Vibration	Vibration due to Decrease in Function of Squeeze Film Damper	Rotating Machinery
Resonance		

Object Machine

A rotating shaft supported by ball bearings with squeeze film dampers having O-ring end seals (Fig.1)

Observed Phenomena

Shaft vibrations with a component of the rotating speed suddenly increased near the rated speed, resulting in excessive vibrations (Fig.2). At the time of initial development, such a phenomenon did not occur, and vibrations were of only a small amplitude and stable. However, at the overhaul for inspection, a residual unbalance was found to be large, and the end seal (O-ring) of the squeeze film dampers swelled and crushed.

Cause Estimation

Unbalance was excessive and a critical speed existed near the rated speed.

Analysis and Data Processing

(1) Check of balancing condition
Check of residual unbalance indicated the presence of a shaft part having 10 times an allowable unbalance. A defect due to wear of the fitted part of a balancing jig (arbor) was identified as a cause. After an overall assembly, a low-speed balancing (overall balancing) was conducted, which turned out to be a cause of large unbalance in the elastic mode near the rated speed.

(2) Investigation of the cause of natural frequency near the rated speed
The natural frequency under a free-free condition was measured, and the bending rigidity of the rotating shaft was matched with the test result (Fig.3). Consequently an estimated cause was an influence of the dynamic characteristics of the squeeze film damper.

(3) Analysis of dynamic characteristics of squeeze film damper of actual equipment
- Use of linearization equation by means of boundary layer approximation based on Navier Stokes equation. Modeling of annular lubrication groove of damper and end seal (Fig.4).
- Examination of the dynamic characteristics of O-ring under normal condition and when swelled and crushed. Crush of O-ring leads to substantial change in the damping coefficients ($C_{\varepsilon\varepsilon}$, $C_{\psi\psi}$) and inertia coefficients ($M_{\varepsilon\varepsilon}$, $M_{\psi\psi}$) (Fig.5).
- Simulation of unbalanced response
  Crush of O-ring results mainly in the reduction of inertia coefficient, and this causes a critical speed to increase and get closer to rated speed (Fig.6).

Countermeasures and Results

Balance correction was conducted. The countermeasures considered included replacement of the end seal of the damper with a piston ring, or changing the material of the O-ring to another material not liable to swelling and together with periodic replacement. Actually, the later measure was employed, and no such excessive vibrations have occurred thereafter.

Lesson

The inertia coefficient of squeeze film dampers has a significant impact on a critical speed.

References

M. Kobayashi, D. Ishihara, “Dynamic characteristics of squeeze film damper with a seal”, Transaction of the Japan Society of Mechanical Engineers, D&D, No.98-8, CD-ROM 512, (1998)

Keywords

Squeeze Film Damper, O-ring, end seal, inertia coefficient, added mass, annular lubrication groove, curvic coupling

