Vibration	Excessive Vibration due to Cavitation of Pit Barrel Type Vertical Mixed Flow Pump	Rotating Machinery
Forced Vibration		

Object Machine

Pit barrel type vertical mixed flow pump
(diameter 900mm, 590min^{-1}~137.2m^3/min~21.5m~670kW)

Observed Phenomena

At the time of start-up of a multi-stage flush type seawater desalination plant, the pit barrel type vertical mixed flow pump (refer to Fig.1) for the BBDP (Brine Blow Down Pump) delivered to this plant, on the motor top, excessive vibrations exceeding 20(mm/s)rms against the specified value of 4.5(mm/s)rms has been measured. As shown in Fig.2, vibrations suddenly increases when NPSHA went down to about 11m or less during the process of depressurization of the evaporator inside pressure from the atmospheric condition to a specified suction state (NPSHA = 8.9m).

Cause Estimation

It was judged from the following three conditions: the vibration value suddenly changes according to the suction condition; results of frequency analysis of vibrations in Fig.3 indicate that the major component of excessive vibrations is the natural frequency of the motor top; and the vibration value decreases to maximum 6(mm/s)rms, when air was injected from the suction piping at the time of maximum vibrations. It was assumed that the cause of excessive vibrations is that air bubbles has been generated due to cavitation excited the blade surfaces randomly with impulsive force occurring when they collapse.

Analysis and Data Processing

In order to verify the assumed cause, a model pump, 1/4 scale of the prototype (as shown in Fig.4), was fabricated to perform a model test. In this test, the current blades without countermeasures and new blades with modified tip shape for restricting the generation of cavitation were used, and bearing vibrations were determined by changing the pump performance, suction performance and suction condition. In addition, the condition of occurrence of cavitation on the blade surface was observed through a transparent acrylic window provided on the model pump bottom. Fig.5 compares vibration values of different impellers in the model pump before and after taking countermeasures. It is clear from this figure that vibration values of the new impeller were greatly reduced compared to the conventional one without modification. As for the condition of occurrence of cavitation (refer to Fig.6), it was visually confirmed that cloud-like large scale cavitation occurring at the specified NPSHA before taking countermeasures, while in case of the new impeller, only thin sheet cavitation occurring. From these results, it has become clear that the cause of excessive vibrations was cavitation.

Countermeasures and Results

As in Fig.2, the vibration value was reduced to maximum 2.3(mm/s)rms or less after replacing with the new impeller.

Lesson

Magnitude of cavitation generally tends to increase from NPSHi at the first point of generation of cavitation and to have a maximum value at NPSH that is larger than NPSH3 where the pump head decreases by 3%. Therefore, in case of pumps to be operated at lower NPSHA in this case, it is necessary to perform detailed verification also from the view point of vibration.

References

Guideline of the Turbomachinery Society of Japan, TSJG001: 2003 “Estimation and evaluation of cavitation damage of pumps”

