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Recent Topics in Japanese Pump Industry

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1. Introduction

It is not easy to find a quite nevel design or a very innovative in the recent products of Japanese pump industries. While, most of pump manufacturers are now positively advancing into the field of engineering to totally deal with the system containing pumps. Using a modern expression, their recent works seem to aim at customer's satisfaction (CS). Then I decided to search some practically interesting topics among their works. I read over volumes of the Journal "Turbomachinery" issued in these five years from Japan Turbomachinery Association. I picked up some topics from their articles with respect to the application and operation of pumps from practical point of view. I hope that the topics here introduced would be interesing to you.

2. Stand-by type pumps

In the recent years, abnormal meteorological phenomena have been observed throughout the world. The most careful of all is a particular localized heavy rainfall. We have heard of the disasters brought by this type of rainfall. In a modern urbanized area where almost of all the earth surface is completely paved, most amount of rain water has to flow into drains. If this area is hit with such a heavy rainfall, the drainage pump stations at the area will experience an abrupt increase of water level like a surge. Under the circumstances, the failure of drainage causes a flood invading into the underground traffic systems and underground shopping areas, which are widely developed and absolutely needed in a modern city. It is a serious damage to our lives.

Using pumps of conventional type, it takes a considerable time to start up and reach the normal run. Against a suddenly rapid rise of water level brought by a localized heavy rain, we have to provide some new measure. In Japan, the municipal authorities and specialists requested pump manufactures to make a new type of pump which is capable of keeping run at full speed in the atmosphere, appropriately in advance of arrival of rise of water level by the rainfall. Naturally, the drainage system should be controlled with the information sent off from the sensors located widely over the relevant area. Let us call this new type of pump stand-by type. I will introduce the stand-by type pumps developed by KUBOTA CORPORATION. In Fig. 1; a conventional type of pump and two stand-by types of pump are shown. There is no essential difference in structure between the conventional type and the stand-by type, except that the stand-by type has a longer suction tube shown as figure (A) and an air pipe connecting the atmosphere to the upmost part inside the suction tube, shown as (B) and (C).

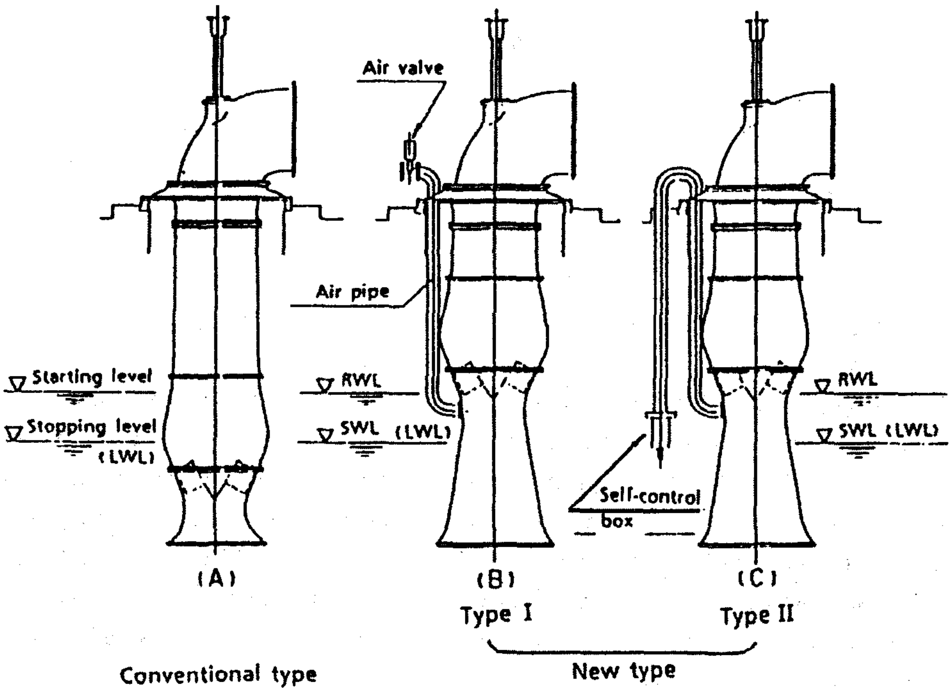

Fig. 1 Stand-by pump construcyion
(M.Konishi and thers, The 3rd Japan-China Joint Conf., 1990)

