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Design of Centrifugal Pump

Ketki Shirbavikar[1], Krushna Lohar[2], Aarya Kurlekar[3], Shreyash Patil[4]

Assistant professor, Department of Mechanical Engineering, VIT, Pune, India[1]

Student, Department of Mechanical Engineering, VIT, Pune, India[2-4]

Abstract: In the world, pump technology has been successfully applied. Today, pumps are used and applied everywhere. If these devices did not operate, modern public utilities, chemical factories, municipal water, and sewage works, and other fields too numerous to mention would be severely hampered. As everyone is aware, a pump uses a motor to transform mechanical energy into hydraulic energy. We will design the centrifugal pump for this fluid engineering project by creating components, including the volute casing. We adhere to the accepted design process in this design process. we modelled it in SolidWorks and used this modelling to understand how the centrifugal pump functions.

Keywords: Centrifugal Pump, Speed, Input Power, Blade Number.

I. INTRODUCTION

The centrifugal pump is a mechanical device that moves water from one area of lower pressure to another area of higher pressure. kinetic energy is provided to the pump, which transforms the fluid's hydraulic energy. It consists of a revolving impeller inside a pump casing. The dynamic action of the dynamics pump involves the transfer of energy through rotating motion. The drive shaft's mechanical energy serves as the pump's input power, while hydraulic energy serves as its output power. The fluid experiences a force from the rotating blade system, which causes it to move. Mechanically, the fluid entering the pump is forced in the direction of the exit, where positive pressure is produced. Pumps are categorized in a variety of ways depending on their use, requirements, design, and environment.

The liquid is forced into a series of revolving vanes in a centrifugal pump by pressure from the atmosphere and other sources. A centrifugal pump uses centrifugal force to add energy to a fluid by having a series of revolving vanes enclosed inside of a housing or casing.

A pump converts mechanical energy from an outside source to the liquid passing through it, and losses always occur during energy conversion. The Euler equation makes a prediction about the transmitted energy. Losses between fluid power and mechanical power of the impeller or runner are the energy transfer quantities.

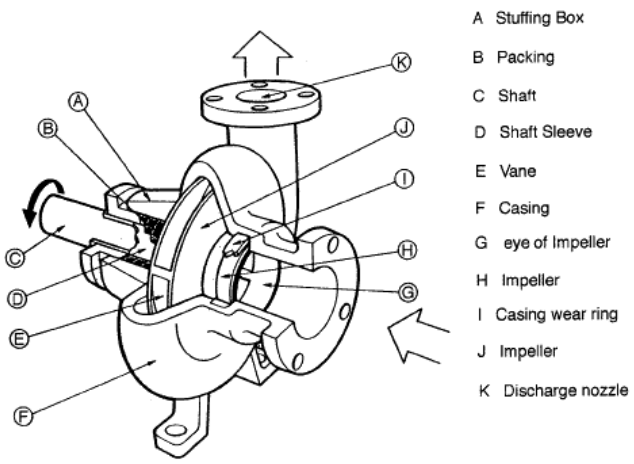

Fig 1. Components of a Centrifugal pump

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A. *BASIC PRINCIPLE OF CENTRIFUGAL PUMP*

Centrifugal pumps are also necessary so that the fluid can be made powerfully available to the pump suction nozzle. Liquid cannot be drawn into the pump housing using centrifugal pumps. The volute and impeller are a centrifugal pump's main pumping components. The shaft to which the impeller is attached. Some pumps are connected to pulleys or transmissions, so the shaft is driven by the motor or driver. The liquid enters the impeller's eye and becomes wedged between the blades. As the liquid moves from the impeller eye toward the outside diameter of the impeller, the impeller blades contain it and give it speed. Low pressure develops in the impeller's eye as the fluid's velocity increases. The liquid needs to enter the pump with enough force. At a rapid rate of speed, the liquid exits the impellers outside diameter and enters the volute's interior casing wall. The mechanical power is the centrifugal pump's input, while the hydraulic energy is its output. To transport water or other materials to the desired location, a mechanism for converting mechanical energy to hydraulic energy is used.

II. DESIGN CALCULATIONS

The following design parameters are used in the design calculation:

1.Static Suction head, H_S = 2.5m
2.Static head at delivery, H_d = 16m
3.Length of suction pipe, L_s = 5m
4.Length of delivery pipe, L_d = 18m
5.Actual discharge, Q_{act} = 1500 lpm
6.Working fluid = water at room temperature
7.Density of water, ρ = 1000 kg/m3

i.Design of Suction and Delivery Pipe

A pump is a mechanical device that moves fluids, solid wastes, chemicals, slurries by mechanical action.

