Case History / Self-excited Vibration	Stabilization of Liquid Containing Rotor by Active Magnetic Bearing	Active control

Object Machine

Centrifuge for hospital/laboratory-use featuring ultra-high-speed and continuous separation

Observed Phenomena

Figure 1 shows the structure of an ultra-high-speed centrifuge. In the conventional structural design, damping is ensured by oil film bearings using squeeze film on the journal bearings. In Fig.2 are shown the rotational speed and frequency with a mark "☆" of unstable vibration phenomena that occurred on the conventional ultra-high-speed centrifuge. In addition, Fig.3 shows the construction of an electromagnetic damper type ultracentrifuge, and Fig.4 indicates the natural frequency map of this electromagnetic damper type ultra-high-speed centrifuge. The rotational speed and frequency at which unstable vibrations occurred are marked with "★".

Cause Presumed

It was estimated that since liquid was sealed in the rotating drum rotor and it formed layers in the drum due to the difference in specific gravity, the layer boundary surface had almost the same effect as the free surface, thus generating an unstable force.

Analysis and Data Processing

Figure 5 shows a calculation model where an electromagnetic damper type centrifuge is placed on a station of the shafting, while Figure 6 provides vibration modes of this rotor system. Figure 4 indicates changes in the natural frequency against the rotational speed. The natural frequency of the 2nd order backward mode decreases down to about 10 Hz before reaching the rated rotational speed 4200rpm, while the forward mode reaches up to 100 Hz, since these change is due to gyroscopic effect. As is noted in Fig.2, the onset frequency to generate self-excited vibration differs depending on each rotational speed, showing a rising to the right tendency from about 43 Hz to 90 Hz. In addition, the self-excited vibration frequency as indicated in Fig.4 goes up from 60 Hz to 100 Hz with a rising to the right, which means that it is an unstable forward vibration.

Countermeasures and Results

An electromagnetic damper was mounted on the plain bearing, located at the top, for damper, and a cross control circuit was employed to the electromagnetic damper against the self-excited vibration. The purpose of this arrangement was for the oscillator to generate the same frequencies as the self-excited vibration, which were introduced to the tuning filter, and then from among the x direction vibrations and y direction vibrations, only unstable vibration components of the self-excited frequency were extracted. The x components thus extracted were crossed to y components, while y components to x components for the control, thereby providing a significant damping effect on the self-excited vibration frequency (Figs.7, 8 and 9).

As the forward natural frequency of the self-excited vibration varied with the rotational speed, the tuning frequency was changed for every rotation so as to follow it, and thus the self-excited vibration was successfully stabilized (Figs.10 and 11).

Lesson Learned

A rotor containing liquid generates a forward self-excited vibration. An electric damper together with a cross control circuit is effective for stabilizing the rotor system subjected to whirl motion including self-excited vibration.

References

Matsushita, et al. *Transactions of the JSME* 53-496 (1987): 2453

Keyword

Unstable vibration, electromagnetic damper, self-excited vibration, control, liquid containing rotor, instability

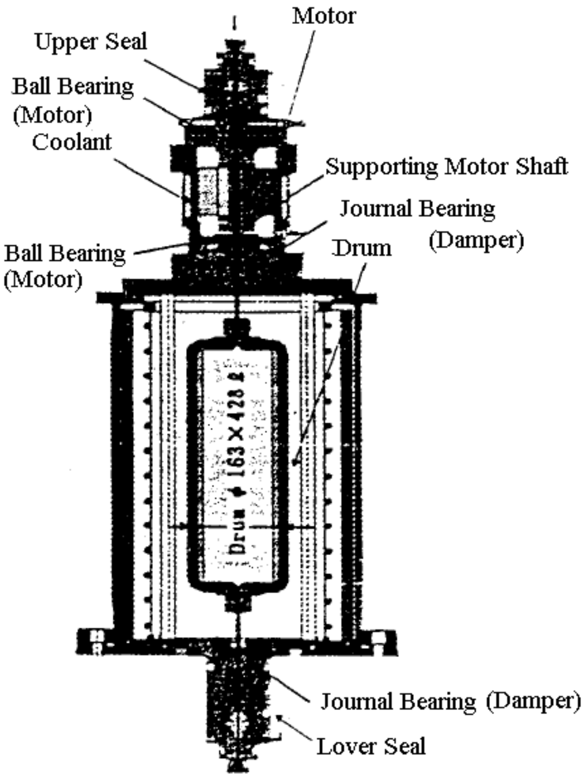
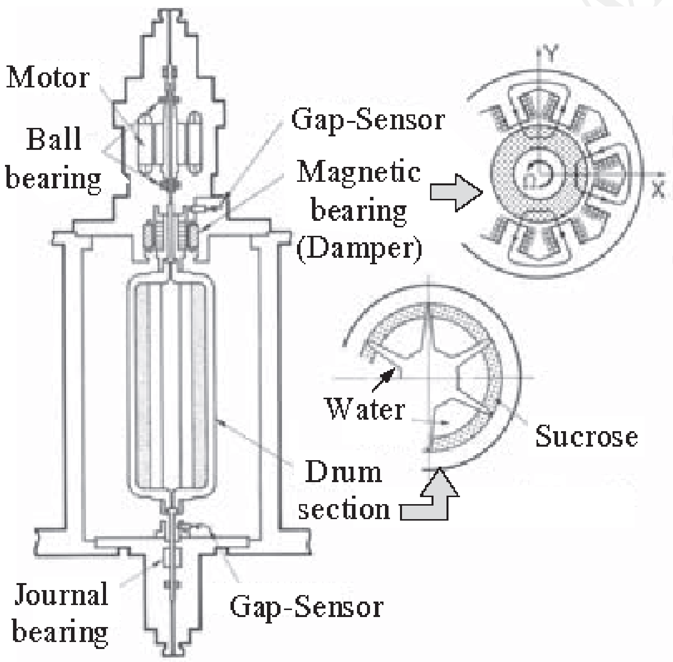


