Vibration	Vibration and Noise due to Vortex in Pump Suction Sump	Rotating Machinery
Forced Vibration		

Object Machine

Vertical mixed flow pump; H = 4.4m Q = 60 m^3/min, n = 410 min^{-1}, L = 65kW, discharge diameter = 700mm

Observed Phenomena

At the time when the pump was delivered, vibrations were within the normal range. After that, the operation water level was changed lower as a countermeasure against concentrated heavy rain. Change in the suction sump water level caused incompatible strange sounds and vibrations during pump operation.

(1) At the time of drainage operation of the pump, strange sounds like "Goo" and vibrations occurred intermittently.

(2) The motor current exceeded the rated current to cause overloading, and at the time of overloading during operation, sounds like "Goo" were heard.

Cause Estimation

Since vortices inside of the water suction sump were suspicious, CFD analysis was conducted for the periphery of the suction bellmouth during pump operation, as shown in Fig.1. Free surface vortex and submerged vortex were formed from the water suction sump bottom and the water surface toward the pump suction port by lowering the operation water level. It was thus considered that when the impeller blades passing the vortex sucked from the suction sump, unbalanced fluid excitation force was generated, and vibrations and noised occurred due to vortex-based forced vibrations.

Analysis and Data Processing

(1) During the pump operation, pictures were taken near the suction bellmouth and its periphery, and two free surface vortices were identified. It was also observed that dusts on the water surface that passed through the dust collector screen were sucked inside the pump as if they were pulled into the vortex core (Fig.2).

(2) Comparative examination of countermeasures against vortex flow (Fig.3)

(Proposal A) Construction of civil structures for preventing the occurrence of vortices.

To construct a splitter wall on the backside wall to prevent submerged vortices and a curtain wall on the front side of pump to prevent the free surface vortices. There are many construction results of civil structures for preventing vortices. However, during the construction period, water in the suction sump shall be drained to make the tank empty, thus drainage operation of the pumping station will become impossible.

(Proposal B) To attach a vortex prevention device to the pump main body as shown in Fig.3.

1) As there is no need for the construction of a vortex flow prevention plate, installation of a large-scale temporary cut-off wall in the suction sump or water replacement work as well as sludge treatment, the construction cost will be reduced, and also civil engineering work in the water suction sump is not required, which is desirable from the safety point of view.

2) As there is no need either for splitter, framework or concrete placement for the construction of a vortex flow prevention plate, and for a subsequent period for curing, as well as for installation and removal of a large-scale temporary cut-off wall in the suction sump, the construction period would be substantially reduced. Thus, the countermeasure method (B) to attach a vortex prevention device to the pump main body was adopted.

Countermeasures and Results

(1) The shape of a vortex prevention device for the pump main body was obtained by means of CFD analysis. As a result, the free surface vortex and the submerged vortex were eliminated, and were restricted to a weak rotational flow that will not disturb the pump operation.

(2) The effect of the vortex prevention device was verified by using a model pump water suction sump test. Temporal transitions of the dynamic thrust force in the radial direction in case of the presence and absence of the vortex prevention device is shown in Fig.4, and FFT of the dynamic thrust force in the radial direction at different water levels is shown in Fig.5 (a), and a photograph of vortex and a trajectory of variations in the dynamic thrust force in the radial direction is shown in Fig.5 (b), respectively. In accordance with lowering of water level, 2n (n: rotational speed) and nZ components appearing in the dynamic thrust force in the radial direction will be growing. 2n component of the dynamic thrust force in the radial direction is generated by two free surface vortices generated due to the lowering water level and passing through these two vortices per one revolution of the impeller.

(3) Fig.6 shows the reduction effect of vibrations on the actual equipment obtained by the countermeasures against the vortices. The vortex prevention device caused the reduction in vibrations in the vertical direction, discharge direction and discharge right angle direction of each part of the pump, that were present before taking the countermeasures. During operation before taking the countermeasures, intermittent sounds like "Goo" were generated. There was a tendency for reduction of discharge pressure and flowrate, but now, no variations in the pump performance. Taking the countermeasures led to the elimination of the strange sound "Goo" and reduction of noises by about 6 to 7dB (A).

Lesson

Vortex causes a major problem for pumps. Thus measurement shall be made of pressure and flowrate fluctuation in addition to vibration data. The vortex prevention device restricts free surface vortex and submerged vortex, and also settles the problems of noise and vibration. Free surface vortex causes dusts on the suction sump water surface to be sucked into the pump, leading to motor overloading due to biting of dusts. Evaluation of countermeasures against vibration and noise shall be made not only from the viewpoint of their effects, but from the economic efficiency including their cost.

