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Design of Centrifugal Pump Piping System and Calculation of Losses Occurs

Shreyas Basagare[1], Chetan Metkar[2], Kunal Minde[3]
[1,2,3]*Student, Department of Mechanical Engineering, RMD Sinhgad School of Engineering, Pune, India*

***Abstract*: A centrifugal pump is the one of the simplest equipment in any process plant. The main purpose of centrifugal pump is to convert energy of prime mover (electric motor or turbine) first into kinetic energy and then into pressure energy of fluid. The energy changes occur by virtue of two main parts of pump, the impeller and volute or diffuser. The basic concept of piping design is to safely transport fluid with two-phase flow to the destination with acceptable pressure loss. Pump piping system is most commonly used system in industries and chemical plants. Piping systems are like arteries and veins of process plant. The best piping configuration is the best expensive over a long-term basis. This requires the consideration of installation cost, pressure loss, bending losses, friction loss and sudden enlargement loss. This report addresses the mechanical engineering approach based on newly designed piping system, which leads to ease in pump testing and in mass production.**

***Keywords*: Centrifugal Pump, Catia, Solidworks, Krt Pumps.**

1. Introduction

In Newtonian mechanics, the centrifugal force is an inertial force also called as pseudo force directed away from the axis of rotation that appears to act on all objects when viewed in rotating frame of reference. Centrifugal pump works on the principle of centrifugal force. Centrifugal force does not exists when a system is described relative to inertia frame of reference. In a rotating reference frame, all objects regardless of their state of motion appear to be under the influence of radially outward force that is proportional to their mass, to the distance from the axis of rotation of the frame, and to the square of the angular velocity of the frame.

A pump is a device that moves fluids, or sometimes slurries, by mechanical action. Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the fluid. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power, come in many sizes, from microscopic for use in medical applications to large industrial pumps. A submersible pump [6] is a device, which has a hermetically sealed motor close-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. The main advantage of this type of pump is that it prevents pump cavitation, a problem associated with a high elevation difference between pump and the fluid surface. Submersible pumps push fluid to the surface as opposed to jet pumps having to pull fluids. Submersibles are more efficient than jet pumps.

This project mainly focuses on the newly launched pumps that those are AMAREX and KRT. These pumps came into demand after the idea of "Swachha Bharat Abhiyan" proposed by our prime minister "Mr. Narendra Modi". These pumps are widely used for pumping of sewage and effluent in water treatment and industry, especially untreated sewage with long and fibrous and solid substances, liquids containing air and gas as well as raw, activated and digested sludge.
The two pumps in consideration are:

A. Amarex

The Amarex pump has axial inlet and radial outlet. The Amarex pump is available in eight models to fit a variety of applications, such as:

- Wastewater transport
- Fluids containing long fibers and solid substances
- Fluids containing gas/air
- Raw, activated or digested sludge

Grinder pumps [2] with 2-inch discharge and featuring S-type impeller macerate and grind solids that meet the pump, easily carrying them through the pump for discharge.

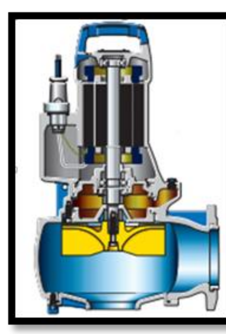

Fig.1. Amarex pump

Fig. 2. S-Type impeller

B. KRT

The submersible motor pump KRT [6] overcomes all the problems associated with the handling of sewage and wastewater, both in economic and environmental terms. KRT pump function reliably in transfer pumping station and pressure drainage system. Also in industrial applications such as those in steel, paper, textile and food industry. Corrosive and adhesive nature of municipal and industrial wastewater demand the use of specific materials that will provide resistance are used. KRT works on the stator rotor principle. It has a motor inbuilt hence; no external motor is required to run the pump.

Material:

1. Standard version of cast iron with stainless steel impeller
2. G = All main parts in cast iron.
3. G1 = All main parts in cast iron only impeller in stainless steel

2. Literature review

E. Farsirotou et. al. [1] In this paper experiments of an essentially incompressible fluid flow in horizontal circular pipes system of different cross section diameters are graphically presented. Higher minor head losses are observed [1] at higher mass flow rate values and the increment is more pronounced at abrupt cross-section changes. The experimental results are applicable in the development of new and the refinement of existing codes for computing head losses variation in horizontal circular pipes system of various cross-section geometries.

