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

Object Machine

Multi (6)-stage centrifugal pump (Fig.1)

Observed Phenomena

After replacing the gland packing of a normally operating actual machine by a mechanical seal upon request by the customer, vibrations with a frequency of about 40 Hz (about 80% the shaft rotating speed) occurred whose amplitude increased over time (Fig.2).
* Generally speaking, ω_{whirl} = (50~90)%)･N (rotational speed)

Cause Presumed

The following four possible causes were considered.

(1) Decrease in critical speed because of the lack of gland packing
→Main frequency component ≠ (rotational speed) × n → Unlikely to be cause

(2) Friction whip
→Amplitude has flow dependence. → Unlikely to be cause

(3) Abnormal wear caused by increasing surface pressure of the wear ring parts because of the lack of gland packing
→Likely to be one of the causes.

(4) Hydraulic force of pump impeller
→Swirling flow may be a cause of self-excited vibration (in particular, a shroud portion)

Analysis and Data Processing

Based on the above assumption, the following vibration generation mechanism was considered.

(1) Since the gland packing that functioned as a bearing was replaced, the effective shaft support distance increased (1,680→2,238 mm).
(2) Because of (1) above, the shaft natural deflection increased (0.40→0.88 mm).
(3) Because of (2) above, wear developed to cause the wear ring to deflect to a large extent.
(4) As a result of (3) above, eccentricity between the diffuser and the impeller became excessive.
(5) Due to (4) above, hydraulic force due to swirling flow at the impeller shroud portion grew to cause abnormal vibration.

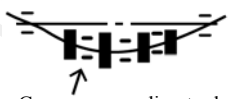
Countermeasures and Results

Since the replacement of the seal was a customer's request, it was impossible to employ gland packing again, so that the following two countermeasures were mainly examined.

(1) Concentric machining of the casing and the rotor considering shaft deflection
→Reduction of eccentricity between the diffuser and the impeller

(2) Mounting of swirl breaker (Fig.3)
→Reduction of swirling flow and resultant restriction of hydraulic force

The above countermeasures made it possible to suppress the vibration of the asynchronous component of rotational speed (Fig.4).



Lesson Learned

- Gland packing may function as a bearing.
- A swirl breaker may be effective for suppression of the hydraulic force caused by swirling flow.

Keyword

Self-excited vibration, swirling flow, multi-stage centrifugal pump, mechanical seal, gland packing

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Main L.O. Pump

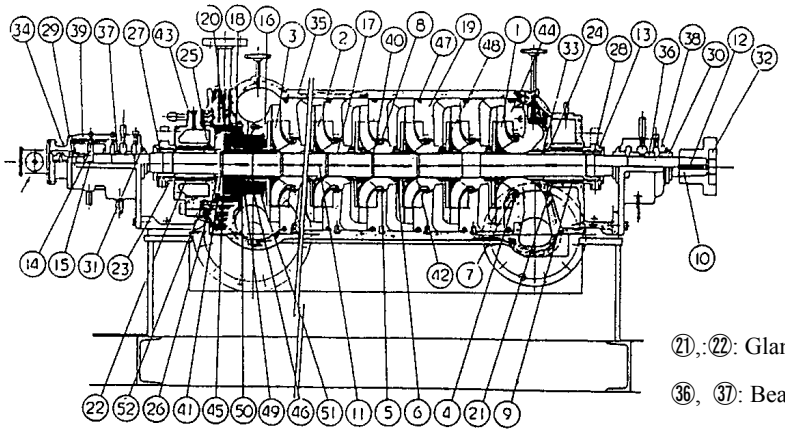
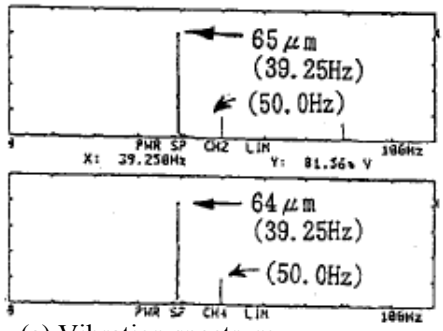
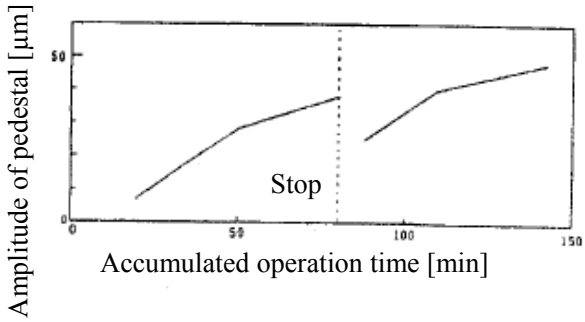


Fig.1: General arrangement of pump

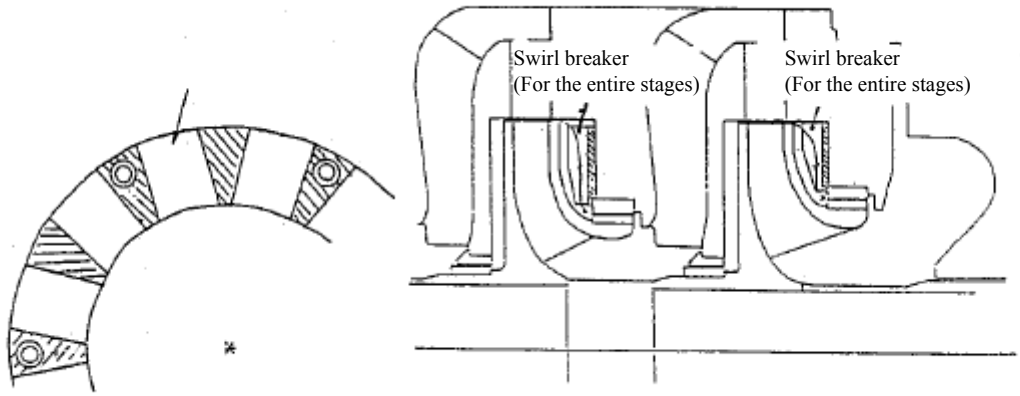


(a) Vibration spectrum
(Top: suction side, bottom: discharge side)



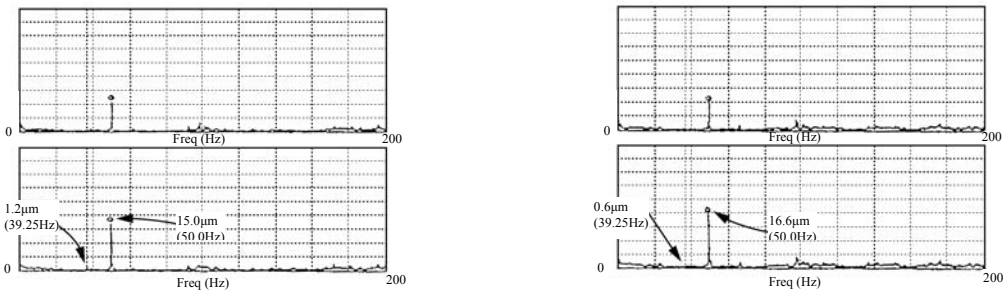
(b) Temporal change of amplitude

Fig.2: Vibration of pedestal at vibration repeatability test



*Found quite effective

Fig.3: Swirl breaker



(a) After 29 hours (b) After 195 hours

Fig.4: Vibration spectrum of pedestal after taking countermeasures
(Top: suction side, bottom: discharge side)