

Case History	Self-Excited Shaft Vibration in Boiler Feed Pump	Rotating machinery (pump & water turbine)
Self-excited Vibration		

Object Machine	Boiler feed pump (multi-stage turbine pump)								
	(1) General construction	Fig.1	Table 1: General specification <table><tr><td>Rotational speed</td><td>Water supply</td><td>Discharge pressure</td></tr><tr><td>95 l/s</td><td>950 m<sup>3</sup>/h</td><td>30 MPa</td></tr></table>	Rotational speed	Water supply	Discharge pressure	95 l/s	950 m <sup>3</sup> /h	30 MPa
Rotational speed	Water supply	Discharge pressure							
95 l/s	950 m <sup>3</sup> /h	30 MPa							
	(2) Specification	Table 1							
	(3) Shape of initial balance bush	Fig.2, type C							
Observed Phenomena	The anti-drive side (anti-CP side) vibration level suddenly increased at a high pressure multi-stage pump for feeding water to a boiler in the thermal power station. Thus, response curves for rotor vibration were measured, and an analysis of vibration frequencies was made. The results are indicated in Fig.3. The frequency analysis result corresponds to a case of 4,500 rpm.								
Cause Presumed	Considering the fact that the anti-CP side rotor vibration amplitude suddenly increased at around 4,500 rpm and any increase in rotational speed resulted in no decrease in vibration amplitude as shown by the vibration response curves in Fig.3, that the vibration frequency remained nearly constant irrespective of the rotational speed, and that the direction of whirl matched the direction of rotation, the following causes were estimated. (1) Oil whip due to bearing oil film characteristics (2) Self-excited vibration due to defective gear coupling (3) Self-excited vibration caused by hydrodynamic force at the annular seal								
Analysis and Data Processing	Thus, the following investigations were conducted. (1) Investigation on bearings Check of spherical seat of bearing.....contact normal Change in bearing lubricant temperature & pressure...no change in vibration value Increase in bearing surface pressure.....almost no change in vibration amplitude (grooving on bottom metal) (2) Investigation on coupling Check of tooth surface of gear coupling.....contact normal Check of external alignment.....within tolerance (3) Investigation on annular seal Only probable cause when eliminating the impossible?								
Countermeasures and Results	(1) Temporary countermeasures The gap on the balance piston (initially Type C) was enlarged to 1.5 times, and the parameters changed to those of Type B (so as to decrease the hydrodynamic force of the seal: refer to Fig.4), while the increase in leakage was ignored. Consequence: The self-excited vibration disappeared, with only N vibration component left (refer to Fig.5). (2) Permanent countermeasures The shape of bush on the annular seal (balance piston) was changed to that of Type A (so as to stabilize the hydraulic force and reduce the leakage level: refer to Fig.4). Consequence: After taking this countermeasure, no self-excited vibration of this kind has been observed. (3) Remarks Stability is enhanced by changing the internal alignment to shift the bearing pedestal upward. Bearing stabilization contributes to some extent (★ "considerably") to the stability. (Some cases demonstrate that stabilization cannot be attained even by changing to a tilting pad bearing).								

## Lesson Learned

Annular seals are also a good type of bearing!  
Pay attention to the groove shape of annular seals having a large L/D ratio.

## References

Takagi, et al. *Transactions of the JSME* 51(466), C (1985-6): 1235

## Keyword

Self-excited vibration, boiler feed pump, annular seal

★ Tilting pad bearings have a small damping force, although not generating an unstable force.