P. Sonawane et. al. [2] This paper includes work carried out on many parameters related to pump piping. This includes hydraulic parameters like flow, velocity, and pressure drop for piping optimization. It targets a broad spectrum of single and multi-objective problems in the topics of design. Author proposes the new concept of unavoidable minimum energy, as the reference for defining an energy efficiency indicator. Based on design mechanical design parameter, calculation for thickness, force and expansion, piping configuration, which are also crucial, are needed to be consider in piping system design.

José Luis Henríquez Miranda et. al. [3] This paper is based on the best piping configuration is the least expensive over a long-term basis. This requires the consideration of installation cost, pressure loss effect on production, stress level concern, fatigue failure, support and anchor effects, stability, easy maintenance, parallel expansion capacity and others. The expansion loops most commonly used in cross- country pipelines are L bends, Z bends, conventional 90° elbow and V bends are studied.

K. Hilding Beij et. al. [4] This paper focuses on the 90^{o} bend, which is most frequently used fitting in piping system. The pressure losses in such bends are therefore of considerable engineering importance. By increasing the curvature of pipe head and friction losses [5] can we reduced, this is experimentally carried out and obtained the specified results.

Kelvin Fergussion et. al. [5] The paper includes how the installation of flow meter in accordance with the manufacturer written specifications is necessary for flow meter to be accurate. The meter requirements, lengths at which flow meter should be installed and calibration are studied.

3. Component Selection

A. Selection of Flow Meter

A flow meter is a device used to measure the flow rate or quantity of gas or liquid moving through a pipe. Flow measurement applications are very diverse and its situation has its own constrains and engineering requirement. Flow meters are referred by many names such as flow gauge, flow indicator, liquid meter etc. depending on particular industry; however, the function to measure flow, remains the same. Precision flow meters are used to provide accurate monitoring and flow control. Some industrial application requires precise calculation of quantity, such as precision servo-valve development for aerospace industry. On the other hand, an application to measure water flow to a vineyard may only require measurement accuracy of 5% to 10% [5].

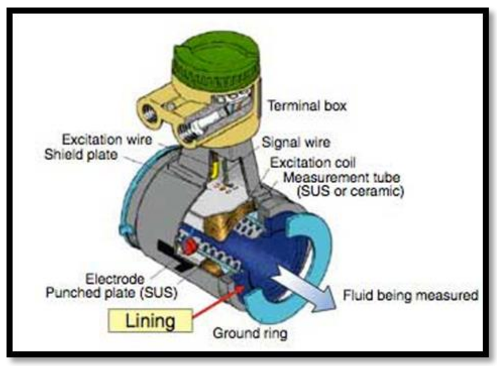

Fig. 3. Electromagnetic flow meter

We are considering electromagnetic flow meter as; the electromagnetic flow meter uses Faraday's Law of electromagnetic induction to measure the process flow. When an electrically conductive fluid flows in the pipe, an electrode voltage E is induced between a pair of electrodes placed at right angles to the direction of magnetic field. The electrode voltage E is directly proportional to the average fluid velocity V. magnetic flow meter simply known, as mag flow meter is a volumetric flow meter, which is ideally used for wastewater applications and other applications that experience low-pressure drop and which appropriate liquid conductivity required. The device does not have any moving parts and cannot work with hydrocarbons and distilled water. Magnetic flow meters are also easy to maintain.

If the magnetic field direction were constant, electrochemical and other effects at the electrodes would make the potential difference difficult to distinguish from the fluid flow induced potential difference. To mitigate this in modern magnetic flow meters, the magnetic field is constantly reversed, cancelling out the electrochemical potential difference, which does not change direction with the magnetic field. This however prevents the use of permanent magnets for magnetic flow meters

Parameters for flow meter selection:

- Fluid flowing: Water
- Rotor speed
- Maximum and minimum flow rate
- Head range
- Diameter of pipe

Calculations [5]:

Discharge (Q) = Area (A) X Velocity (v)
Where, Area = $\pi/4$ (Diameter)^2

From this, we can achieve maximum and minimum velocity and flow meter can be selected using following relation.

Velocity range:
Minimum: 0.3 mm / sec
Maximum: 3mm / sec
Should not exceed: 10mm / sec

B. Selection of Control Valve

The first step in control valve selection involves collecting all relevant data. The piping size must be set prior to valve sizing, and determining the supply pressure may require specifying a pump [3]. The novice might have to iterate on the needed piping, pump pressure and pressure drop through the piping network.

