Advanced Materials
Manufacturing & Characterization

journal home page: www.ijammc-griet.com

Design of Centrifugal Pump for Pulp Handling in Paper Plant.

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A R T I C L E I N F O

Article history:
Received 17 Nov 2012
Accepted 26 Dec 2012

Keywords:
centrifugal pump,
paper plant.

A B S T R A C T

This paper aimed at designing a pump which can handle under the pulp of 5% consistency pumping for the existing system (suction and delivery lines are there in position).For the design of pump the system resistance (total head) is calculated by considering head and capacity correction factor for 5% consistency of pulp. This factor is taken from data book. Power required and specific speed calculated by standard formulae. For pulp pumps above 3% consistency semi open impeller is preferable. Impeller vane angles, number of vanes, vane curvatures are designed as per standards

Introduction

Since the olden times, the man has been trying to find out some convenient ways of lifting water to higher levels, for water supply and irrigation purposes. It is believed, that the idea of lifting water, by centrifugal force, was first given by L.D Vinci an Italian Scientist and Engineer at the end of 16th century. Then this idea was put to experiments by French scientists and they designed centrifugal pump having impeller and blades.

In the daily life of people it has become necessary to handle water in one form to another. The most trouble free pump within the reach of the people is centrifugal water from a well to the surface for irrigation. The object of pumping is to raise the energy of a liquid in one of the three forms datum head, pressure head or velocity head. In the first type the liquid is raised from a low level to a high level liquid is stored at atmospheric pressure. The velocity in pump. For the rural folk, excepting those who are in delta regions, living in upland areas have to raise water required for their corps from wells. The driving unit may be a petrol or diesel engine or electric motor.[1,5]

A pump, in general may be defined as a machine, when driven from some external source, lifts water or some other liquid from a lower level to a higher level. Ex:- Lifting of water from a lower level to a higher level (Over head tank) or lifting

the pipe remains constant liquid available under high pressure can be made to flow under high velocity i.e., by converting pressure head to velocity head. [2,7]

Role of pump in paper industry:

Paper is being produced with bamboo, and hard woods. Various methods are being adopted to convert bamboo/ wood chips into pulp. Various chemical water is used for making paper and they are being transported from source of supply to the point of use. Pumps are used to transport water, black liquor, hypo solution, hot water, Alum, Talcum, Rosin, Acids, Oils etc. for various applications different type of pumps are being used. It is very much essential to select a suitable pump for the above purposes. Types of pump are determined by the application and their capacity, head etc. are chosen as per the requirement.

Normally in the paper industry centrifugal type pumps are used. Depending upon the material to be

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- Doi: http://dx.doi.org/10.11127/ijammc.2013.02.074

transported the pump is selected. E.g. for transporting water centrifugal pump of closed impeller, for transporting pulp of consistency of pulp 1 to 2.5%

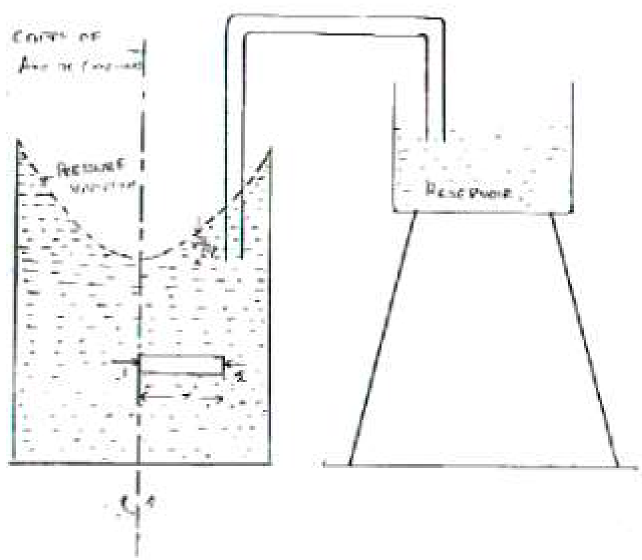
Basic principle and working of centrifugal pump

Deffinition of pump

Pump is apparatus to transport liquid from lower level to higher level. Pump is a mechanical device to increase the pressure energy of a fluid. In most of the cases pump is used for raising fluids from a lower to higher level. This is achieved by creating a low pressure at the inlet or suction end and high pressure at the out let or delivery end of the pump. Due the low inlet pressure the fluid raises from a depth where it is available and the high outlet pressure forces it up to height where it is required of course, work has to be done by a prime mover on the pump to enable it impart energy to the fluid.