References

Kanemori, Pan, "Surface vortex prediction and prevention technique in pump intake sump", Turbomachinery Society of Japan, Vol.43, No.2, (2015), pp.90-98

Kanemori, Handa, "Behavior of dynamic radial thrust acting on a vertical mixed flow pump impeller", Transaction of the Japan Society of Mechanical Engineers, Vol.82, No.837 (2016), DOI:10.1299/transjsme.15-00580.

Keyword Flow-induced vibration, noise, dynamic thrust force in the radial direction, vortex, forced vibration, suction sump, pump, overload

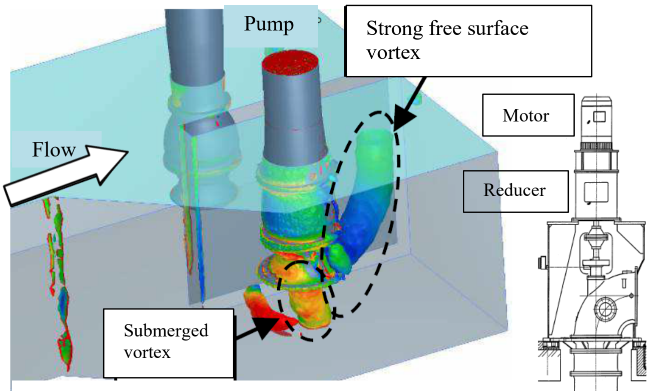


Fig.1 CFD_Q isosurface diagram
(free surface vortex and submerged vortex)

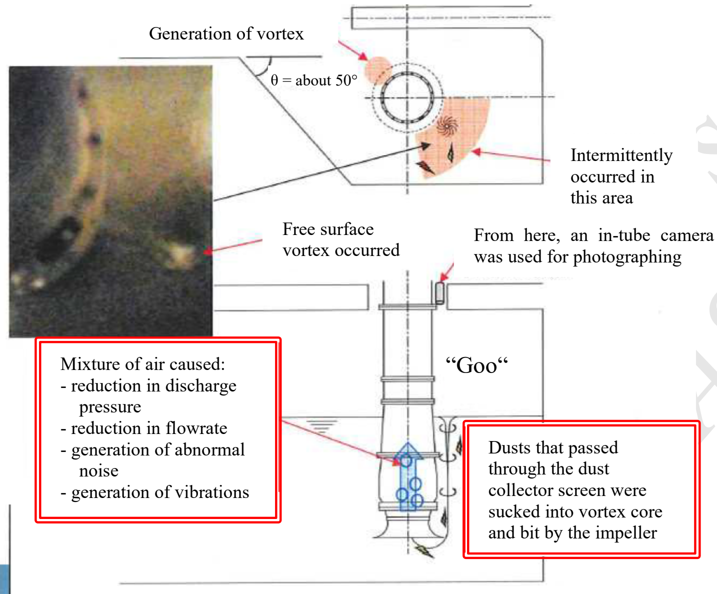
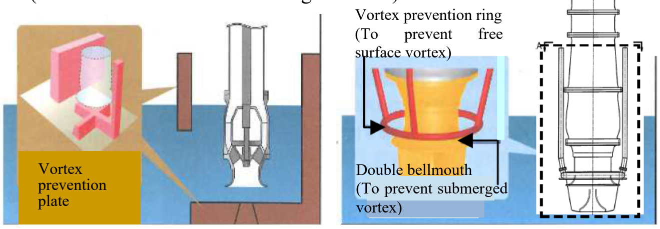
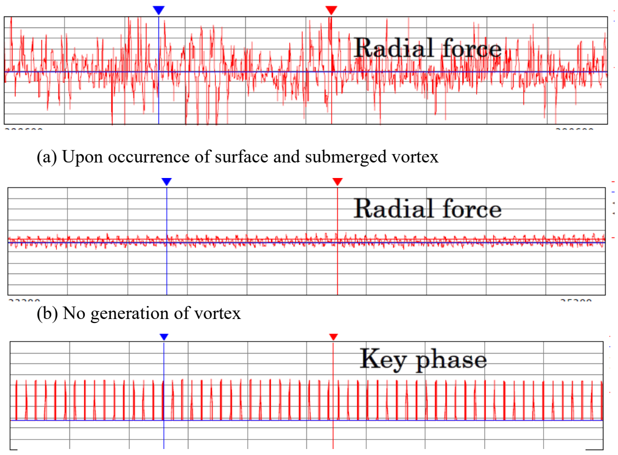


