Vibration	Self-Excited Vibration of Vertical Pump	Rotating Machinery
Self-Excitation		

Object Machine

Drainage pump (vertical mixed flow pump : Fig.1 shows general construction)
Pump specification: rotating speed = 273min^{-1}, diameter = 1,500mm, motor power = 860PS

Observed Phenomena

Five minutes after starting of the pump during management operation 12 years after delivery of the pump, excessive vibrations of the pump occurred, together with spout of water from the shaft seal part. Fig.2 shows the construction of the shaft seal part (shaft seal part: non-water supply gland packing)
(Damaged situation of shaft seal part)

- ・Gland bolt : 3 bolts damaged of total 4 bolts
- ・Packing box : excessive wear of inner circumference (whole circumference worn)
- ・Gland sleeve : excessive wear of outer circumference (whole circumference worn)

Cause Estimation

Specific points of this phenomenon are as flows:
(1) As it occurred 12 years after delivery of the pump, secular change is a highly probable cause.
(2) Only the shaft seal part has a trace of an excessive whirling, while the impeller and underwater bearing have no abnormality damage.
(3) The excessive whirling occurred at the maintenance operational rotating speed (70%N : 191min^{-1}).
(4) The shaft seal part was dry-operated upon occurrence of the trouble.
Judging from the above specific points, friction whirling[1], a kind of self-excited vibration, was generated due to contact frictional resistance of rotor at the shaft seal part during the management operation. As shown in Fig.3, the (revolution) speed at which the shaft rotates within the packing box becomes higher than the rotating (rotation) speed of the shaft as Equation (a) indicates [2]. As a result, it was assumed that the whirling amplitude increases according to the natural frequency of the shaft, leading to damage of the shaft seal part.

Analysis and Data Processing

In order to grasp the vibration mode of the pump rotor including the reducer shaft and the intermediate shaft, an eigenvalue analysis of the pump rotor was conducted, with the result given in Fig.4. The result of the analysis proved that the primary natural frequency of the rotor was 382min^{-1}, which is 1.4 times the pump rotating speed of 273min^{-1}, while the vibration mode had the maximum amplitude at the shaft seal part. It was also made clear that the head was low at the management operational rotating speed (70%N : 191min^{-1}), and that the shaft seal part was dry-operated because of suction level.

Countermeasures and Results

As countermeasures against self-excited vibrations, the following were effectuated, and thereafter, excessive vibrations have not occurred at the shaft seal part.
(1) Prevention of contact with the rotor: increase in the gap at the packing box part (one side 1mm => 2mm)
(2) Prevention of dry operation of shaft seal part: change in the rotating speed during management operation (70%N => 80%N)
(3) Prevention of increase in sliding resistance: recommendation of periodic replacement of gland packing (once/year)

Lesson

Non-water supply gland packing may cause self-excited excessive vibrations of rotors due to friction force acting on the contact part, thus attention must be paid.

References

(1) “Vibrations & noises of rotating machinery, their causes and counter measures, analysis, investigation and diagnosis”, Management Development Center (P717)
(2) Fujii, “Role of resistance in vibrations of rotating shaft”, Transaction of the Japan Society of Mechanical Engineers, Vol.55, No.400 (1952.5)

Keywords

Friction whirl, self-excited vibration, frictional resonance, shaft seal part, vertical shaft pump