Basic principle of centrifugal pump

If the liquid is rotated with a sufficient high velocity so as to enable it to raise beyond the walls of the container and if more liquid is constantly supplied at the center by some suitable means, the tendency of the liquid would be to flow out as in fig 3.1 such a system in principle is a Centrifugal Pump.



Principle of Centrifugal pump

If the cylindrical vessel is closed at top and filled up-to top and rotated about its central vertical axis the entire liquid volume also rotates. The angular velocity is constant at all points. The linear velocity is directly proportional to the distance of the point from the center. The stream lines are concentric circles. Since the tangential velocity is constant there is no conventional tangential acceleration there results only the normal acceleration of magnitude V^2/R.

closed impeller, more than 2.5% to 5% open impeller is used.

onsider a small cylinder of area A and length X as shown in figure. The mass contained in the cylinder = WAX/g

the velocity at the center of the cylinder =WX/2

Let P_1 and P_2 be the pressure force acting on the ends of this cylinder. The difference of these two forces must be equal and opposite to the centrifugal force on the cylinder.

The equation being of 2nd degree the difference in pressure at any point and another at the center at the same elevation of parabolic form. The pressure head at the axis is zero and at the cylinder wall the pressure head is $V_0^2/2g$ where $V_0 = W_{ro}$.

The radius of the cylinder is r_0, if a set of piezometers are arranged in radial line the pressure head at the cylinder wall such that its height is less than $V_0^2/2g$, then the liquid begins to flow. If the reservoir is at a higher level , floe does not takes place because the pressure developed is insufficient. It can be increased either by increasing the diameter of cylinder or speed of rotation what ever be the diameter and speed. If a pipe is located at the center of the cylinder ,the liquid does not rise at all. If the liquid in the cylinder is initially at a pressure head h_1, then the total pressure head at any point will be $h_0+h_1+ V^2/2g$. in this case the parabola has to be raised vertically by a depth equal to h_r.

Operation of centrifugal pump:-

The first step in operation of a pump is priming that is, the suction pipe and the casing are filled with water up to delivery valve. This is done for the removal of air, with the pressure of air, it is not possible to create pressure because the pressure generated by the impeller is directly proportional to the density of the liquid to be handled. Thus, if impeller is run in air, negligible pressure will be produced because of very less density of air and hence no liquid will be lifted the pump.

Thus it is very essential to prime the pump properly and it should be noted that during priming delivery valve is kept closed. After priming the delivery valve is kept still closed and prime mover (generally electrical motor) is started to rotate the impeller. The rotation of impeller in the casing full of liquid produces a forced vertex which is responsible for imparting a centrifugal head to the liquid. Rotation of impeller effects a reduction of pressure at the center. This causes liquid in the suction pipe to rush in to the eye. The speed of the pump should be high enough to produce centrifugal head sufficient to initiate discharge against the delivery head. When pump attains a constant speed, delivery valve Is gradually opened and thus liquid is allowed to flow in a radially outward direction through the impeller vanes and attains a higher velocity and pressure nat the outer periphery. With in the help of special shape of casing (volute, vortex or diffuser) this higher velocity energy is converted into pressure energy and reduce high velocity. Now this water at higher pressure rises through the delivery piper in to a desired height. At the same time centrifugal action creates partial vacuum at the center. The partial vacuum causes the water to rush through the suction pipe towards the impeller eye, to take the place of water which has left the impeller vanes, from the pump (where the pressure is atmospheric). Thus, in this way water reaches and leaves the impeller continuously and water is raised to a certain height at a constant rate.

Hydraulic losses due to friction:-

Fluid friction:-

Frictional losses occur due to flow of fluid closed containers (passages in impeller) which are made of metallic surfaces. The method of determining the loss of head due to friction is by considering the pump to be a series of short passages and find the loss in each for given flow. This procedure is too laborious to be practical and seldom used. The losses also increases with the wetted areas of the passages, hence they should be kept small. It increases too with the roughness of the surfaces of the impeller, volute and casing passages. They should therefore, be made as smooth as possible.