Fig.1: Conventional ultracentrifuge



(a) Centrifuge (AMB type)

Fig.3: Electromagnetic type ultracentrifuge

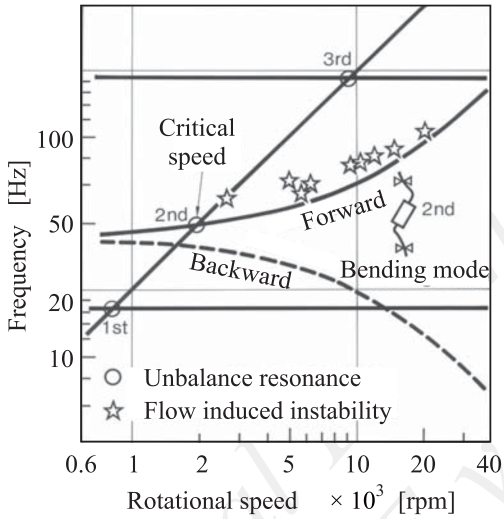


Fig.2: Unstable vibration phenomenon
(conventional type)

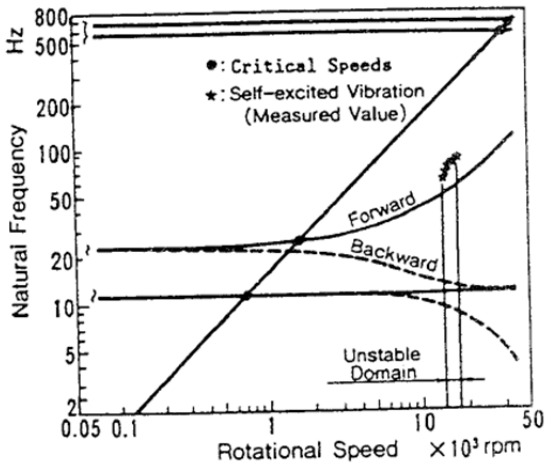


Fig.4: Natural frequency map

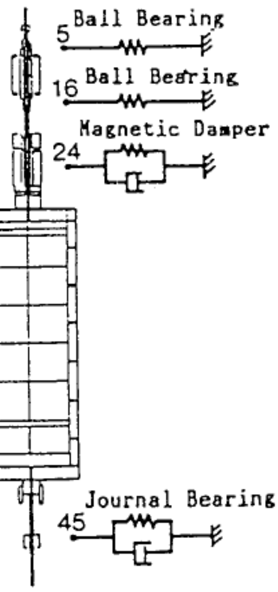
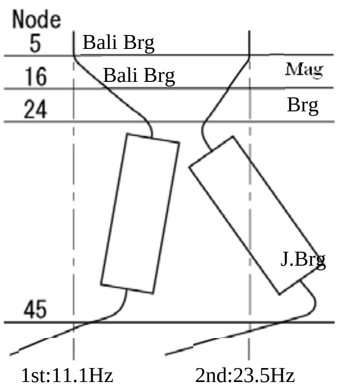
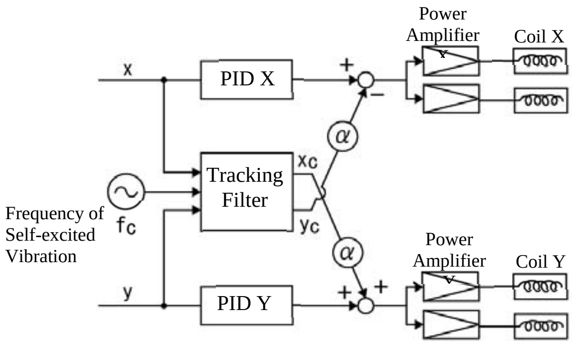