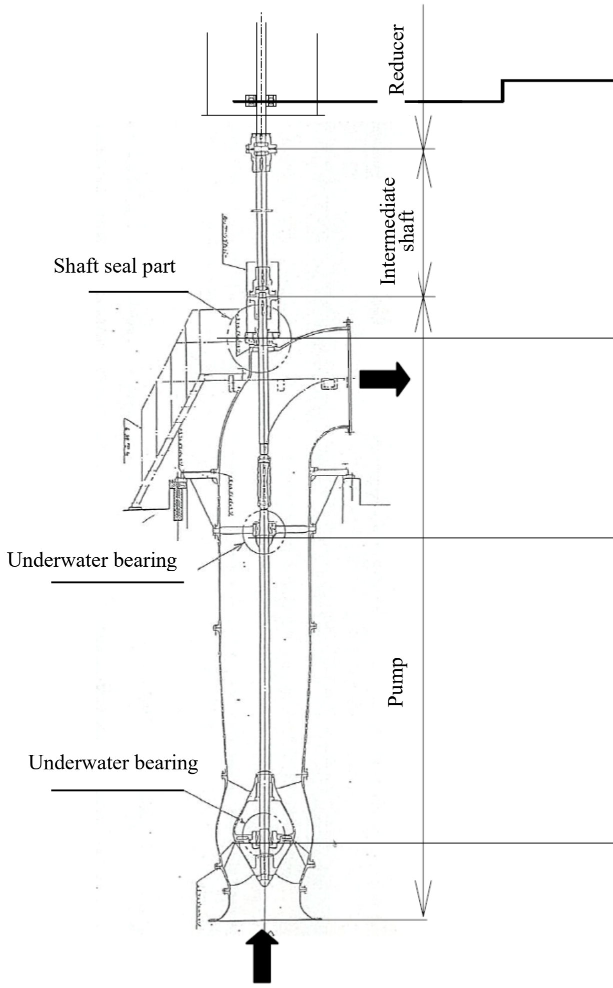
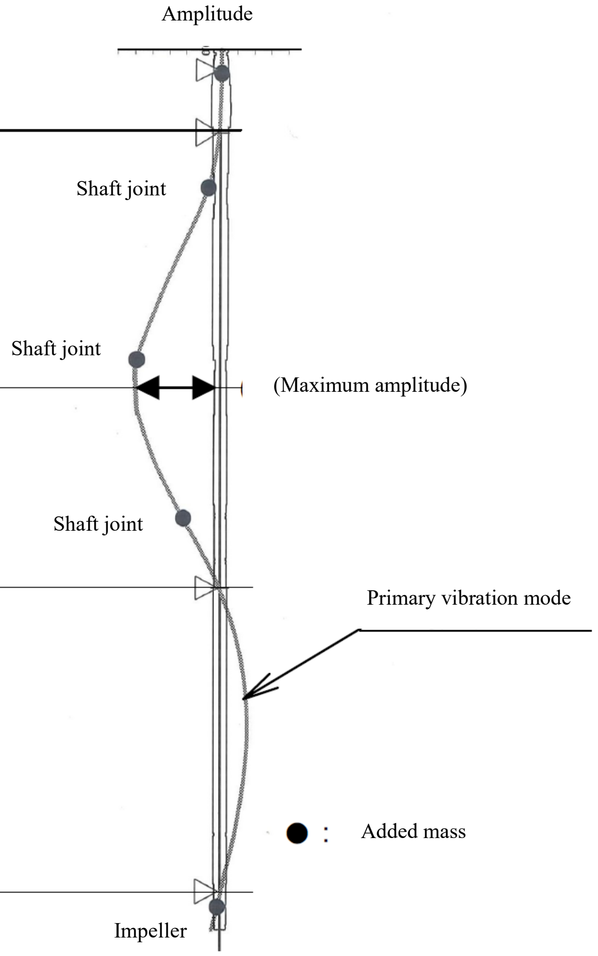


Fig.1 Structural drawing of drainage pump



Primary natural frequency (Nc): 382/min^{-1}
Pump rotating speed (N): 273/min^{-1}
Nc/N: 1.4

Fig.4 Result of rotor eigenvalue analysis

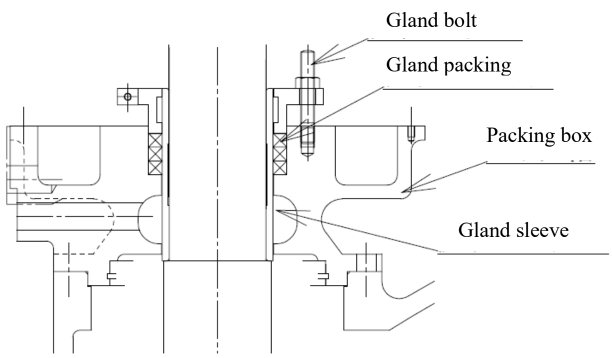


Fig.2 Structural drawing of shaft seal part

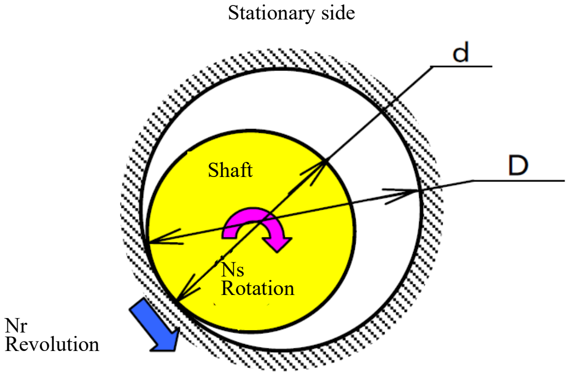


Fig.3 Relationship between rotation and revolution on friction whirling

Shaft whirling (revolution) speed (Nr) in case the shaft rotates in the packing box inside without slip is in the opposite direction to the shaft rotating (rotational) direction, and is given by the following equation[(2)]:

$Nr = Ns \cdot d / (D - d)$ …… (a)

$Nr > Ns$

(Ns: shaft rotating (rotation) speed, D: packing box inner diameter, d: gland sleeve outer diameter)