ANTI-CONTROLLING NEIMARK-SACKER BIFURCATION IN A TYPE OF CENTRIFUGAL GOVERNOR SYSTEM UNDER WEAK IMPULSE EXCITATION

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ABSTRACT

Anti-controlling problem of designing Neimark-Sacker bifurcation in a centrifugal governor system under weak impulse excitation is addressed. A feedback control method with polynomial functions is proposed to achieve three aspects of controlling problem including existence, stability, and mean radius of cross section of the torus solution. An explicit criterion of Neimark-Sacker bifurcation is utilized to derive the linear gains responsible for control of the bifurcation existence. The center manifold theory and normal form reduction is utilized to derive the nonlinear gains responsible for control of the stability of torus solution. The expressions of mean radius of cross section of the torus solution is developed to derive the nonlinear gains responsible for control of the thickness of torus solution. Numerical simulations for a centrifugal governor system show that Neimark-Sacker torus with desired properties can be created at any a pre-specified parameter point.

Keywords: anti-control of bifurcation, Neimark-Sacker bifurcation, weak impulse excitation, centrifugal governor system.

INTRODUCTION

The centrifugal governor is a device that automatically controls the speed of an engine by regulating the amount of fuel. It plays an important role in many rotational machines such as steam engine, internal combustion engines, various fueled turbines and so on. Many researchers focus on the stability (Denny, 2002) and bifurcation (Sotomayor et al., 2007) of equilibrium of centrifugal governor system. Moreover, the controlling bifurcation and chaos of centrifugal governor system has been studied (Ge et al., 2003).

Anti-control of bifurcation, as the inverse problem of conventional bifurcation control, is aimed at creating a certain bifurcation with desired dynamic properties at a specified system parameter location via control method (Chen et al., 2000). As for a centrifugal governor system, if the speed of the engine is requested to fluctuate continuously above and below the mean speed with the demand of practice, this sort of motion admits that the centrifugal governor has a reciprocating motion. Therefore, it is certain practical signification for some special practical problems to create a certain bifurcation solution in centrifugal governor and design stability, amplitude of the solution by control. In this paper, a feedback control method is proposed to create a Neimark-Sacker bifurcation in a centrifugal governor system under weak impulse excitation and design the bifurcation torus solution with desired properties.
RESULTS AND CONCLUSIONS

To overcome the limitations of calculating the eigenvalue required in classical critical criterion, an explicit criterion of Neimark-Sacker bifurcation is employed to determine the linear gains. The control parameter bifurcation diagram is shown in Fig.1. The azure area stands for the stable field of period-one orbit. The red curve represents the bifurcation curve. The points on the orange curve make the transversality condition fail. The selection of control gains should be away from the point of intersection $p$ in a process of designing the solution of bifurcation.

The stability of the torus solution of bifurcation depends on the nonlinear property of the system. We use the center manifold reduction and normal form theory to analytically derive the stability condition with respect to the nonlinear control gains. The stability field of torus is shown in the Fig.2. The cyan area in Fig.2 stands for the stable field of torus which ensure that the created bifurcation solution is stable. Through choosing the proper linear and nonlinear gains, a stable torus solution of system is created at a pre-specified parameter point (see Fig.3 and Fig.4).

After the torus solution of system is created, we develop an expression of mean radius of cross section of the torus to derive the nonlinear gains for controlling the thickness of torus. The control effects of thickness of torus subject to the nonlinear control gains are shown by the phase portraits on Poincaré section (see Fig.5).

This study shows that a stable torus solution of a centrifugal governor system under weak impulse excitation can be created at a pre-specified parameter point by choosing the proper linear and nonlinear gains and the thickness of torus can be adjusted by the nonlinear gains derived from the developed expressions of mean radius of cross section of the torus.

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REFERENCES