# Design of Double-Suction Centrifugal Pump Impeller and Casing

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***Abstract- The main objective of this paper is to design a double-suction centrifugal pump which can produce hydraulic energy by using water pressure. The double-suction centrifugal pump is chosen because it can widely use in the field of municipal water works, drainage system, power plants, agriculture, irrigation work and many other utility services and industries. A centrifugal pump includes an impeller mounting on a shaft coupled to the driving unit. The impeller comprises a central hub on which the curved vanes are mounted. The unit has a finite number of vanes; the number of vanes is selected to assure motion of the liquid in the desired direction varies with the specific speed. A centrifugal pump consists essentially of rotating element, stationary element, suction pipe and delivery pipe. In this research, dimensions are calculated for the design point of 45 m head, 25m³/min of flow rate and rotational speed of 1450 rpm. The inner diameter of impeller is 297 mm and the outer diameter is 471 mm. The passage width at inlet is 50 mm per side and total passage width at outlet is 80.838 mm. The blade angles at inlet and outlet are 13.31° and 20° respectively. The number of blades is eight. The design of volute is based on the impeller outside diameter and impeller outlet width. In this design, volute circle diameter is 546 mm, volute width is 88 mm and volute casing is horizontal split type.***

***Indexed Terms- Casing; Centrifugal Pump; Design; Double Suction; Impeller***

## I. INTRODUCTION

Pumps are used in a wide range of industrial and residential applications. Pumping equipment is extremely diverse, varying in type, size, and materials of construction. There have been significant new developments in the area of pumping equipment. They are used to transfer liquids from low-pressure to high pressure in this system, the liquid would move in the opposite direction because of the pressure difference. Centrifugal pumps are widely used for irrigation, water supply plants, stream power plants, sewage, oil refineries, chemical plants, hydraulic power service, food processing factories and mines. Moreover, they are also used extensively in the chemical industry because of their suitability in practically any service and are mostly used in many applications such as water pumping project, domestic water raising, industrial waste water removal, raising water from tube wells to the fields. The application of designed pump is used to water pumping for irrigation. A centrifugal pump delivers useful energy to the fluid on pump age largely through velocity changes

That occur as this fluid flows through the impeller and the associated fixed passage ways of the pump. It is converting of mechanical energy to hydraulic energy of the handling fluid to get it to a required place or height by the centrifugal force of the impeller blade. The input power of centrifugal pump is the mechanical energy and such as electrical motor of the drive shaft driven by the prime mover or small engine. The output energy is hydraulic energy of the fluid being raised or carried.

The centrifugal pump may be either single or multi-stage. In addition, the single-stage centrifugal pumps may be either single-suction or double-suction. In single-suction centrifugal pumps, the water enters on one side of the casing and impeller. Double-suction centrifugal pump is usually used in water service. A double –suction impeller is the same as in effect as two single-suction impellers placed back to back on a horizontal shaft, supported by bearings on either side. This type allows liquid to enter the eye of impeller from both sides.

## II. DESIGN OF DOUBLE SUCTION CENTRIFUGAL PUMP

The design pump is a double suction centrifugal pump. Impeller is designed on the basic of design flow rate, pump head and pump specific speed. So design data are required. For design calculation, the design parameters are taken as follows:

Head, H = 45m
Discharge, Q = 25$m^3$/min
Rotational speed, n = 1450 rpm
Density of water ρ = 1000kg/$m^3$
Acceleration due to gravity, g = 9.81m/$s^2$

Specific speed, $n_s = \frac{n \times \sqrt{Q}}{H^{3/4}}$ (1)

The input power P is calculated by the following.Equation. $P = \frac{\rho g Q H}{\eta}$

(2)

The volumetric efficiency is determined by the following equation. $\eta_V = \frac{1}{1 + 1.124/n_s^{2/3}}$ (3)

The diameter of shaft is obtained by the following equation, $d_s^3 = \frac{16T}{\pi S_s}$ (4)

The torsion moment is estimated by:

$$T = \frac{P \times 60}{2\pi n} \quad (5)$$

The diameter of the impeller eye

$$D_0 = K_0 \sqrt[3]{Q/n} \quad (6)$$

Impeller inlet velocity $V_{m1} = K_{m1}\sqrt{2gH}$ (7)

Impeller outlet Velocity $V_{m2} = K_{m2}\sqrt{2gH}$ (8)