Fig.2 Observation of vortex in the vertical shaft type mixed flow pump water tank



(Proposal A) Construction of civil structures (Proposal B) Vortex prevention device attached to the pump main body

Fig.3 Comparative examination of vortex prevention measures



(a) Upon occurrence of surface and submerged vortex

(b) No generation of vortex

(c) Key-phaser

Fig.4 Relationship between vortex and dynamic thrust force in the radial direction

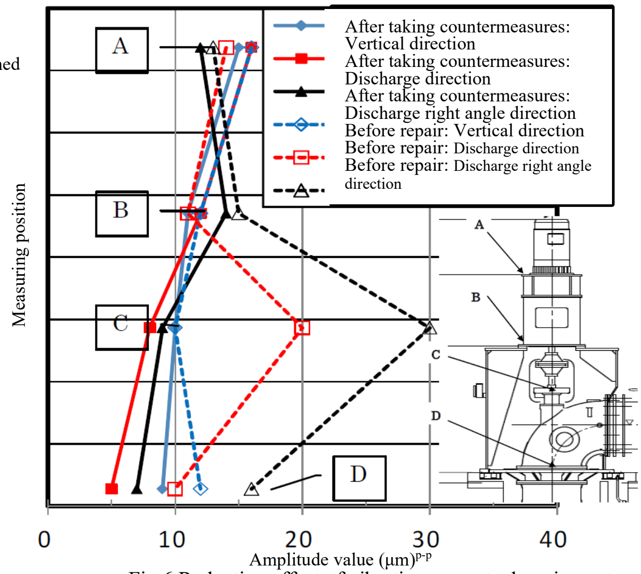
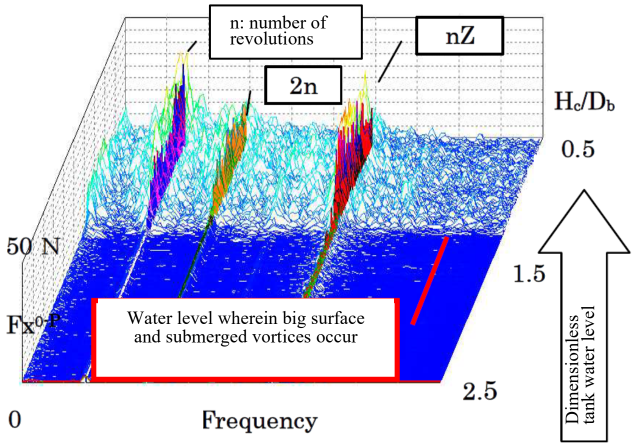
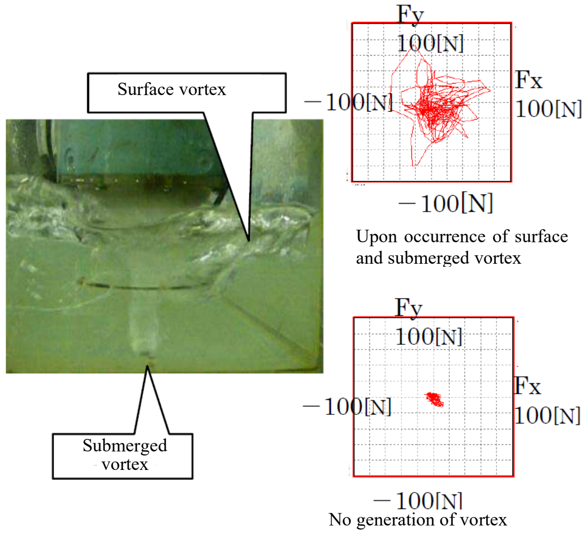


Fig.6 Reduction effect of vibrations on actual equipment by means of vortex countermeasures



(a) FFT of water level and dynamic thrust force in the radial direction (H_c= Suction sump water level, D_b=Bellmouth diameter)



(b) Photograph of vortex and trajectory of variations in the dynamic thrust force in the radial direction

Fig.5 Generation of vortex due to suction sump water level reduction (Froude number F_D=1.79, bell mouth flow speed V_b=2.17m/s)