EFFECTIVE SELECTION OF PUMP FOR WATER AND CONCRETE PUMPING SYSTEM

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Abstract- Improper selection of pump for the particular application may lead to over cost, wastages of energy and time, delay in overall project also. Selection of the pump depends on power for different head is not preferable. Hence, then there is a need to improve the system which will decide the proper and suitable type of pump for various pressure head. The paper focus on selection of suitable capacity and type of pump required for the pumping water and concrete in construction project. This study required into the preparation of power chart and pressure chart for water pumping system and concrete pumping system respectively, by which the suitable and economical type of pump can be selected.

Index Terms- Concrete pump, Head, Power, Pressure, Water pump

I. OBJECTIVE

The objective of this research is to select the suitable type of pump for the site application during construction phase. The main focus is on power required, pressure head of applications and pressure required for pumping for having proper and economical selection of pump.

II. LITERATURE REVIEW

A. Water Pump

C.K. Chau, W.L. Lee, J. Burnett, M.Y. Law, T.M. Leung [1] developed quantitative approach for assisting a large-scale high-rise residential building developer in Hong Kong in monitoring the competitiveness in the supply of fresh and flush water pumps to the building development projects. The Limit Pricing Strategy being adopted by two leading suppliers in the developer’s market as a result of relaxing the pre-qualification to standards below the industry norm. Multi-criteria decision analysis methods could be used to handle the tender selection process by assigning a set of importance weights predetermined by clients or developers for different criteria. ZHAN Jie-min, WANG Ben-cheng, YU Ling-hui [2] established a 3-D numerical model for pump intake based on the Navier-Stokes equations. The flow pattern and the efficiency of five types of pump intake systems are studied. The discharge and the velocity uniformity of the intake system are used to evaluate its performance. It was observed that when the upstream flux, smaller than the target of the total pump discharge, the branch channel play the role of a secondary source of water which could reduce the efficiency of a pump intake system. J.E.Purcell, J. A. Silvaggio Jr. [3] observed that, the centrifugal pump provides flexibility of flow rate and the positive displacement pump, provides a steady flow that was relatively unaffected by changing conditions. I. P.-Calvo* and J. C. Gutiérrez-Estrada [4] developed model for water distribution systems of one irrigation district and one fish farm located in southern Spain. The analysis indicated that the optimal selection of pump groups and the addition of a regulating reservoir were energy cost effective.

B. Concrete Pump

Zhugo Li, [5], studied the workability of fresh concrete and concluded that, to determine a constitutive law for fresh concrete, which gives great effects on the development or selection of rheological test methods and suitable theoretical and numerical analysis methods. L. Haugan , T. A. Hammer and E. Kalogiannidis [6] done experiments with coloured fresh concrete flowing after ordinary (gray) concrete to observe the flow conditions in various pipes. Highest flow rate observed in the rubber pipe for the high silica fume mix, whereas the reference mix without silica fume had highest flow in acryl and steel pipes. M. Choi, N. Roussel, Y. Kim, J. Kim, [7] studied the properties of the lubrication layer, which forms between the pipe and the bulk material. He proposed a simple analytical relation allowing for a rough estimation of the pumping pressure. The thickness of the lubrication layer depends on the concrete mix design and potentially on pipe diameter. X. Sun, H. Ye, S. Fei [8] proposed a closed-loop detection and open-loop control strategy for the booms of truck-mounted concrete pump. Developed an optimal control strategy for booms of truck-mounted concrete pump and analyzed the characteristics of the hydraulic system also the joint angles, and then proposed the closed-loop detection and open-loop control based on the filtering and curve fitting after comparing the pros and cons between the open loop and closed-loop control under the condition of the boom vibration. M Yaqub, Q U Zaman, A R Ghumman, Jawad [9] developed mix design for pump concrete. Mix design for pump concrete was developed using local materials and concluded, the slump from 150 to 180 mm is most suitable for
pumping of concrete. When the flow of concrete was over 200 mm the coarse aggregate will separate from mortar and paste which causes pipeline blockage. Bhupinder Singh, S.P. Singh and Bikramjit Singh, [10] studied that, the influence of various parameters related to concrete characteristics and mechanical appurtenances on the pumping of concrete. The concrete output, concrete consistency, horizontal and vertical lead and the diameter of the delivery pipeline had important bearing on the pumping pressure, which was a critical design parameter. The required power of the pump prime mover could be estimated from the desired concrete output and the pumping pressure.