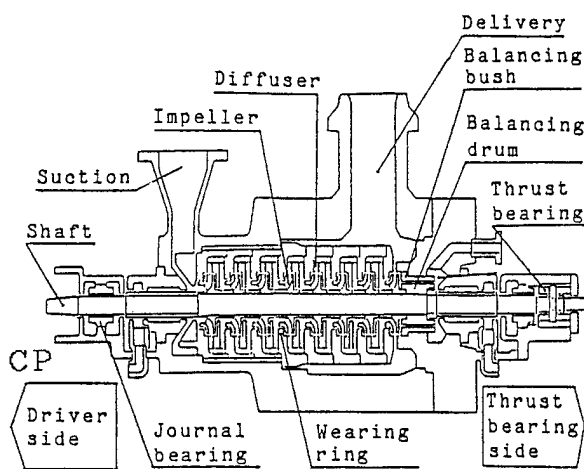


Fig.1: Schematic drawing of prototype pump

C : Radial clearance  
D : Diameter  
L : Length  
u : Circumferential velocity  
 $\rho$  : Density  
 $\mu$  : Viscosity  
N : Rotational speed  
 $R_a$  : Axial Reynolds number  
 $R_r$  : Rotational Reynolds number

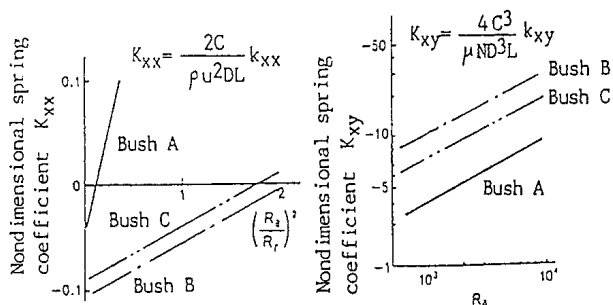


Fig 4: Spring and damping in annular seals

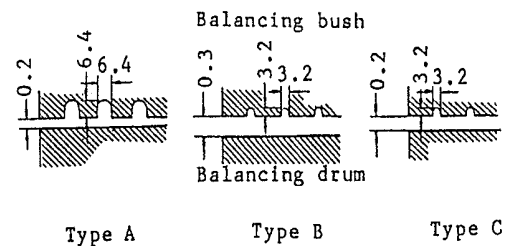


Fig. 2: Configuration of balancing device

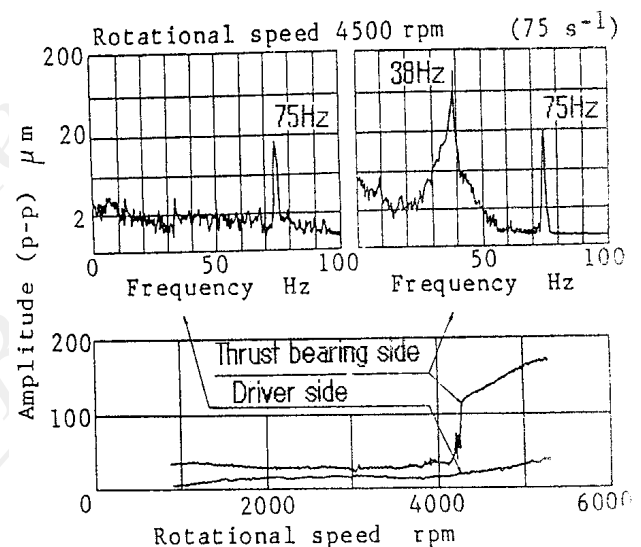


Fig. 3: Measure response and FFT (Before modification)

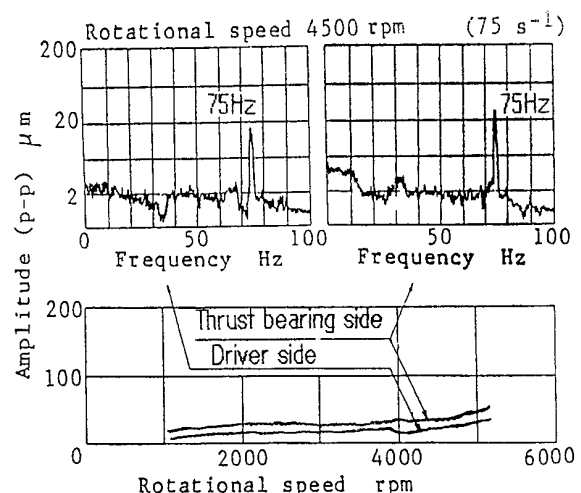


Fig. 5: Measured response and FFT (After modification)