Case History / Self-excited Vibration	Self-Excited Vibration in Multi-Stage Turbine Pump	Rotating machinery (pump & water turbine)

Object Machine

Multi-stage turbine pump for boiler feed pump (See Fig.1 for its general arrangement.)
Rotational speed of pump = 5,800 (rpm), rated pump head = 13.6 (MPa), rated discharge rate = 5.44 (m^3/min)

Observed Phenomena

When the discharge rate of the boiler feed pump reached about 50% of the rated flow rate, nonsynchronous vibration of 72 Hz (0.75 x number of rotations) as shown in Fig.2 suddenly occurred together with abnormal noise. As indicated in Fig.3, the relationship between this nonsynchronous vibration and the pump discharge rate did not apply for mini flow, but once nonsynchronous vibration occurred, it did not stop even by increasing the discharge rate.

Cause Presumed

It was estimated that this vibration was self-excited vibration because the vibration exhibits a sudden change according to the discharge rate even at the constant speed of the pump. In addition, considering that the impeller wear ring was not a parallel annular seal, but a group seal, the seal damping force was believed to be insufficient.

Analysis and Data Processing

Based on the above estimated causes, the following experiment and theoretical analysis were conducted.

(1) Experimental verification: In order to verify how the impeller wear ring seal contributed to the stability of a rotating body, the rotating body was shifted by 2 mm in the axial direction as shown in Fig.4 and the seal differential pressure was intentionally changed. As a result, the discharge rate at which nonsynchronous vibration developed was shifted to the large flow rate side, as indicated in Fig.3.

(2) Theoretical analysis: In order to evaluate the stability of a rotating body, an eigenvalue analysis was conducted to obtain a logarithmic decrement δ. As shown in Fig.5, the result revealed that the third mode turned out to be unstable.

Countermeasures and Results

Effective countermeasures to stabilize the pump were examined.

(a) A case where the bearing was changed from a circular cylindrical bearing to a three lobe journal bearing having higher stability.

(b) A case where the shape of a wear ring was changed from a group seal to a parallel annular seal to enhance the shaft stiffness.

The results of these analyses are indicated in Fig.6, which suggests that the change of a seal is more effective than that of a bearing. In fact, changing the seal eliminated the nonsynchronous vibration, thus solving the pump problem.

Lesson Learned

(1) The influence of a seal on the stability of a high speed rotating multi-stage turbine pump is so significant that the design shall be such as to fully utilize the hydraulic force of a seal.

(2) Enhancement of the accuracy of vibration analysis requires the boundary condition of a seal to be accurately obtained. It is thus necessary to consider the flow path made by an impeller and a casing as shown in Fig.4.

References

(1) Kanemori; Iwatsubo. *Transactions of the JSME* 57(543), C (1991-11): 3451

(2) Kurokawa; Toyokura. *Transactions of the JSME* 41(346), B (1975): 1753

Keyword

Self-excited vibration, boiler feed pump

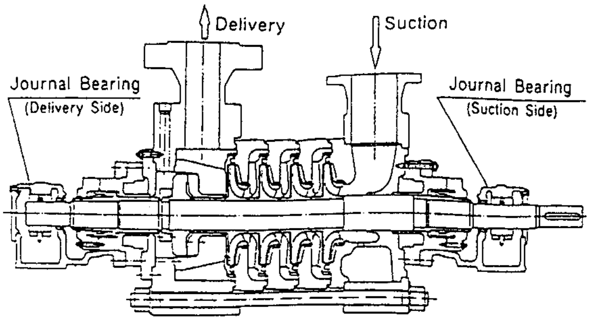
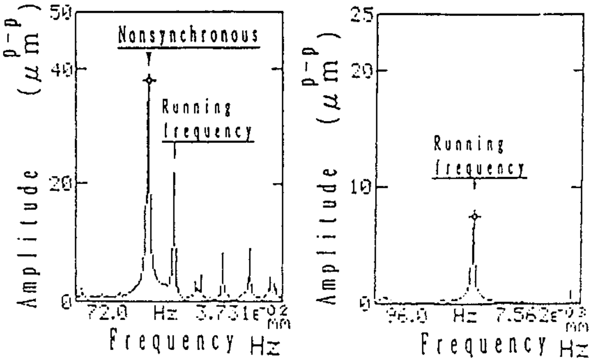


