Finite Element Modeling and Vibration Analysis of Sprag Clutch-Flexible Rotor System

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Abstract

To study the overall vibration characteristics of the sprag clutch-flexible rotor system (SC-FRS) under high-speed operating conditions, a finite element model of SC-FRS considering rotor flexibility and bearing support stiffness is established based on the proposed calculation method of the stiffness matrix. According to this model, the natural frequency and mode shape of the system are calculated, and the correctness of the model is verified by comparing it with the calculation results of ANSYS software. Under the action of unbalance, the bending-torsion coupled vibration and the dynamic load of the inter-shaft bearings are analyzed, and it is found that the resonant peak in the torsional direction has the same resonance frequency as that in the bending direction. A test rig for the sprag clutch-rotor system is built, and the axis trajectory and critical speed are tested. The test results show that the finite element model of SC-FRS can accurately describe the vibration characteristics of the system.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Table

Table 1			
Natural frequency of rotor system calculated by various models			
Order	The proposed model(Hz)	The ANSYS model (Hz)	Relative error
1	168.8	168.4	0.24%
2	169.5	169.9	0.24%
3	538.2	539.5	0.24%
4	538.5	540.1	0.30%
5	604.0	605.0	0.17%
6	604.2	605.3	0.18%

Figures

Figure 1

Schematic diagram of the division for the finite element unit of the system

Figure 2

Coordinate system and degrees of freedom of the sprag clutch

Figure 3

Tangential stiffness corresponding to pre-contact deformation

Figure 4

Radial deformation coefficient under preloading torque

Figure 5

Division of the slices in the axial direction of the sprag roller

Figure 6

Schematic diagram of the assembly of the stiffness matrix

Figure 7

Representative mode shapes of the system: a, c, e The first, third, fifth mode shapes of ANSYS model; b, d, f The first, third, fifth mode shapes of the proposed model

Figure 8

Campbell diagram of rotor system with sprag clutch

Figure 9

AFR of all nodes in the x and θ_z directions: a, c In the x direction of nodes on the outer and inner rotors; b, d In the θ_z direction of nodes on the outer and inner rotors

Figure 10

AFR of special nodes in the x and θ_z directions: a, c In the x direction of nodes on the outer and inner rotors; b, d In the θ_z direction of nodes on the outer and inner rotors

Figure 11

AFR of nodes 4 and 19 in the x and θ_z direction under unbalanced mass 2: a, c In the x direction of node 4 and 19; b, d In the θ_z direction of node 4 and 19

Figure 12

AFR of the dynamic load of the inter-shaft bearing in x direction under unbalanced mass 2: a The inter-shaft bearing 3; b The inter-shaft bearing 4

Figure 13

Schematic of the test bench of sprag clutch-rotor system

Figure 14

The test bench of sprag clutch-rotor system

Figure 15

The test bench of sprag clutch-rotor system

Figure 16

Comparison of critical speed of SC-FRS between theoretical calculation and experiment of the x-direction