Impeller inlet diameter,

$$D_1 = (1.1 \sim 1.5) K_0 \sqrt[3]{\frac{Q}{n}} \quad (9)$$

The outlet diameter of impeller

$$D_2 = 19.2\left(\frac{n_{sopt}}{100}\right)^{1/6} \frac{\sqrt{2gH}}{n} \quad (10)$$

Inlet peripheral velocity is calculated by using equation, $U_1 = \frac{\pi D_1 n}{60}$ (11)

Outlet peripheral velocity is calculated by using equation, $U_2 = \frac{\pi D_2 n}{60}$ (12)

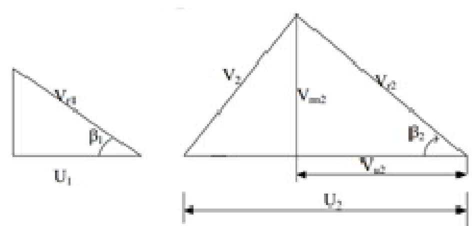

Figure 1. Inlet and Outlet Velocity Diagram

Impeller Inlet and Outlet Angle

The water is assumed to enter the vanes radially, so that the absolute velocity is 90°. After $V_{m1}$ and $U_1$ have been determined, the impeller inlet angle is obtained by the equation,

$$\beta_1 = \tan^{-1}\left(\frac{V_{m1}}{U_1}\right) + (0 \sim 6) \quad (13)$$

The blade outlet angle may be selected within fairly limits. The outlet angle is usually made between 15˚ and 35˚. It is usually made slightly larger than the inlet angleto obtain a smooth and continuous passage. The number of blades is calculated by using the following equation.

The number of blades

$$Z = 6.5 \times \frac{(D_2 + D_1)}{(D_2 - D_1)} \times \sin\left(\frac{\beta_1 + \beta_2}{2}\right) \quad (14)$$

The impeller inlet passage width,

$$b_1 = \left(\frac{Q'_s}{2\pi D_1 V_{m1}}\right) \times \left(\frac{\pi D_1}{\pi D_1 - S_1 Z}\right) \quad (15)$$

$$b_2 = \left(\frac{Q'_s}{\pi D_2 V_{m2}}\right) \times \left(\frac{\pi D_2}{\pi D_2 - S_2 Z}\right) \quad (16)$$

| Sr No | Dimension | Value | Unit |
|---|---|---|---|
| 1 | Specific speed | 295 | rpm |
| 2 | Pump output power | 238.89 | kW |
| 3 | Motor Power | 334.4 | kW |
| 4 | Volumetric efficiency | 97.5 | % |

| | | | |
|---|---|---|---|
| 5 | Diameter of hub | 120.57 | mm |
| 6 | Length of hub | 138 | mm |
| 7 | Diameter of impeller eye | 270.56 | mm |
| 8 | Impeller inlet diameter | 297.6 | mm |
| 9 | Impeller outlet Diameter | 471.2 | mm |
| 10 | Impeller inlet tangential velocity | 22.60 | m/s |
| 10 | Impeller outlet tangential velocity | 35.77 | m/s |
| 11 | Impeller Inlet width | 49 | mm |
| 12 | Impeller outlet width | 80.84 | mm |
| 13 | Number of blades | 8 | - |
| 14 | Impeller inlet angle | 13.31 | Degree |

Required Parameters for Impeller Blade Shape

To draw the curvature of the blade curve equally spaced circles are drawn between impeller outside circle and impeller inside circle. Vane slope angles are also drawn. The angle between $\beta_1$ and $\beta_2$ are equally divided into three angles.
Impeller outside diameter = 471.2 mm
Radius = Diameter/2 = 471.2 = 235.6 mm
Impeller inside diameter, $D_D = D_{1h}$ = 189.392 mm
Radius, $R_D$ = 94.66mm

$$\rho_A = \frac{\left(R_A^2 - R_B^2\right)}{2\left(R_A \cos\beta_2 - R_B \cos\beta_B\right)} = 237.8mm$$

$$\rho_B = \frac{\left(R_B^2 - R_C^2\right)}{2\left(R_B \cos\beta_B - R_C \cos\beta_C\right)} = 180.96mm$$

$$\rho_C = \frac{\left(R_C^2 - R_D^2\right)}{2\left(R_C \cos\beta_C - R_D \cos\beta_1\right)} = 125mm$$

Base circle radii and blade curved angles for impeller are shown in the following table 2.