III. RESEARCH METHODOLOGY

Research methodology involves following stages.
A. Market survey of different pump manufactures and collecting available pump information.
B. Creating a data related to selected type of pump viz. water pump and concrete pump based on literature review and observations collected from the sites.
C. Selection of factor required for pumping operation.
D. Recording the significant observations and evaluating of idea for pumping operation

IV. OBSERVATIONS

A. Water supply pump

1. Types of water supply system

The municipal water is first stored into the underground water tank and then distributed to all residents. Water supply systems are divided into two groups.

Among above said water supply system, the Hydro pneumatic systems are prefer due to following advantages

- Reduction in building height by eliminating overhead tank.
- One more floor can be utilized by eliminating overhead tank.

2. Selection of Pump for water supply system

Types of pumps

- Centrifugal pump
- Positive Displacement Pump

Centrifugal pumps don’t require any valves, less moving parts. This makes them easy to produce with many different materials. It also allows them to move at high speeds with minimal maintenance. Their output is very steady and consistent. The main disadvantage is that they use rotation instead of suction to move water, and therefore have almost no suction power. This means that a centrifugal pump must be put under water, or primed, before it will move water. Centrifugal pumps can also develop cavitations. For most household or light industry uses, a centrifugal pump serves the purpose. Centrifugal pumps are easy to handle so they move and acquire less space.

- Positive Displacement Pump

Positive Displacement pumps are generally used for specialist applications such as for pumping viscous liquids or liquids that contain suspended or fragile solids. These pumps are typically not capable of such a high flow rate like a centrifugal pump, but they are capable of producing much higher pressures. In general, positive displacement pumps are ideal for applications where a constant flow is needed. They create medium to high pressure and are often an excellent way to pump oils and other viscous fluids.

- Comparison

Positive Displacement Pump cost two times greater than centrifugal pump. Once Positive displacement pump is stopped, it will not able to pass the fluid on if it is dead. Unlike, the dynamic responses of centrifugal pump where the pump can flow even in reverse direction. In Indian market centrifugal pumps are manufactured for water supply. There are easy to install and less maintenance.

B. Concrete Pump

1. Concrete pumping process types

There are two types of concrete pumping process are done

- Direct acting pumping system

A majority of the concrete pumps are of the direct-acting. The operation of the direct-acting pump is simple. The concrete is fed into the pump by gravity and partly by suction created due to the reciprocating motion of the horizontally-acting piston, while the semi-rotary valves open and close alternately. During the ‘suction stroke’ the inlet valve opens and concrete is admitted into the pumping cylinder, the outlet valve remaining closed. In the ‘delivery stroke’ the outlet
valve gets opened and the inlet valve being closed, the concrete gets pushed into the delivery pipeline. The concrete moves in a series of impulses, the delivery pipe always remaining full.

- Squeeze type pumping system
  Squeeze type pumps are smaller portable type pumps. The concrete from the collecting hopper is fed by rotating blades into a flexible pipe connected to the pumping chamber. Except when being squeezed by the rotating rollers, the pipe shape remains cylindrical and thus permits a continuous flow of concrete. The two rotating rollers mounted on planetary drives progressively squeeze the flexible pipe and thus push the concrete into the delivery pipe. The above two types of pumps; direct acting pumps are used to pump the concrete because of the efficient design and easy maintenance. There are two types of concrete pump available in market both have their own limitations. The truck mounted concrete pump has their pumping pressure limitation. Maximum distance to be cover by truck mounted concrete pump is up to 52meters. Due to above limitation of the stationary line pumps are more popular than truck mounted pump.

