Case History	Unstable Vibration of Rotor Containing Liquid Inside	Rotating machinery
Self-excited Vibration		

Object Machine

Centrifuge

Observed Phenomena

In a certain operation speed range, the amplitude of vibration showed a sudden increase. Unlike resonance phenomena, the vibration did not cease even when changing the rotational speed to some extent.
It was reported that the frequency fell under the following cases:

(1) A case where vibration occurred at the rotor natural frequency independent of the rotational speed
(2) A case where the frequency increased for increasing rotational speed, although not in synchronism with the rotational speed.

Cause Presumed

In consideration that vibration occurred under the presence even of a slight amount of fluid inside, the fluid seems to have generated unstable force. (Occurred even at depth t = 1 mm)

Analysis and Data Processing

A number of analyses and experiments have been performed (but, unstable vibration remains as an actual problem).
Fig.1 shows an example of unstable vibration. Upon occurrence of an unstable vibration, the frequency becomes equal to the natural frequency. Furthermore, the unstable region is relatively extensive. This instability occurs independently of the presence or absence of free surface of the fluid. A visualized example is given in Fig.2, which indicates the generation of flow inside the fluid.

By obtaining the sloshing vibration mode and its eigenvalue, a trial has been made to treat the unstable vibration as a coupled vibration with a flexible rotor (Fig.3).
Jorgensen has compared the theory and experiments, with the results shown in Fig.4.

Countermeasures and Results

The following countermeasures were conceived.

(1) To provide a partition plate on the inner wall of a rotor along the axial direction, so as to restrain the flow of fluid in the rotational direction.
(2) To provide a doughnut-shaped partition plate on the inner wall of a rotor in the direction perpendicular to the shaft, so as to restrain the flow in the axial direction.
(3) To constantly supply a slight amount of fluid required to be separated, so as to form a forced flow in the fluid.
(4) To stop the flow anyway by using a magnetic damper or the like.
(5) To miniaturize the slenderness ratio of a rotor.

★ Although there are a large number of research examples on this type of vibration problems, analytical prediction of self-excited vibrations produced in actual machines is yet to be attained. Thus, in designing actual machines, it is considered necessary to investigate the actual situations of similar machines and to prepare stability determination charts.

Lesson Learned

Once occurred, unstable vibration will not come to cease easily, thus requiring sufficient examination at the design stage.

References

Saito, S., Someya, T., Kobayashi, M.: *Investigation into the Vibration of a Rotating Hollow Shaft Partially Filled with Liquid- 4th Report Experiments*, Trans. JSME, Vol.48, No.427 (1982) p.321 (in Japanese)
Kaneko, S., Hayama, S.: *Self-excited Oscillation of a Hollow Rotating Shaft Partially Filled with a Liquid -1st Report, Instability Based on the Fluid Force Obtained from Boundary Layer Theory*, Bull. JSME, Vol.28, No.246 (1985) pp.2994-3001
Mroszczyk, J.W.: PhD Thesis
Colding-Jorgensen, J.: *Rotor whirl measurements on a long rotating cylinder partially filled with liquid*, ASME, Rotating Machinery and Vehicle Dynamics, DE-Vol.35 (1991) p.127

Keyword

Centrifuge, unstable vibration

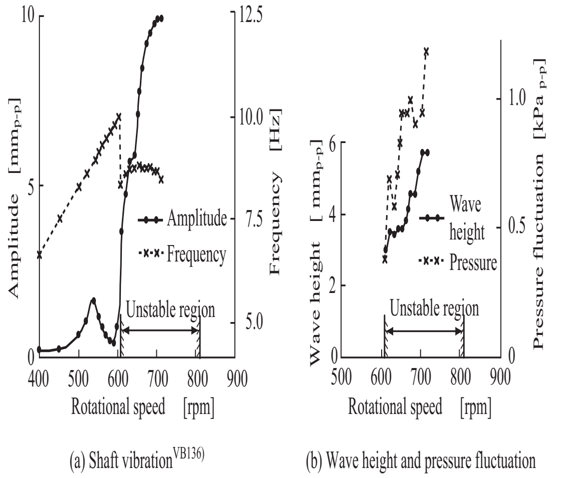


Fig. 8·26 Self-excited vibration occurring in fluid contained hollow shaft

Fig.1 Example of unstable vibration
(Saito, Someya, Kobayashi)