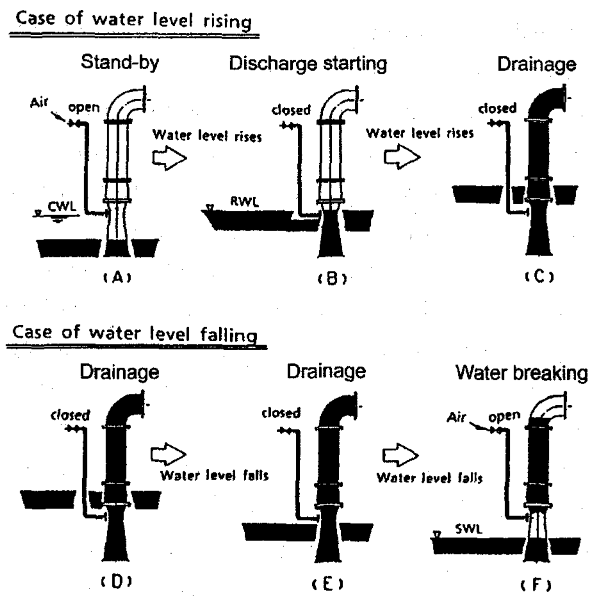

Fig.2 Operation sequence of stand-by pump
(M.Konishi and thers, The 3rd Japan-China Joint Conf., 1990)

The air pipe shown in (B) has an air valve at the upper end on the upper floor. The valve is closed or opened by electronic control system according to the water level, that is it is opened as the water level is coming down to a certain level SWL and closed as water level is rising up to another certain level RWL. While the air pipe shown in (C) is always open to the atmosphere but this pipe has an inverse U shape, which can self-control shut-off and release of the passage of air.

The sequence of the running state of the stand-by type pump is shown in Fig. 2. The figure (A) is stand-by running. In this running state, the water level is low and the air valve is open. But the impeller is rotating at full speed. The figure (B) shows that the water level is rising up due to rapid inflow of rain water and air valve is about to be closed. The figure (C), (D) and (E) indicate a normal running state. The impeller is performing drainage. Of course, the air valve is closed at this running state. The figure (F) is the state called Water breaking. That is, the air valve has been opened by the control system which is activated by sensing fall-off of the water level to the prescribed position, SWL. In this running state the water left in vertical part of the delivery pipe usually does not fall down through the impeller. Possibly, the existence of the water column gives a vibratory load to the pump parts. But so far this vibration is considered not serious, from calculations and experiments. Moreover, another device may be attached to reduce the vibration, when the need arises.

In order to perform such operations as stated above, the bearings and seals must endure a long running in a dry situation. To the early types of stand-by pump, rubber bearings and gland packings with a water feeding system were applied. But recently, ceramic bearings and mechanical seals have been used and they don't need any special lubricating system. And these bearings are held by elastic supports, because they have to sustain the vibratory load induced by the movement of the water column left in the vertical pipe section at the water breaking state. Besides, these bearings and seals are made of the materials which are insensitive to thermal impact. The thermal impact happens when the pump running transfers from the stand-by state or the water breaking state to normal drainage state.

The stand-by type pumps were originally developed for the use of drainage in the urbanized area. But, this type of pumps are applicable to the other uses. For instance, the water suction from a reservoir or pond with a frequently and largely deviating water level, is a good application of this type of pump. This application saves the expense of operation by eliminating the necessity of frequent on-offs and becomes free from making a large pond for regulating water level.

The stand-by type pumps which have been manufactured so far are all vertical mixed-flow. Some of other sorts of pump, like a vertical propeller pump may be easily converted to the stand-by type. The possibility will be realized in near future.

3. Elbow with a pump driving gear train

In Japan, now 80~90% of the needed drainage-station have been already build. We are afraid that a demand of drainage pumps is decreasing. While another demand is growing up graduately. Many of the old stations have had to replace some of their pumps and their supplementary machines. At this time, it has become a trend that the old horizontal pumps are replaced by new horizontal pumps. Generally speaking, the vertical pump doesn't need a vacuum pump, primig pump and their auxiliaries.

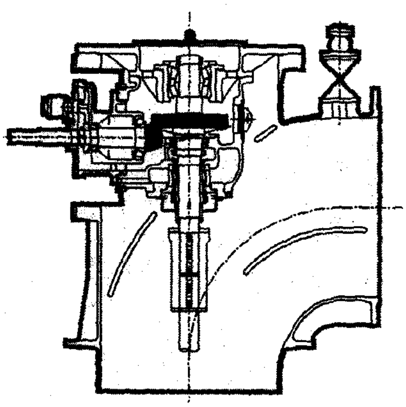

Fig.3 Elbow with a pump driving gear train
(by courtesy of Kubota Corporation)

The replacement would be able to decrease the expense for maintenance of the drainage system. At the same time it is strongly desired to utilize the power machinery which was hither used, in order to decrease the whole cost of the renewal of the pumping system. For this purpose, a new structure of vertical pump was developed. In that structure, necessary bevel gear wheels and a reduction gear train, are both installed compactly in the wall of the elbow part of delivery pipe. An example of this structure of elbow is shown in Fig.3. This is a product of Kubota Corporation, though the first structure was developed by Dengyosha Company. Both structure differ in details. As understood from Fig.3, this structure composed of a water duct and gear trains is very compact and light. Vertical pump with this structure can be widely applied to drainage stations in future.