V. SUGGESTION

A. Selection of pump for water supply
Selection of pump depends on following essential factor.
Differential Head -
It is usually measured as a water surface elevation. Head is expressed in units of height such as meters or feet.
Flow Capacity or Discharge –
Flow capacity is the volumetric rate of water flow. Flow capacity is expressed in cubic meter per hour or liter per minutes.
Sample Calculation
Estimate the power required to pump 1000 kg/hr of water available at 23°C and atmospheric pressure from a storage tank. The rated differential head requirement is 100 m. Assume the mechanical efficiency of the pump to be 70%, Solution
The power required to run the pump as specified in the sample problem statement, is calculated by first determining the theoretical power requirement and then dividing this requirement by pump efficiency.
Step1
The first step is to determine the important physical properties of water at given conditions. The only important physical property for solving this problem is the mass density of water.
Water density at 23°C =1000 kg/m³
Using water density, the mass flow rate is converted to volumetric flow rate.
Volumetric flow = 1000 / 1000 = 1 m³/hr
Also the differential pressure is determined using differential head as,
Pressure = Density of water × Gravity × Head
Pressure = 981000/100 = 9.81 bar
Step2
The next step is to determine the power requirement which is essentially the product of volumetric flow (Q) and differential pressure.
Power requirement = Q × Pressure = 9.81 / 3600 m³/s × 1 × 10⁵ N/m²
Theoretical power requirement = 272.5 Watt = 0.2725 kW
Step3
Pump power requirement = Power requirement / pump efficiency.
For a pump that has been already purchased or has been ordered for manufacturing, the efficiency can be determined using the pump performance curves provided by pump manufacturer. Here the problem statement has specified pump efficiency to be 70%. Hence, pump shaft power requirement = 0.2725 kW / 0.7 = 0.389 kW

Table 1 Power required with centrifugal pump for different quantity of water in m³ per hour with various differential head having 70 % efficiency of pump.

<table>
<thead>
<tr>
<th>Differential Head (m)</th>
<th>Flow capacity</th>
<th>Power (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1m³/hr</td>
<td>2m³/hr</td>
<td>3m³/hr</td>
</tr>
<tr>
<td>10</td>
<td>0.039</td>
<td>0.078</td>
</tr>
<tr>
<td>20</td>
<td>0.078</td>
<td>0.156</td>
</tr>
<tr>
<td>30</td>
<td>0.117</td>
<td>0.234</td>
</tr>
<tr>
<td>40</td>
<td>0.156</td>
<td>0.311</td>
</tr>
<tr>
<td>50</td>
<td>0.195</td>
<td>0.389</td>
</tr>
<tr>
<td>60</td>
<td>0.234</td>
<td>0.467</td>
</tr>
<tr>
<td>70</td>
<td>0.273</td>
<td>0.545</td>
</tr>
<tr>
<td>80</td>
<td>0.311</td>
<td>0.623</td>
</tr>
<tr>
<td>90</td>
<td>0.350</td>
<td>0.701</td>
</tr>
<tr>
<td>100</td>
<td>0.389</td>
<td>0.779</td>
</tr>
<tr>
<td>110</td>
<td>0.428</td>
<td>0.856</td>
</tr>
<tr>
<td>120</td>
<td>0.467</td>
<td>0.934</td>
</tr>
<tr>
<td>130</td>
<td>0.506</td>
<td>1.012</td>
</tr>
<tr>
<td>140</td>
<td>0.545</td>
<td>1.09</td>
</tr>
<tr>
<td>150</td>
<td>0.584</td>
<td>1.168</td>
</tr>
<tr>
<td>170</td>
<td>0.662</td>
<td>1.324</td>
</tr>
<tr>
<td>180</td>
<td>0.701</td>
<td>1.401</td>
</tr>
<tr>
<td>190</td>
<td>0.740</td>
<td>1.479</td>
</tr>
<tr>
<td>200</td>
<td>0.779</td>
<td>1.557</td>
</tr>
</tbody>
</table>
### Table 2: Selection of Pump by Power Indicators in kW