Table 1
Information on Standard (9906) Commercial Control Valves [6]

Body Type	Size (in)	Maximum Pressure (psia)2	Temperature (°F)
Globe	1/4 to 16	50,000	cryogenic to 1200
Ball	1/2 to 36	2500	up to 1400
Butterfly	3/4 to 200	2500	cryogenic to -2200
Diaphragm	1/4 to 20	100	-30 to 2200

The valve body can be selected based on the features in Table 1. Note that the valve size is either equal to the pipe size or slightly less

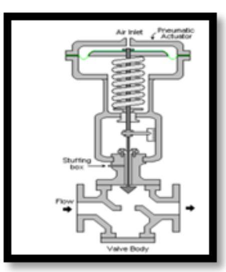

Fig. 4. Control valve

C. Pressure tapping (For head measurement)

Pressure tapping is used to measure outlet head of pump and can be derived from the measured gauge head. The determination of total head can be affected by any swirl or irregular velocity or pressure distribution. Numbers of pressure tapings needed are selected based on their standard grades.

International standards of grade acceptance (ISO 9906):

- Grade 1 (Tighter tolerance): Four static pressure tapings are to be provided symmetrically placed above the circumference of each measuring section [6].
-

Fig. 5. Grade 1 Pressure tapping

- Grade 2 & 3 (Broader tolerance): it is normally sufficient to provide not more than one pressure taping at each measuring section.

Fig. 6. Grade 2 Pressure tapping

The diameter of pressure taping should be of 6mm – 3mm or equal to 1/10th pipe diameter, whichever is smaller is selected. The length of pressure taping hole should not be less than 2.5 times its pipe diameter [6].

D. Butterfly Valve

A butterfly valve isolates or regulates the flow of fluid. The closing mechanism is a disc that rotates. Operation is similar to that of a ball valve, which allows for quick shut off. Butterfly valves are generally favored because they cost less than other valve design, and are lighter weight so they need less support. The disc is positioned in the center of the pipe. A rod passes through the disc to an actuator on the outside of the valve. Rotating the actuator turns the disc either parallel or perpendicular to the flow. Unlike a ball valve, the disc is always present within the flow, so it induces a pressure drop, even when open. There are different kinds of butterfly valves, each adapted for different pressures and different usage. The zero-offset butterfly valve, which uses the flexibility of rubber, has the lowest pressure rating. The high-performance double offset butterfly valve, used in slightly higher-pressure systems, is offset from the centre line of the disc seat and body seal (offset one), and the centre line of the bore (offset two). This creates a cam action during operation to lift the seat out of the seal resulting in less friction than is created in the zero offset design and decreases its tendency to wear. The valve best suited for high-pressure systems is the triple offset butterfly valve. In this valve the disc seat contact axis is offset, which acts to virtually eliminate sliding contact between disc and seat. In the case of triple offset valves the seat is made of metal so that it can be machined such as to achieve a bubble tight shut-off when in contact with the disc.

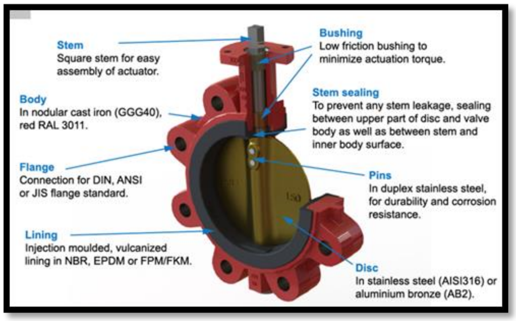

Fig. 7. Butterfly valve

E. Design of Piping System

Design of Amarex Discharge Piping System: The testing of amarex pump is a crucial procedure which requires absolute assessment and lots of attention while testing of pump. So it is essential to design a system which will achieve better characteristics as per required by the customer [2].