4. Selection of a pump after introduction of inverters

In our country, lately the application of inverters, strictly speaking, induction motors controlled with inverter system have been noticed from various mechanical engineering fields owing to easy speed regulation. The reason is that a recent remarkable progress of power electronics and micro electronics has made it possible to supply inverters or inverter motors of high efficiency and reliability with enough low cost to compete against other power machine systems. They have been considered best adapted to drive pumps and blowers, because the performance characteristic of a turbo machine is very well matched to the power characteristic of a motor speed controlled by an inverter.

On designing a pump, usually required performance values are head H m and volume flow rate Q m^3/min. The design work starts from to decide the value of rotating speed, n. Until now, only two values corresponding to 2 pole motor and 4 pole one under the frequency of the available electricity would be taken practically, except in special cases. The next step is to calculate the value of specific speed: $N_s = nQ^{1/2}H^{-3/4}$. With above two values of n, two values of specific speeds are gained. This means that the selection of the impeller shape being based on the value of N_s is extremely restricted.

While, by using an inverter, an arbitrary value of the rotating speed can be taken up from a wide range of the rotating speed of the inverter motor and then an desirable value of N_s can be adopted by using an appropriate rotating speed. Thus, the use of inverters expands the range of the selection of impeller shape and for the same values of H and Q, various impeller designs become possible. Furthe, by making the value of N_s equal to that of the pump of a existing series peculiar to a manufacturer in the same way as stated above, we can utilize an existing pump to the required performance. This is a very large economical merit.

5. Energy save by use of inverters

A centrifugal pump runs at speed of n_A. Its performance is shown as $H(n_A)$ in Fig.4. It is supplying the flow rate of Q_A at the actual head H_0, through the pipe line having a hydraulic resistance curve, h_l. Its working point is the point of A on the performance curve, $H(n_A)$. It is often experienced that the flow rate Q_A is much larger than the flow rate Q_B which is needed in the actual operation. Such a situation is caused from the overestimation of the hydraulic resistance at design, which is done conventionally. And in another case, Q_A is the maximum value but it is very rare to need this large value. Usually, the pump is being operated at a less flow rate. To these case, it is the conventional measure to adequately close the delivery valve to throttle the flow. By closing the delivery valve, the working point of the pump shifts along $H(n_A)$ from the point A to the point B which is the intersecting point of $H(n_A)$ and the new hydraulic resistance curve h_l' having a larger loss coefficient. While, if an inverter motor is applied to run the pump, the working point of the pump can be shifted along h_l from the point A to the point B' which is located on the performance curve $H(n_B)$ at the new rotating speed n_B. The speed n_B has to be determined so as to make $H(n_B)$ intersect $h_l(B)$ at the point B'.

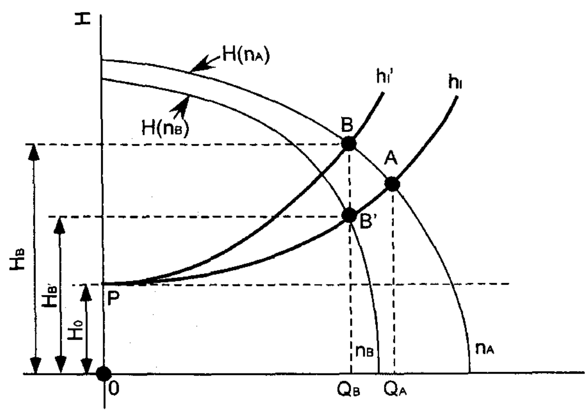

Fig.4 Controls by throttling and rotational speed change

Comparing both methods to decrease the flow rate from Q_A to Q_B, apparently the measure by closing the delivery valve wastes hydraulic energy necessary for passing through the narrow aperture of the valve. The correct value of wasted power is gained as follows

$$\Delta L = \left(\frac{0.163 Q_B H_B}{\eta_M \eta_P} - \frac{0.163 Q_B H_B'}{\eta_M \eta_P \eta_{INV}} \right) kW ,$$

where $\eta_M, \eta_P, \eta_{INV}$ are the efficienciy of motor, pump and inverter respectively. The efficiency of an inverter is now considered $\eta_{INV} = 0.90 \sim 0.95$ as reasonable value. It is reported as an example that by converting all the motor to inverter control types, 36% decrease of the annual electricity consumption was gained, in a factory having the total area 530,000 m^2 and 1,200 employees, where total amount of electricity consumption was 41,640,000 kWh/year and 13% of total amount had been consumed for the pump operation. The above decrease of electricity consumption yields nearly $2{,}300 \times 10^4$ Yen/year of the profit if the electricity price is 12 Yen/kWh. (quoted from Yoshio Miyake, Turbomachinery, Vol.27 No.7 (1999), 420)