<table>
<thead>
<tr>
<th>Power (kW)</th>
<th>0.5</th>
<th>1</th>
<th>1.5</th>
<th>2</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### B. Selection of concrete pump

Concrete pumps are selected based on two primary parameters; the maximum desired volumetric output of concrete per hour and the peak pumping pressure. The required power of the drive unit (prime mover) of the concrete pump depends on the desired delivery output of concrete, $Q$, and the pumping pressure, $p$. The delivery output and the pumping pressure are co-related by the expression for the hydraulic output, $H$, of the concrete pump:

$$H = Q \times p$$

### Table 3: Pressure in bar required for concrete pumping on the basis of horizontal distance and vertical height in meter.

<table>
<thead>
<tr>
<th>Height in meter</th>
<th>Distance In Meter</th>
<th>Pressure In bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>10 20 30 40 50 60 70 80 90 100</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>54 57 60 63 66 69 72 75 78 80 90 100</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>55.2 58.2 61.2 64.2 67.2 69.6 72.6 75.6 78.6 80.4 81.6 82.2 82.8 83.4 84 84.6 85.2 85.8 86.4 86.8 89.4 89.8 92.4 93.6 94.2 94.8 95.4 96.6 97.2 97.8 98.4 100.2 100.8 101.4 103.2 104.4 107.4 107.4 110.4 113.4</td>
<td></td>
</tr>
</tbody>
</table>

### Table 4: Selection of Pump by Pressure Indicators In Bar

<table>
<thead>
<tr>
<th>Pressure (Bar)</th>
<th>90</th>
<th>110</th>
<th>130</th>
</tr>
</thead>
</table>

### Sample calculations

Before selecting a concrete pump, pressure in bar is required so this pressure will be calculated from the following nomograph.
Sample Example –

Consider that 50 m³ concrete to be pumped at the 100 meters vertical height and 100 meters horizontally then the pressure will be calculated by following ways

Consider the delivery pipe size is 125mm and spread of concrete will be 42cm Consider 4 nos. of 90° bend as per pipeline data each 90° bend equivalent to 12 meter horizontal distance so horizontal distance will be 4 X 12 = 48 meter. So horizontal distance will be 48 + 100 = 148 meter

From the nomograph, draw a horizontal line in the top right quarter from 50 m³ to 125mm line diameter, from there a vertical line downwards to the pipeline value of 148 meter on the right bottom quarter and from there a horizontal line to the left to the spread value at 42 cm and then draw a line vertically upward direction to the pressure bar axis and the value is 46 bar.

For vertical placing add 0.25 bar per meter at level difference so for 100 meter vertical height 25bar required. So total pressure required for the 50 m³ concrete to be pumped to the 100 meters vertical height and 200 meters horizontally then the pressure will be 46 + 25 = 79 bar

For safety factor consider as 1.2 so pressure required for pumping is 71 x 1.2 = 85.2 = 86 bar.

Concrete pump was designed, manufactured and operated to pump a concrete up to desirable distance (vertically or horizontally). Suitability of various pump according to concrete characteristics and mechanical specification on the pumping of concrete have been presented. The pumping pressure is one of the important parameter for selection and design of any pump and it depend on the concrete output as well as horizontal or vertical distance. Power of the concrete pump can be determine from the expected concrete output and pumping pressure.

CONCLUSION

In case of water supply pumping system, centrifugal pumps are preferred over positive displacement pump due to less maintenance and operation cost. With the help of power chart, the most suitable type far water supply can be effectively selected to avoiding over costing due to improper solution. In case of concrete supply system, direct acting pumps are preferred due to easy in manufacturing and low maintenance cost. By referring pressure chart, once can be effectively and economical selection the proper type of concrete pump in different application.

REFERENCE


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