$$Q_{act} = 1500 \times \frac{10^{-3}}{60} = \mathbf{0.025\ m^3/s}$$

To avoid cavitation let's assume that

1. Velocity at Suction pipe, V_s = 2 m/s
2. Velocity at Delivery pipe, V_d = 5 m/s

$$Q_{act} = Q_{th} \times \eta_v$$

Theoretical Discharge,

$$\mathbf{Q_{th} = 0.0263\ m^3/s}$$

- For Suction Pipe,

By Continuity Equation,

$$Q_{th} = A_s \times V_s$$

Here, $A_s = \frac{\pi}{4} \times d_s^2$

Diameter of Suction pipe, $\mathbf{d_s}$ **= 0.1294 m**

- For Delivery Pipe,

By Continuity Equation,

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$$Q_{th} = A_d \times V_d$$

Here, $A_d = \frac{\pi}{4} \times d_d^2$

Diameter of Suction pipe, $\boldsymbol{d_d}$ **= 0.0818 m**

ii.Manometric head, H_m

The head against which a centrifugal pump must work is known as the manometric head.

$$H_m = H_S + H_d + \frac{V_d^2}{2g} + H_{losses}$$

- Losses in pipe, H_{losses}

$$H_{losses} = h_{fs} + h_{fd}$$

Here, h_{fs} = frictional head loss in suction pipe

h_{fd} = frictional head loss in delivery pipe

Formula for head losses in pipe,

$$h_f = (f\frac{L}{D} + K)\frac{V^2}{2g}$$

Here, f = frictional factor

L = pipe length

D = pipe diameter

K = fitting factor

V = liquid velocity

g = acceleration due to gravity

frictional head loss in suction pipe, h_{fs}	0.5219 m
frictional head loss in delivery pipe, h_{fd}	12.5 m

Manometric head,

$$H_m = 2 + 16 + 0.5219 + 12.5 + 1.27$$

$$\boldsymbol{H_m = 25.78\ m}$$

iii.Selection of Motor

Power required to run impeller aka Input Power (P)

The mechanical power that the drive transfers to the pump shaft or coupling is known as input power. Watts are the SI unit used to measure input power (W)

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$$P = \frac{\rho \times g \times H_m \times Q}{\eta_o}$$

Here, P = input power of the centrifugal pump

ρ = density of water

η_o= pump overall efficiency

for, $\eta_o = \eta_{mano} \times \eta_v \times \eta_m$

Here, η_{mano} = Manometric Efficiency = 95%

η_v = Volumetric Efficiency = 95%

η_m = Mechanical Efficiency = 95%

Hence, **η_o = 0.8513**

Hence, Input power required will be,

P = 7.764 KW

From required input power to shaft selecting 11KW foot mounted 3∅ induction motor running at 1440 rpm selected (PSG 5.124)

$$n_s = N\frac{\sqrt{Q}}{{H_m}^{\frac{3}{4}}}$$

Here, n_s = Specific Speed

Q = Capacity

N = rotational Speed

H_m= Manometric head

iv.Design of Impeller

Finding the no of required blade, z

$$z = 6.5[\frac{D_1 + D_2}{D_2 + D_1}]\sin(\frac{\theta + \emptyset}{2})$$

Here, D_1 = Inlet impeller diameter

D_2 = Outlet Impeller diameter

θ = blade angle at inlet

∅ = Blade angle at outlet

- For Inlet diameter / eye diameter of Impeller,

D_1 = Suction pipe diameter, d_s

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D_1 = 0.1295 m

The blade velocity at inlet, U_1

$$U_1 = \frac{(\pi \times D_1 \times N)}{60}$$

$$\boldsymbol{U_1 = 9.764\ m/s}$$

- For Outlet diameter of Impeller

The blade velocity at outlet, U_2

$$U_2 = K \times \sqrt{2g}H_m$$

$$\boldsymbol{U_2 = 21.37\ m/s}$$

$$U_2 = \frac{(\pi \times D_2 \times N)}{60}$$

$$\boldsymbol{D_2 = 0.283\ m}$$

- Velocity Triangle, ΔV

It is better to explore the various component velocities of flow through an impeller graphically using velocity vectors. These vector diagrams are known as velocity triangles because of their triangular shape. It can be drawn for any point along the flow route through the impeller, although the entrance and outflow triangles typically receive the most attention.

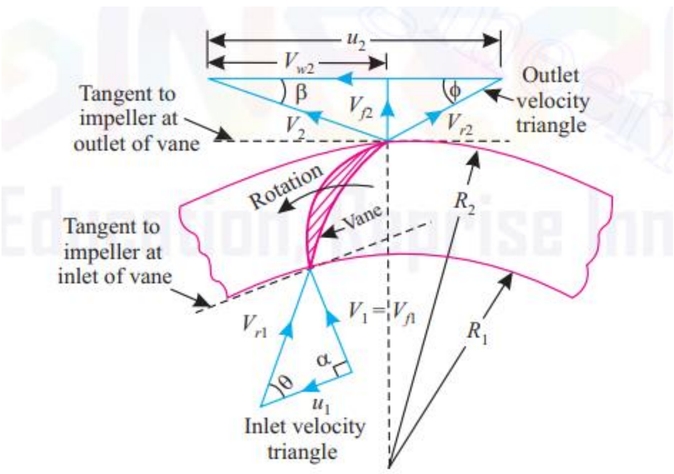

Fig 2. Velocity-Triangle diagram.