6. An effective application of inverter to pump system

In the system which pumps are applied to, inverters are the most essential element. Fig. 5 is a schematic drawing of a water supply system which is quite conventional and the systems like this now can be seen everywhere in the urban areas. But, nowadays the system like this is disliked because of having one or two tanks in the pipeline, which are sometimes found very insanitary. Therefore, now, the system without tanks as shown in Fig. 6 has been prefrred. In this system the revolving speed of pump is controlled by the inverter so as to supply water, keeping pressure constant at the pipe end, regardless of flow rate.

For this control, the performance characteristic is put in into the controlling apparatus, which indicates needed value of the speed to the inverter by making a calculation based on the information from the pressure sensors at suction side and delivery side.

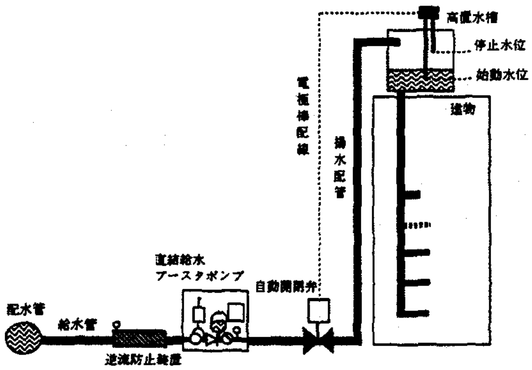

Fig.5 Conventional water supply system
(Kaoru Nakajima, Turbomachinery, Vol.26, No.1 (1998),47)

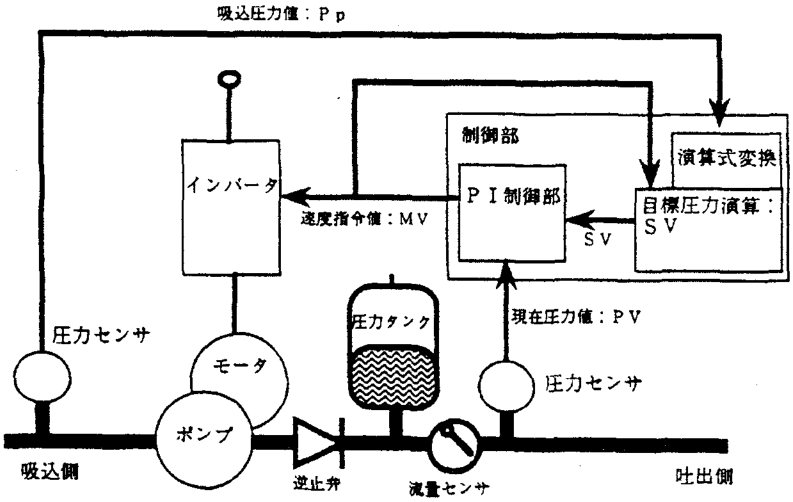

Fig.6 Water supply system with inverter motor
(Kaoru Nakajima, Turbomachinery, Vol.26, No.1 (1998),47)

When a mass of water is directly drawn from the city waterworks, it is legally restricted to give the waterworks a sensible pressure shock or fluctuation by the on-off of the water drawing pumps. Occasionally it becomes a serious problem. Generally, inverter controlled motors can be started up or stopped up so slowly that it takes 3 seconds from stop until full speed or from full speed until stop. By using this characteristics, the valve of the connecting pipe to the city waterworks can be opened or closed at enough low speed of the pump not to cause a sensible impulsive pressure change.

It is now expected that the application of an inverter to driving a pump would bring great benefit to our pump industries.

7. Conclusion

I think it is not probable that something innovative would happen and change thoroughly the design and the structure of a pump, though many of extensive researches are being carried out in their specific fields such as the internal flow of a pump and cavitation phenomena in pumps. So, for the moment, many of problems for us the pump engineers to study and develop, must be those coming from the technology of the application and operation of pumps. It is very luckey for me if my talk could contribute something to your job.

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