Case History	Unstable Vibration of Vertical Pump	Rotating machinery (pump & water turbine)
Self-excited Vibration		

Object Machine

Vertical pump motor

Observed Phenomena

The entire rotor of the vertical pump as shown in Fig.1 is immersed in working liquid, whose bearings are lubricated by this liquid. When four lobe bearings were used for the journal bearings in a trial model machine of the pump as shown in Fig.2 (a), unstable vibration is considered to be occurred.

Cause Presumed

Since the environment where the working liquid is used has a pressure higher than that of lubrication film to be generated on the bearings, such bearings are so-called anti-cavitation bearings. From the structural characteristic of the fluid path, on the other hand, the radial force acting on the pump impellers is not so significant, and thus the coupled terms (Kxy, Kyx) of lubrication film reaction force to be produced at the bearings would be large compared to the primary term (Kxx, Kyy), resulting in generation of unstable vibration.

Analysis and Data Processing

The vibration thus generated has a predominant component of 1/2 times the number of rotations, which indicates that this vibration is evidently unstable one. Thus, through an analysis of the phenomenon by obtaining each bearing portion of hydrodynamic force acting on the impellers, a Reynolds equation considering turbulent flow was numerically solved to obtain the spring constant and the damping constant of each bearing. Using these constants, complex eigenvalues of the rigid mode of the shaft system shown in Fig.1 were calculated. In addition, for the purpose of comparison, the stability of combinations of each type of bearing in Fig.3 (cylindrical bearing, four lobe bearing, three lobe offset journal bearing (Fig.2 (b)) was verified.

Countermeasures and Results

Maximum values of the real parts (Re(λ)) of the complex eigenvalues for each combination (Fig.3) were plotted in Fig.4 for the dimensionless force "F" acting on the impellers. Fig.4 demonstrates the combinations (d), (e), (f), and (g) have a higher degree of stability, each of which consists of the same type of three lobe offset journal bearings. As shown in Fig.5, the application of these three lobe offset journal bearings to an actual vertical pump allowed more stable operation compared to when using four lobe bearings.

Lesson Learned

Vertical rotating machines using plain bearings have less radial load, thus is liable to cause unstable vibration, which is more predominant in case of anti-cavitation bearings. Selection of a proper bearing (shape) requires adequate consideration.

References

(1) Kazao, Y; Kumagai, M; Ohtomi, K; and Uno, S. *Proceedings of the 62nd Annual Meeting of JSME* (1985): 183

(2) Ohtomi, K; and Kazao, Y. *Lubrication* 32.4 (1987): 225

Keyword

Unstable vibration, whirl, anti-cavitation bearing, three lobe offset journal bearing, four lobe bearing

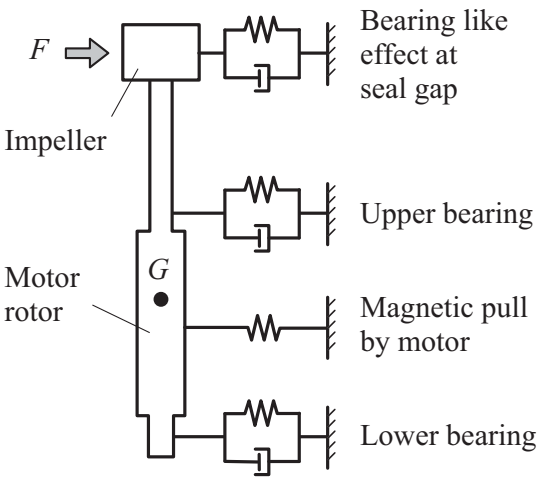

Fig.1: Schematic view of vertical pump motor
* Replacement of the top and bottom bearings was also effective.