Here, V = Absolute velo of water at inlet & Outlet

U = Blade velo of inlet and outlet

V_{f1} = Velocity of flow at inlet

V_{r1} = Relative velo of water at inlet

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V_{w1} = velocity of whirl at inlet

- Blade angle at Inlet, θ

$$\tan\theta = \frac{V_1}{U_1}$$

$$\boldsymbol{\theta = 11.57^{\circ}}$$

- Blade angle at Outlet, $\emptyset$

$$\tan\emptyset = \frac{V_{f2}}{U_2 - V_{\omega 2}}$$

$$\emptyset = \mathbf{22}^{\circ}$$

For no of blade, z

$$z = 6.5[\frac{D_1 + D_2}{D_2 + D_1}]\sin(\frac{\theta + \emptyset}{2})$$

$$\mathbf{z = 5.044} \cong \boldsymbol{6\ blades}$$

width at inlet and outlet of impeller,

$$Q_{th} = AV$$

$$Q_{th} = \pi BDVK$$

Width at inlet, $\boldsymbol{B_1 = 0.035\ m}$

Width at outlet, $\boldsymbol{B_2}$ **= 0.089 m**

v.Design of Casing

Material used for volute casing is GCI40

having, $\sigma_{out} = 400\ N/mm^2$

therefore, $[\sigma_t] = \frac{\sigma_{out}}{6} = \boldsymbol{66.67\ N/mm^2}$

Assuming casing thickness, **t = 20mm**

Volute casing subjected to circumferential hoop stresses given by: $\sigma_t = \frac{PD}{2t}$

Here, P = Pressure inside casing

P = ρgz

Where, z = $H_m + \frac{V_s^2}{2g} = \boldsymbol{25.98m}$

P = $\rho gz = 2548638\ N/m^2$

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Design pressure, $P_d = = 1.3P = \mathbf{331332.94\ N/m^2}$

$D_{eq} = D_2 + clearance = 283 + 20 = \mathbf{303mm}$

$\sigma_t = \frac{PD}{2t} = \mathbf{2509771.28\ N/m^2}$

$\boldsymbol{\sigma_t} < [\boldsymbol{\sigma_t}]$ Therefore, design is safe

Velo of throat will be 30% of impeller velo at outlet, $\boldsymbol{V_{th} = 6.591\ m/s}$

By continuity equation,

$Q_{th} = A_{th} V_{th}$

$d_{th} = 0.071\text{m} = \mathbf{71mm}$

Calculating diameter of casing at different angles,

$$d_\omega = d_{th}\sqrt{\frac{\omega}{360-\theta}} + D_{eq}$$

TABLE I

ω	d_ω
0	303 mm
90	338.5 mm
180	353.35 mm
270	364.49 mm
360	374

B. MODEL

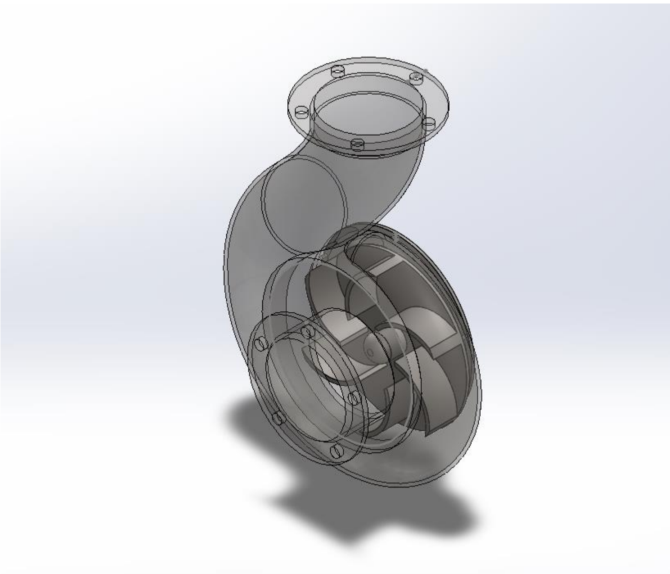

Fig 3. CAD Model

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III. RESULTS

Below are the conclusions drawn from design and specs.

- Diameter of Suction pipe (d_s) = 0.1294 m
- Diameter of Delivery pipe (d_d) = 0.0818 m
- Manometric Head (H_m) = 25.78 m
- Overall Efficiency (η_o) = 0.8513
- Input / Shaft Power = 7.764 KW
- Blade angle at inlet (θ) = 11.57°
- Blade angle at outlet ($\emptyset$) = 22°
- No of required blade in impeller (z) = 6

IV. CONCLUSION

By completing the course project of HMAFP our group come to know –
Design aspects of centrifugal pump (volute casing)

Main components of centrifugal pump and various types of casing and impeller.

Working of centrifugal pump.

Modelling of centrifugal pump in SolidWorks

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