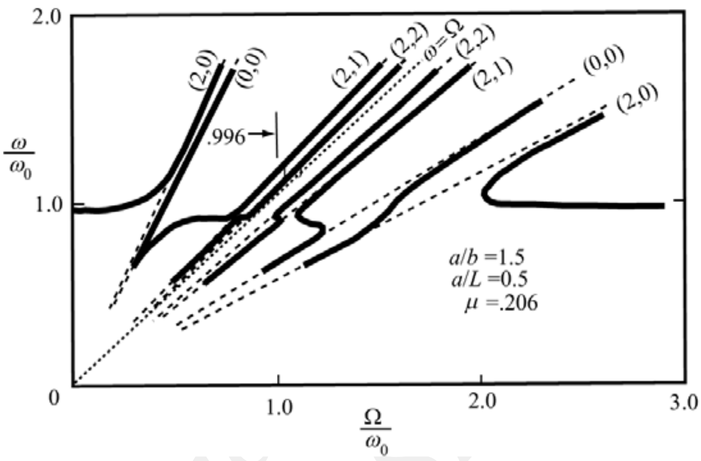


Fig.3 Campbell Diagram (Mroszczyk)

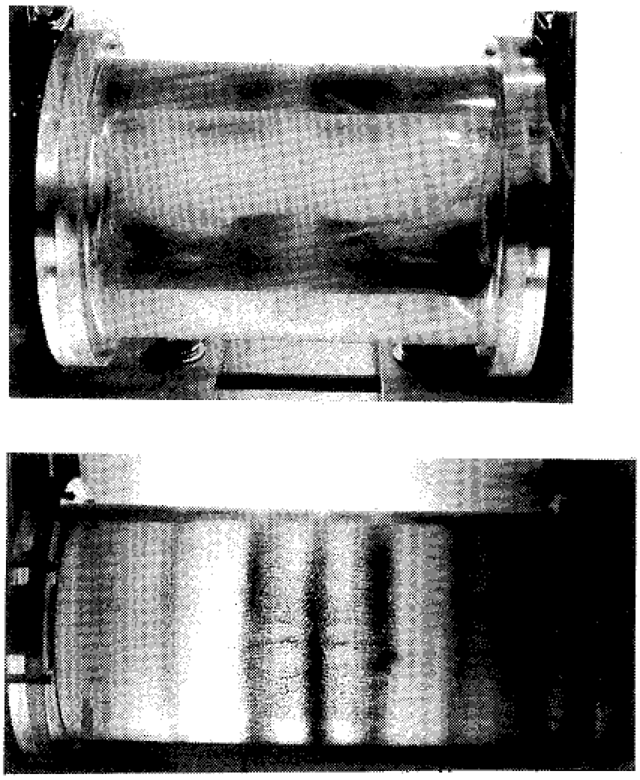


Fig.2 Visualized photograph during instability
(Kaneko, Hayama)

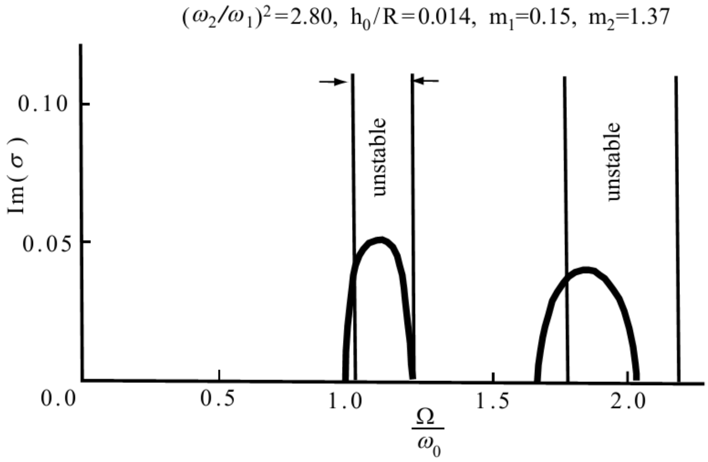
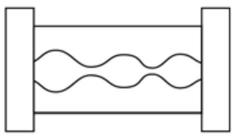


Fig.4 Unstable region (Colding-Jorgensen)



Vibration mode
(liquid)