Fig.5: Calculation model





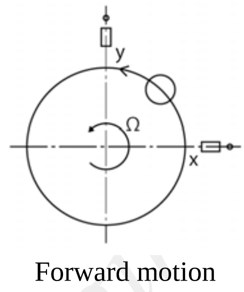


Fig.8: Whirl of rotor vibration and geometrical differentiation

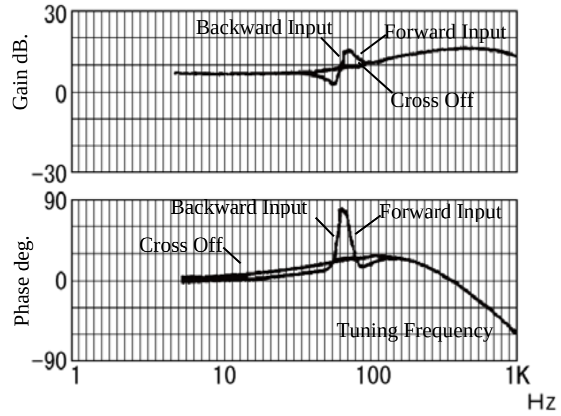


Fig.9: Bode diagram of PID control circuit with cross circuit

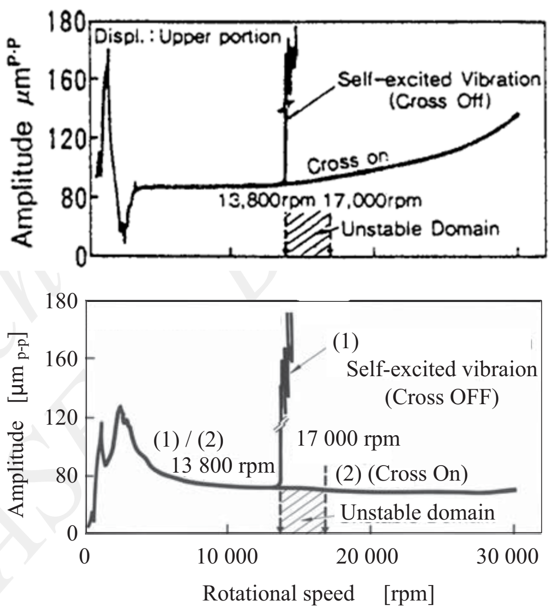


Fig.10: Vibration response curves (two liquid mixtures)

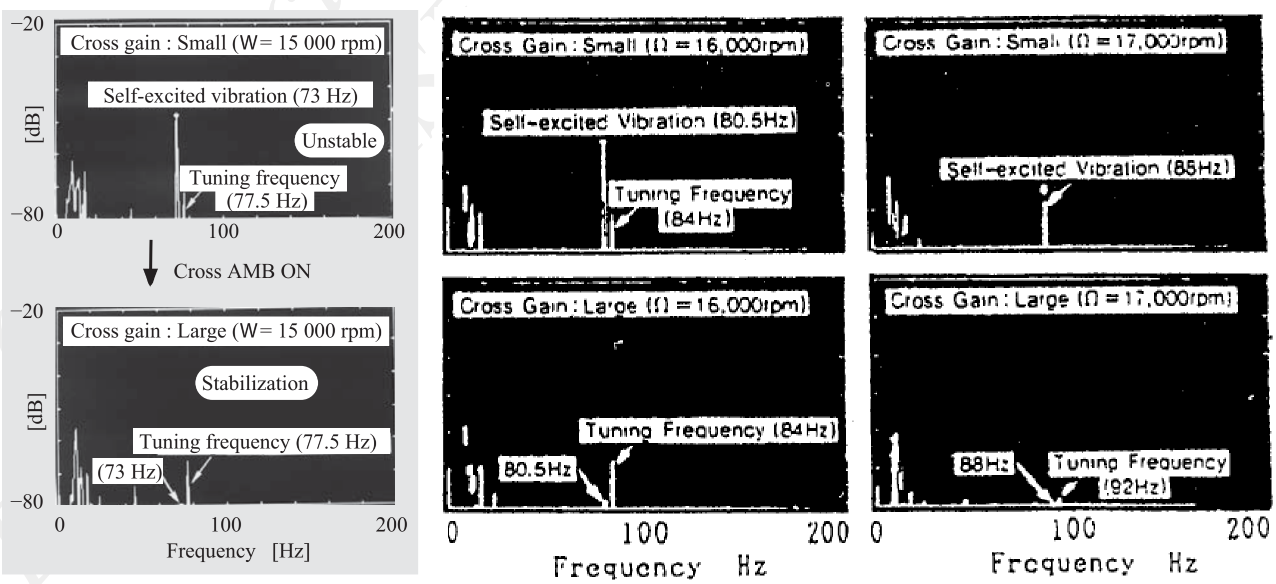


Fig.11: Generation and stabilization of self-excited vibration