Keywords

Flow-induced vibration, cavitation, pump

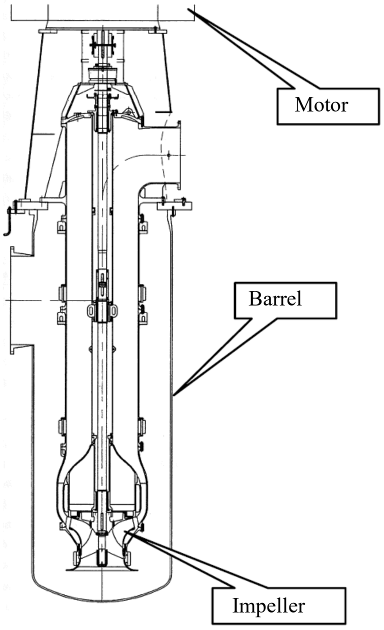


Fig.1 Example of construction of pit barrel type vertical mixed flow pump

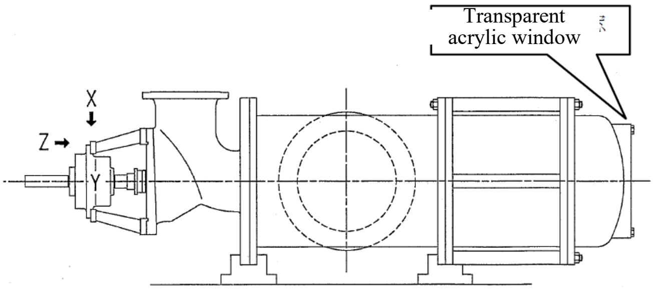


Fig.4 Vibration measurement positions of a model pump

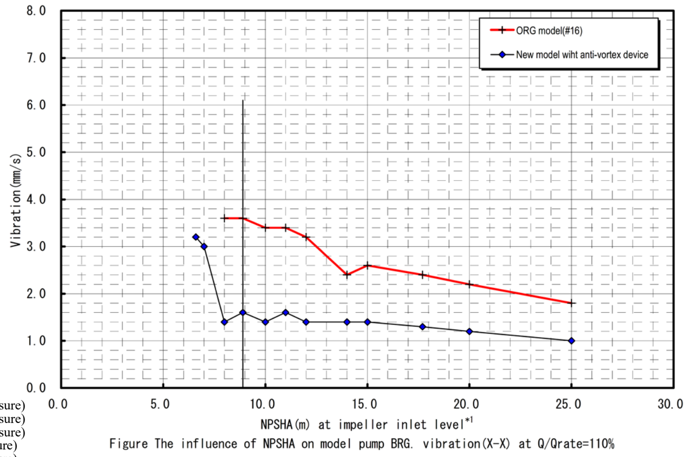


Fig.5 Comparison of vibration values of different impellers in the model pump before and after taking countermeasures (discharge direction, Q/Qrated=110%)

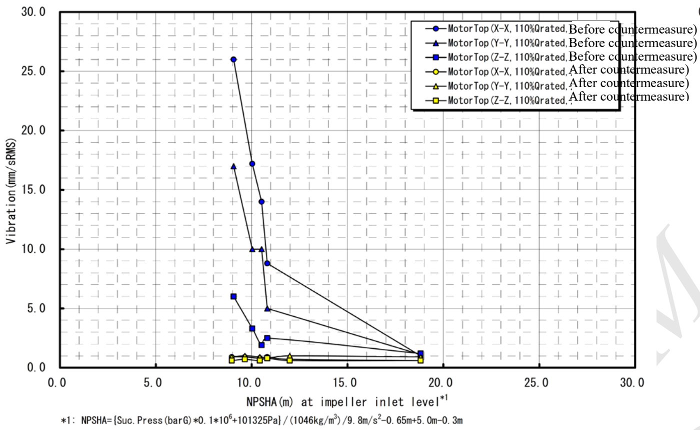


Fig.2 Relationship between vibration value on the motor top and suction condition in an actual machine (Discharge direction, Q/Qrated=110%)

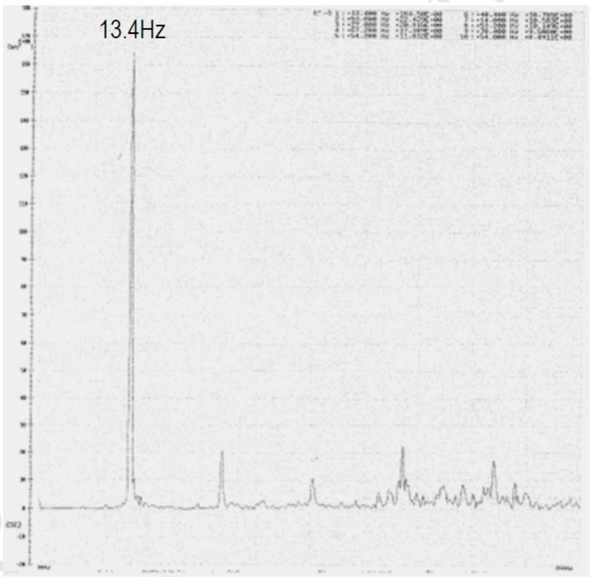
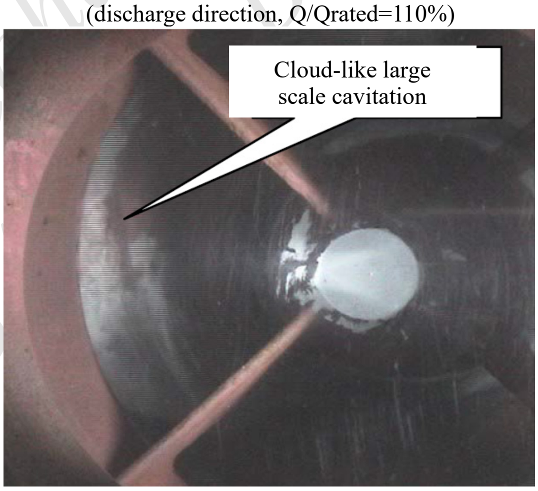


Fig.3 Result of frequency analysis of vibration on the motor top of an actual machine (discharge direction, Q/Qrated=110%)



(a) In case of impeller before taking countermeasures

(b) In case of impeller after taking countermeasures

Fig.6 Comparison of cavitation occurrence conditions before and after taking countermeasures