Dynamic Analysis for Cage in a Ball Bearing Using LS-DYNA

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Abstract: A dynamic model of ball bearing is established based on the explicit dynamic method in ANSYS/LS-DYNA. The dynamic vibrations of bearing are simulated at different radial loads, rotating speeds, cage materials, and then the effects on the vibration and stress of cage are analyzed. The results indicate ANSYS/LS-DYNA is an effective tool for the dynamic analysis for cage in ball bearing.

Key-Words: *Ball Bearing, Cage, Explicit Dynamic, Vibration, Stress*

1. Introduction

Most rolling bearings consist of four major components: an inner ring, an outer ring, a set of rolling elements and a cage. The cage has been considered as one of the weakest parts in high-speed bearings, and the cage life directly affected by its dynamic vibrations [1]. Therefore, the dynamic analysis of the cage is of great significance.

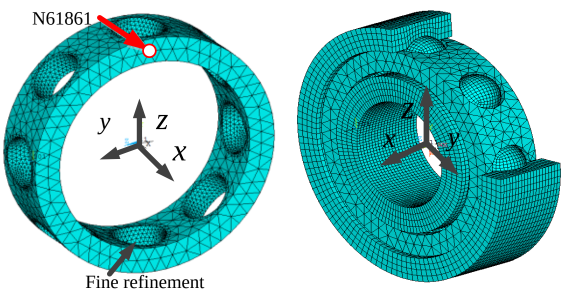
Harris [2], Gupta [3] and Tomoya [4] have already developed different analytical and numerical models of bearing to study the cage behaviors in which the cage is considered as rigid-body. However, traditional dynamic models of bearing unable to analyze the stress of cage due to the rigid cage assumption. Therefore, the dynamic models of bearing with an elastically deformable (flexible) cage are proposed by Ashtekar [5] and Singh [6] to research the deformation and stress of cage.

In this paper, a dynamic model of ball bearing is developed to analyze the vibrations and stresses of the cage under different conditions.

2. Explicit dynamic model for ball bearing

A deep groove ball bearing of 6306 is chosen here, and it's inner, outer and ball are made by GCr15 and its cage is 40CrNiMoA.

Solid164 element with eight-node hexahedron is adopted for inner, outer, cage and balls. Meanwhile, Shell163 with three DOF per node which can be applied to the load and rotation speed is chose for the internal surface of inner ring. N61861 is selected as the analytical node shown as Figure 1(a). The whole bearing model is shown as Figure 1(b), there are 71243 units and 65357 nodes.



（a）cage （b）whole bearing

Figure 1 Finite element meshing of bearing

Automatic surface-to-surface is defined between the bearing contacts. The surfaces for outer or inner raceway and cage pocket are selected as the object surfaces, meanwhile the surfaces of ball are passive. Total number of contact pairs is 36.

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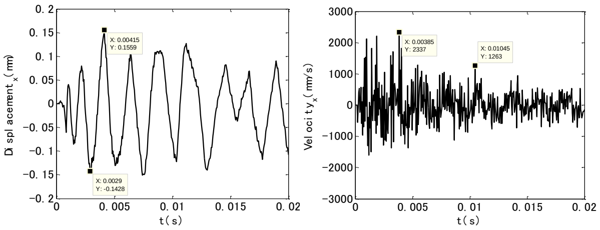
The static friction coefficients between the balls, inner and outer raceways and cage are set to 0.35, 0.35 and 0.2, the dynamic friction coefficients for these are set to 0.16, 0.16 and 0.1, respectively. The constant rotating speed and radial load are applied to the inner ring. All DOFs are applied to the nodes in the external surface of outer ring.

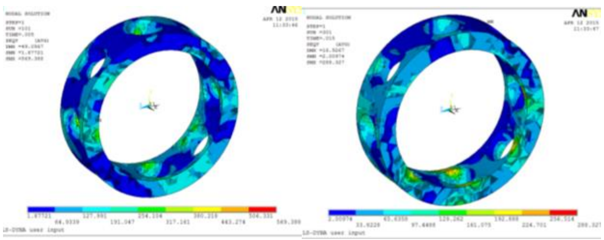
3. Simulation

The simulation of bearing is conducted at the speed of 12000r/min and the radial load 1000N. Its simulation time is 0.02s. Vibration response of N61861 node is shown in Figure 2. Equivalent effective stress of cage is illustrated in Figure 3.



(a) Displacement (b) Velocity

Figure 2 Vibration of cage in *x* direction (N61861)



(a) t=0.010s (b) t=0.020s

Figure 3 Equivalent stress of the cage

4. Results and Discussion

The vibration and stress of cage are simulated at the speed of 12000r/min and two radial loads of 1000N or 4000N, respectively. The results are listed in Table 1. It can be seen that the axial displacement decreases and the equivalent stress increases with the increment of the radial load.

Table1 Results at different radial loads

Rdial load	Axial displacement	Equivalent stress
1000N	0.1559mm	593.5 MP
4000N	0.1398 mm	673.9MPa

The results for the radial load of 1000N and two speeds of 12000r/min and 6000r/min conditions are presented in Table 2. It can be indicated that the equivalent stress increases and the axial displacement of cage little influenced when increasing the rotating speed.

Table2 Result at different rotating speeds

Speed	Axial displacement	Equivalent stress
12000r/min	0.1559 mm	593.5 MPa
6000r/min	0.1537 mm	382.5 MPa

The cage material are chosen QAl10-3-1.5 and 40CrNiMoA, when the speed of 12000r/min and radial load of 1000N. The results are shown in Table 3.

Table3 Result at different cage materials

Materials	Axial displacement	Equivalent stress
40CrNiMoA	0.15mm	594MPa
QAl10-3-1.5	0.14mm	382.4MPa

It can be seen from Table 3, the axial displacement of cage has little difference between QAl10-3-1.5 and 40CrNiMoA, but the stress of cage is obviously different. The maximum stress of cage with QAl10-3-1.5 is 382.4MPa less than 594MPa of 40CrNiMoA, which because the elastic modulus E of QAl10-3-1.5 less than that of 40CrNiMoA.

5. Conclusion

The main conclusions of the study are given as follows: The axial displacement of cage decreases and the stress of cage increase with the increment of the radial load. However, the rotating speed and material of cage have obvious effects on the stress of cage，less influence on the axial displacement.

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