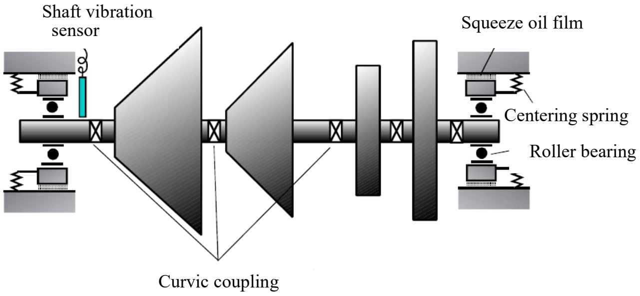


Fig.1 Shaft system supported by squeeze film damper

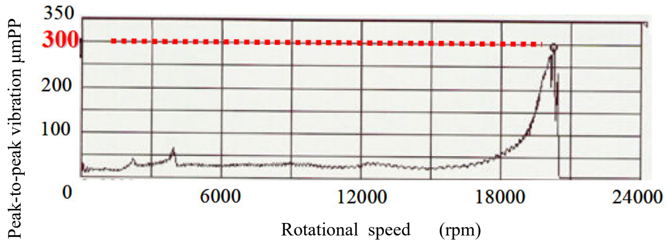


Fig.2 Measured shaft vibration

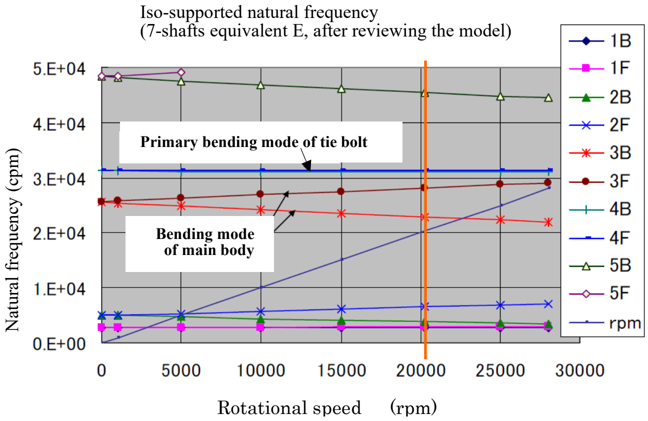


Fig.3 Undamped natural frequency under a condition without damper

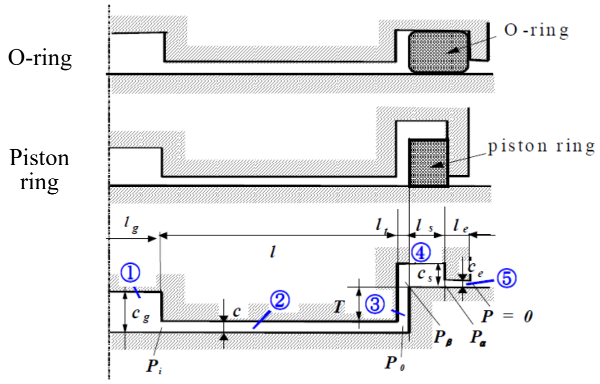


Fig.4 Modelling of squeeze film damper

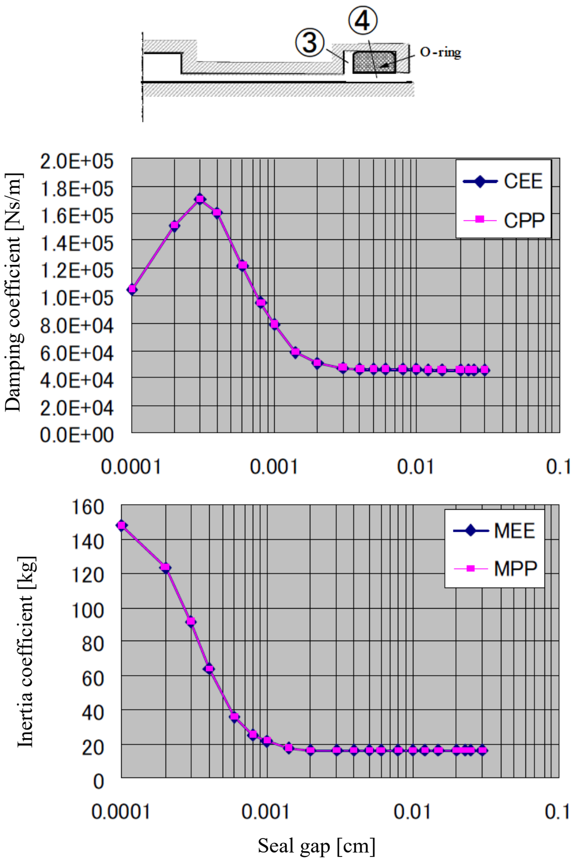
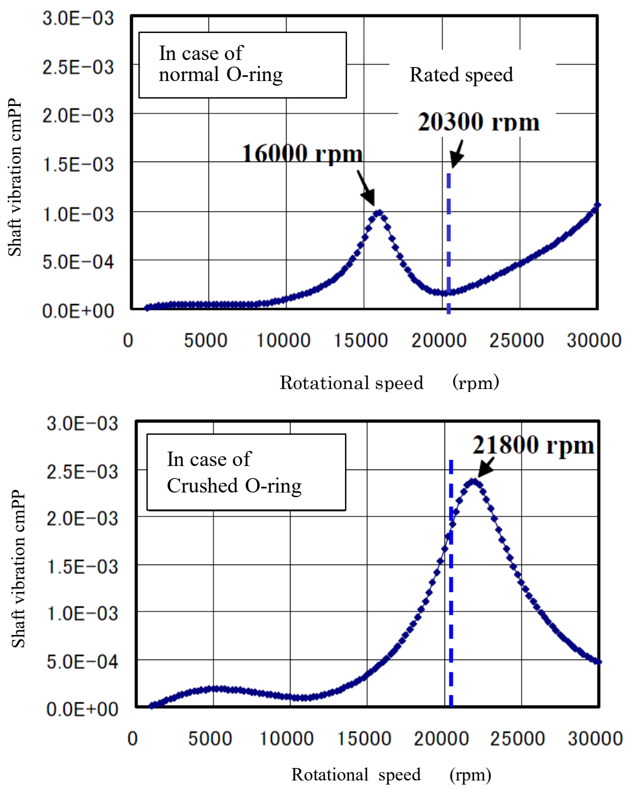


Fig.5 Damping coefficient and inertia coefficient with a crushed O-ring (a gap dimension ④ as parameter)



Fir.6 Difference in unbalanced vibration response with normal O-ring and crushed one (simulation)