The proposed design is:

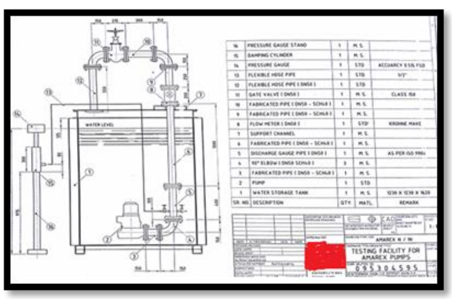
Fig. 8. CAD Design of discharge piping

The considerations that are required to be made for designing the pipes are as follows:

Losses in straight pipe

1. Diameter of pipe: 50mm = 0.05m (as the design is for pump having 50mm discharge diameter)
2. Area of cross-section: $\pi/4\ (0.05)^2 = 0.001963m^2$
3. Velocity: Q/A= (50/36000) / 0.001963= 0.14123m/s
4. Reynolds's number: VD / γ = (0.14123 × 0.005) / 8.01× 10-7 = 8.822× 103
5. Friction factor: 64 / Re = 0.007254
6. Total length of pipe: 2.1m
7. Friction Head loss: $64\gamma V/2gD^2 = 0.000310m$

Losses Due to Bend:

1. Diameter of pipe: 50mm = 0.05m (as the design is for pump having 50mm discharge diameter)
2. Area of cross-section: $\pi/4\ (0.05)^2 = 0.001963m^2$
3. Velocity: Q/A= (50/36000) / 0.001963= 0.14123m/s
4. Le / D = 30 (According to ISO 9906)
5. Friction factor: 0.019 (According to ISO 9906)
6. Resistance coefficient: (Le/ D) × Friction factor = 0.05
7. Number of bends [4]: 3
8. Friction Head loss: (Resistance coeff. × (vel) 2 / 2g) × n = 0.0001527m

Losses in Valve:

1. Diameter of pipe: 50mm = 0.05m (as the design is for pump having 50mm discharge diameter)
2. Area of cross-section: π/4 (0.05)2 = 0.001963m2
3. Velocity: Q/A= (50/36000) / 0.001963= 0.14123m/s
4. Le / D = 340 (According to ISO 9906)
5. Friction factor: 0.019 (According to ISO 9906)
6. Resistance coefficient: (Le/ D) × Friction factor = 6.46
7. Number of valve: 1
8. Friction Head loss: (Resistance coeff. × (vel) 2 / 2g) × n = 0.006576m

Exit Losses:

1. Friction Head loss: V2 / 2g = 0.001018m

Total Head loss:

1. Sum of all Frictional head loss = 0.008056m

Total Head loss:

Calculation for selection of flow meter:

To find the appropriate flow meter for Amarex 50-170 pump.

Speed = 2900 rpm

Qmin = 5.0 m^3 / hr.

Q max= 45 m^3 / hr.

Power = 3.06 KW

Head range:

Min diameter = 9.6-2.3 m

Max diameter = 20.5-7.5 m

Discharge = Area X Velocity

Where Area = (π / 4) (0.05) 2 = 0.001963 mm^2

Calculation for maximum and minimum velocity:

Vmax = Qmax / A = (45 / 0.001963) X 3600 = 6.37 mm/sec

Vmax = 6.37 mm / sec

Vmin = Qmin / A = (5 / 0.001963) X 3600= 0.71 mm/sec

Vmin = 0.71 mm / sec

According to ISO 9906: Velocity range:

Minimum = 0.3 mm/ sec

Maximum = 3 mm / sec

Not exceed = 10 mm / sec

Diameter	Head range
DN50	0-20
DN80	0-40
DN100	0-150

4. Final Proposed Design

After considering all the losses which come during final testing after the fabrication process a final design has been proposed and repeatability and result consistency of this design is almost 90%.

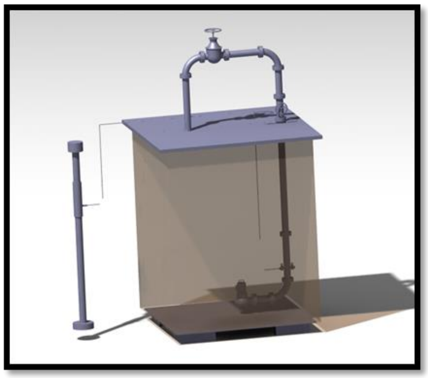

Fig. 9. Final proposed design

5. Conclusion

As studied in the above content, all the parameters needed for designing are considered and after acquiring complete information the design has been put forth which will lead to ease in testing of products and increase production rate. The further enhancement and study will be made to test all the performance characteristics and compare them to ideal characteristics using Ansys. The fluid flow through the pipe will be considered and efficiency of system is calculated. This proposed design will ease in proper testing of the newly developed centrifugal pumps and with the help of proposed design pump manufacture will able to attain the required characteristics along with the proper performance curve.

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