Table 2. Base Circle Radii and Blade Curve Angles

| Parameter | Value | Unit |
|---|---|---|
| $R_A$ | 70.42 | mm |
| $R_B$ | 55.19 | mm |
| $R_C$ | 39.97 | mm |
| $R_D$ | 24.75 | mm |
| $\beta_2$ | 23 | Degree |
| $\beta_B$ | 22 | Degree |
| $\beta_C$ | 21 | Degree |
| $\beta_D$ | 20 | Degree |

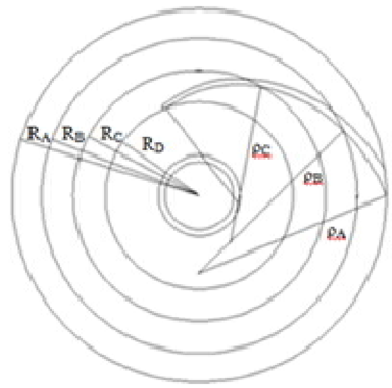


Figure 2. Drawing of Impeller Blade Shape

Design Calculation of Volute Casing

The specifications of the volute casing design are

Flow rate, Q = 0.4167 $m^3$/s
Pump head, H = 45 m
Pump speed, n = 1450 rpm
Impeller diameter at outlet, $D_2$= 471.2 mm
Impeller outlet width, $b_2$ = 80.838 mm
Shroud thickness = 3 mm

Calculation of Average Flow Velocity

Average flow Velocity,

$$V_v = K_v\sqrt{2gH}$$
$$= 10.69 \text{ m/s}$$

Calculation of Volute Area

The volute area at the throat,

$$A_v = \frac{Q}{V_v} = 38980.355mm^2$$

Other volute sections,

$$A_{vi} = A_{vi} \times \frac{i}{8}$$

Where, the value of i is from 1 to 8 representing the volute sections.

So, the value of first section

$$A_{v1} = A_v \times \frac{1}{8} = 4872.544 \text{ mm}^2$$

The values of $A_{v1}$ to$A_{v8}$ are calculated as the calculation of $A_{v1}$ and they are tabulated as follows.

Table 3. Values of VoluteAreas

| Section , i | $A_{vi}$ ($mm^2$) |
|---|---|
| 1 | 4872.544 |
| 2 | 9745.088 |
| 3 | 14617.633 |
| 4 | 19490.177 |
| 5 | 24362.722 |
| 6 | 29235.266 |
| 7 | 34107.811 |
| 8 | 38980.355 |

Calculation of Volute Base Circle Diameter

Base circle diameter is calculated by the following relation

$$\frac{D_3 - D_2}{D_3} \times 100 = 16$$

$D_3$ = 546.59mm

Calculation of Volute Width

Volute width is estimated by the following equation

$$b_v = b_2 + 2 \times \text{shroud thickness} + 2 \times \text{clearance}$$

$b_v$= 91.838 mm

Calculation of Requirements for Laying Out Volute Casing

Other requirements are the value of $\rho_{vi}$ and$r_{vi}$ for laying

$$\rho_{vi} = \sqrt{\frac{A_{vi} + 0.604 b_v^2}{0.367}}$$

For i= 1, i.e., for drawing the cross sectional shape of the first volute cross section,

$$\rho_{vi} = \sqrt{\frac{38980.355 + 0.604 \times 91.838^2}{0.367}}$$

$\rho_{vi}$ = 346.546 mm

The relationship between $\rho_{vi}$ and $r_{vi}$

$r_{vi} = 0.206\rho_{vi}$

$= 0.206 \times 346.546$

$r_{vi}$ = 71.388 mm

Table 4. Values of Volute Areas and Parameter for Laying out Cross Section Shape of Volute Sections

| i | $A_{vi}$($mm^2$) | $\rho_{vi}$(mm) | $R_{vi}$(mm) |
|---|---|---|---|
| 1 | 4872.54 | 164.796 | 33.947 |
| 2 | 9745.09 | 201.082 | 41.423 |
| 3 | 14617.6 | 231.756 | 47.741 |
| 4 | 19490.2 | 258.819 | 53.316 |
| 5 | 24362.7 | 283.309 | 58.361 |
| 6 | 29235.3 | 305.844 | 63.004 |
| 7 | 34107.8 | 326.829 | 67.326 |
| 8 | 38980.4 | 346.546 | 71.388 |

Table 4 shows values of volute areas and parameter for laying out cross section shape of volute sections. Figure 4 shows two dimensional view of impeller. Figure 5 shows volute casing.

