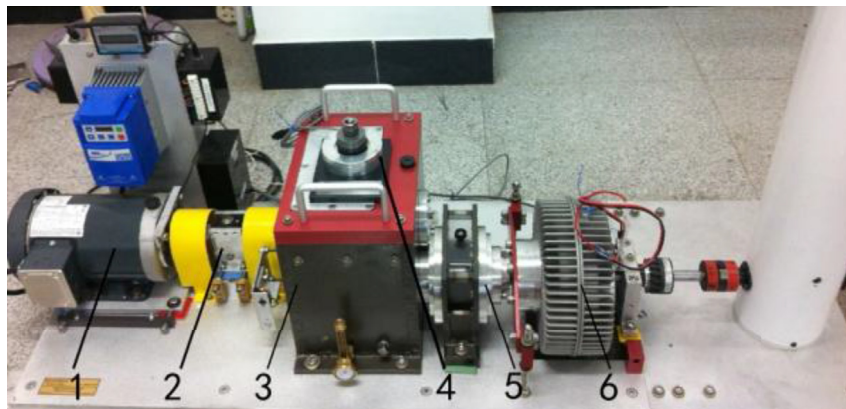


Fig. 1. The test rig of the multistage gear transmission system; 1-Motor, 2-Torque sensor and encoder, 3-Two stage fixed-axis gearbox, 4-Radial load of bearing, 5-One stage planetary gearbox, 6-Brake.

Download English Version:

<https://daneshyari.com/en/article/6752592>

Download Persian Version:

<https://daneshyari.com/article/6752592>

[Daneshyari.com](https://daneshyari.com)