Fig.1: General arrangement of pump



(a) Self-excited vibration (b) After taking the countermeasures

Fig.2: Frequency analysis of vibration

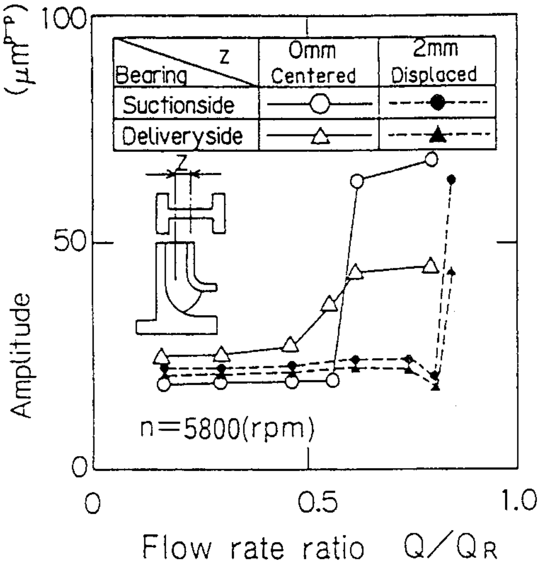


Fig.3: Relationship between vibration and pump discharge rate

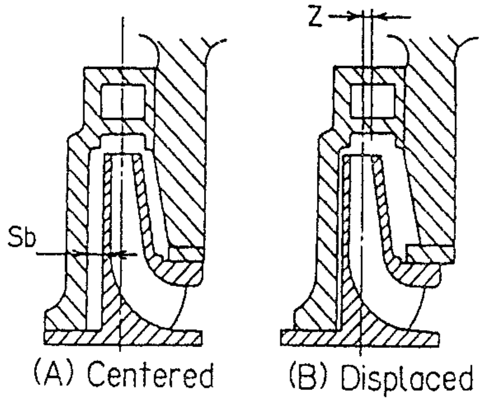


Fig.4: Position of impeller and diffuser

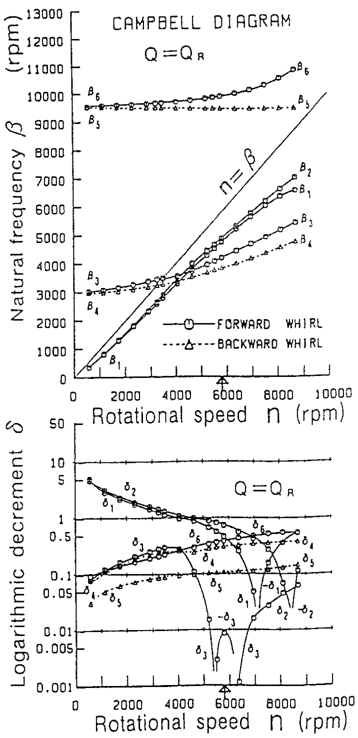


Fig.5: Campbell diagram

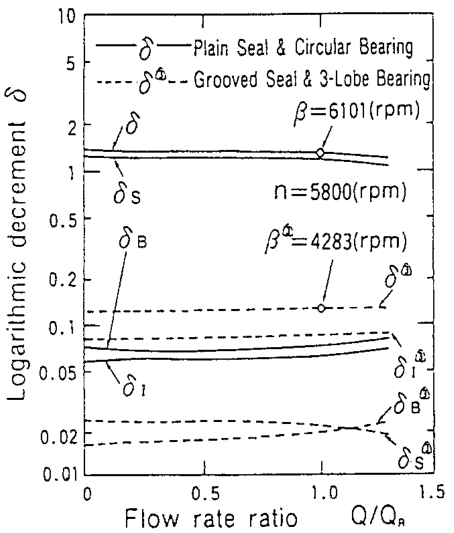


Fig. 6: Relationship between pump flow rate and logarithmic decrement