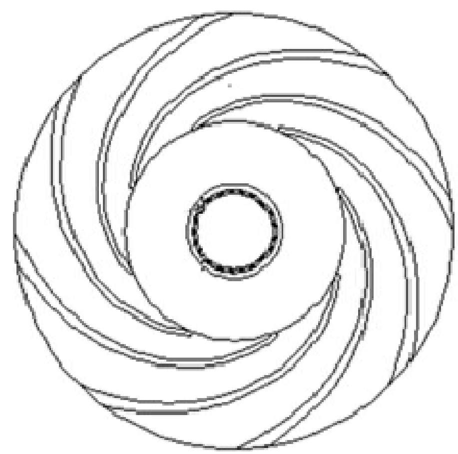

Figure 3. Two Dimensional View of Impeller

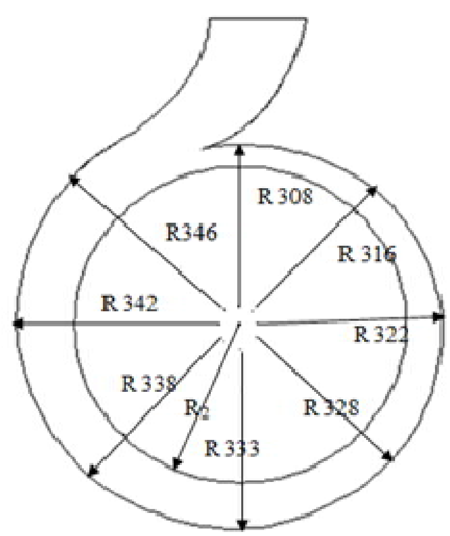


Figure 4. Two Dimensional View of Volute Casing

## III. RESULT AND DISCUSSION

This research is “design of double-suction centrifugal pump for irrigation” which is divided into three main parts. First, detail design calculation of impeller profile and casing is done. And then, prediction of characteristic curve of a centrifugal pump is made. Finally, the performance of centrifugal pump improves by changing geometric characteristic of the impeller. The application and use of centrifugal pumps today are universal. Modern public utilities, chemical plants, municipal gas, water and sewage works, and other fields too numerous to mention would be seriously handicapped if these machines did not exist.

In designing centrifugal pump, the usual design is based upon a certain desired head and capacity at which the pump will operate most of time. The calculation of design consists of not only impeller dimensions but also casing dimensions. Detailed drawings of the impeller and casing are drawn by Auto CAD software. Changing some geometric characteristic of the impeller in centrifugal pumps improves their performance. It is known that blade exit angle plays very important role in the performance of a centrifugal pump. Moreover the blade exit angle has significant effect on the head and efficiency of the centrifugal pump. It is found from this investigation, both head and efficiency of centrifugal pump increases with increasing in blade exit angle.

For higher head to be developed, the inlet vane angle should be low. But if this angle is too small, cavitation can exist. For this effect, the entrance vane angle must be within the limits, from 10° to 25°. The discharge vane angle of impeller must be large to get high head. But the power consumption is large if this angle is greater than 90°. If the angle is lower than 90°, the power consumption is low. The optimum discharge angles are found between 15° and 40°. It is usually made slightly higher than the value of inlet vane angle to obtain a smooth, continuous passage.

In the volute cross-section shapes drawing, the cross sectional shape of each volute section is drafted first. They are of similar shape except they increase in size to the discharge nozzle. So, there are eight volute cross-sectional shapes drawn together in one drawing.

The aim of designed pump is only to pump the water and not for other fluid. There is nothing to clog in the impeller and therefore closed type impeller can be used, because the closed type impeller produced the higher efficiency than the open or semi-enclosed type impeller. Also the close type impeller produces less axial thrust than that of the open one. To reduce the leakage from discharge to suction between the casing and impeller, the clearance must be made very small. Impeller is made of bronze to protect corrosion. The pump efficiency must be maintained by eliminating or reducing the leakage and disk friction losses.

## IV. CONCLUSION

The designed pump is aimed to use in river pumping project which has about twelve working hours per day and requires high head and capacity. So, double-suction centrifugal type is selected. The casing is horizontal split casing type. The design head is 45 m and the discharge is 0.4167$m^3$/s.The pump can run at 1450 rpm to attain higher head. The impeller inlet is 297.616 mm and the outlet diameter is 471.15 mm. The inlet blade angle has 13°and the outlet blade angle of impeller has 20°. The impeller thickness is 4 mm to layout the impeller blade. A volute casing is also calculated from the impeller outlet dimensions.The pump efficiency is 77% in this design.

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