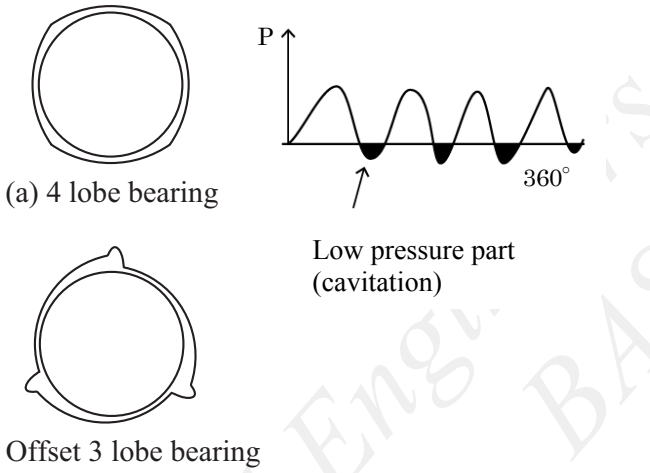

Fig.2: Shape of bearing

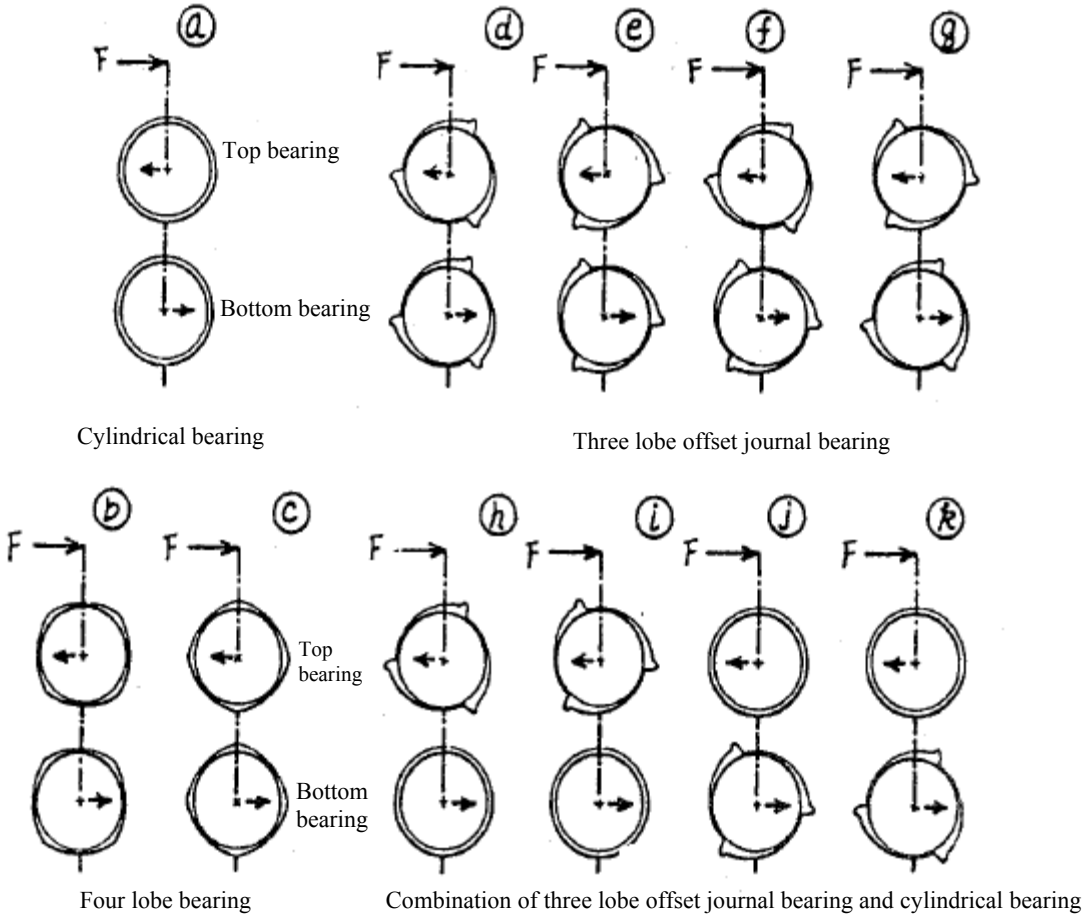

Fig.3: Combination of each shape of bearing