Turbulence:-

Since the velocity of flow in the pump is very high, turbulence is bound to occur in the places where changes in area occurs suddenly, like inlet and outlet edges of impeller and diffuser (or volute). These losses are known as shock or turbulence losses. Since the inlet and out let angles of impeller and diffusers are designed for a particular speed of rotation (or flow rate Q) the guidance to liquid flow shall not be proper at other speeds (or flow rates) due to which eddy current are set up. Eddy current losses are proportional to the square of velocity or flow. Since the impeller is designed for certain discharge rate, at that particular rate, turbulence shall be minimum or zero.

Disc friction:-

The power required to rotate a disc in a fluid is known as the disc friction. The usual impeller has enclosed sides which rotate in the fluid and power required for this rotation must be supplied by electric motor.

H.P lost in disc friction=$1.83 * Vo^3 * D^2/1000$

This is the Pfleiderer's equation in British units.

Where V_0=Rim Velocity in ft/sec,

D=Diameter of the impeller in inches

Lekages:-

In the casing, the liquid at delivery side being at heigh pressure, has a tendency to leak through clearances between casing and impeller to either suction side or out side. Although leakage has no direct bearing on the head developed by a pump, the capacity of pump, i.e., rate of discharge is severely affected.

Mechanical losses:-

The frictional losses involved between the stationary elements of pump and rotating shaft are taken as **mechanical losses.** These include frictional losses in stuffing box (packing) or in mechanical seals, bearings and couplings etc. and may vary from 2 to 4% of B.H.P. (break horse power supplied to pump by its prime mover which may be electric motor, diesel/Petrol/Steam engines and compressors etc.)

Power required by pump:-

The work performed by the pump is equal to the

Weight of the liquid in unit time * Total head in meters.

$$Power = \frac{Disch\arg e \times Sp.Gravity \times H_m}{102 \times \eta}$$

Q= Discharge in Lps

Hm= Manometric head in meters

η_o= Overall efficiency of the pump

Head of pump:-

It is the head at which water is developed is delivered by the pump. According to the range of working head, pumps are divided as

1.Low head

2.Medium head

3.High head pumps.

Different head description was given below.

Velocity head(hv):-

This is the kinetic energy per unit weight of liquid handled at a given section and is expressed by the formula $hv=v^2/2g$

Static suction head (hss):-

When the liquid level in an open vessel is the pump datum, static head is the difference in elevation between the pump datum and liquid level in the suction vessel, the pressure acting on the liquid level in the vessel, is above the atmospheric pressure. Then it is to be added hsl and if it is below the atmospheric pressure then it is to be deducted from hsl. In order to arrive at the static suction head, thus hss = ± hsl ± ps.

Total suction head(hs):-

Suction head exists when the total suction head is above atmospheric pressure head, this is equal to the static suction head minus the friction and entrance losses in pipe line, total suction head as determined on the test bed is the reading of a suction gauge at the suction nozzle of the pump corrected to the pump datum plus velocity head At the point of measurement thus.

$hs=\pm hss-hfs-Vs^2/2g$

It is the value of hs is negative i.e., the total suction head is below atmospheric pressure head. Thus total suction lift exists.

Static delivery head (hsd):-

When the pump discharges into an open vessel, at the static delivery head is the difference in elevation between the pump datum and the highest point of delivery.

When the pump discharges into a closed vessel, the pressure acting on the liquid level in the vessel if above the atmospheric pressure it is to be deducted from hdt, in order to arrive at the static delivery head.

Thus hsd=hdl±pd

Total delivery head:-

This is some of total static delivery head and friction head and exist losses in the delivery pipe line.

$Hd=hsd+hfd+vd^2/2g$

Total head (hm):-

This is the actual head against which the pump has to work. It is equal to the static head plus all the head losses occurring in flow before, through and after impeller.

Hm=Static suction head(hss) + Static delivery head(hd) + total loss of head (hl)

Figure 4.4 shows different heads.

Conclusions:-

In the design of the pump for given problem, the following points are considered.

1. The head & capacity correction factor for 5% consistency pulp is taken as 0.87 from data book.
2. The out let vane angle is kept slightly larger than the inlet angle to obtain the smooth continuous passage.
3. Deep grove ball bearing is selected to take axial and radial loads.
4. Flexible coupling is selected to connect the shafts of motor and pump. This taken care of the motor & pump misalignment.

In order to reduce the turbulence the total divergence in the volute divergent nozzle angle should not exceed 10^0 to 12^0

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