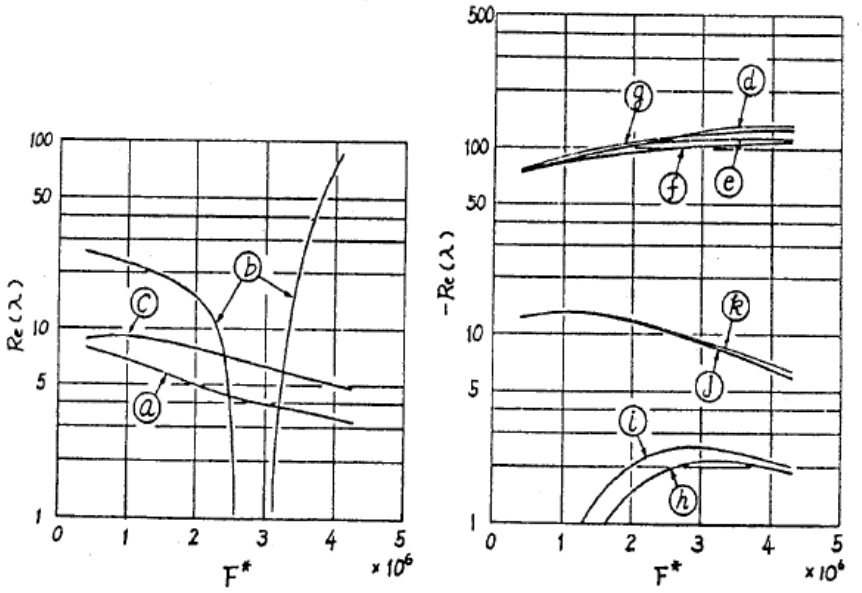

Fig.4: Maximum values of real parts of complex eigenvalues

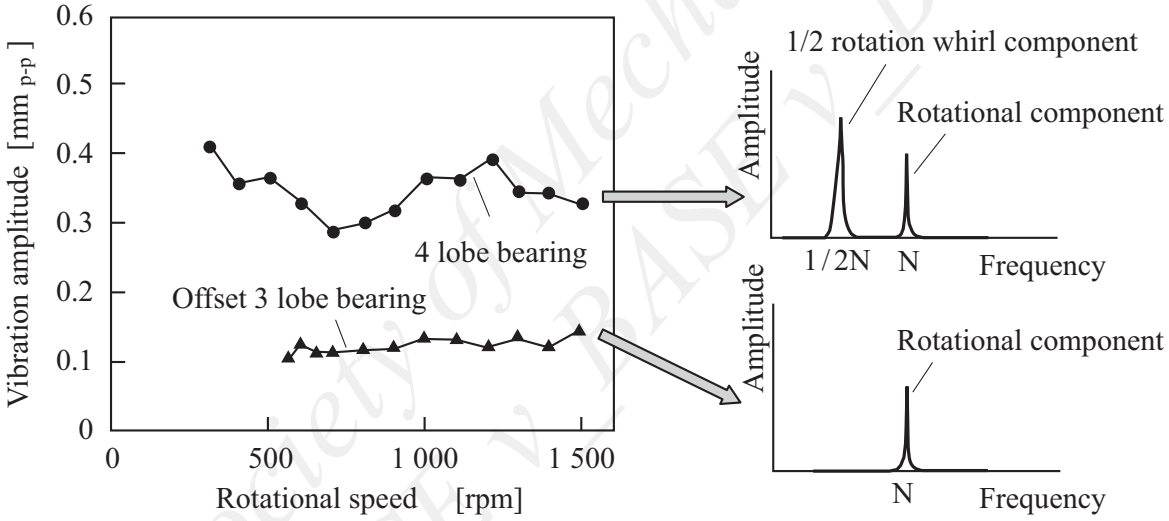

Fig.5: Measured results of rotor vibration values