Design & manufacturing of centrifugal pump

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Abstract - *A pump is a machine that supplies or absorbs mechanical energy and transfers hydraulic energy to the fluid. Within the various components that comprise a pump, the rotor and the volute are responsible for playing an important role in the transfer of mechanical energy into pressure energy into the fluid. The present work deals with the design of the volute of a hydraulic machine approximately radial generating of the centrifugal type, using water as working fluid. The volute is a component generally located around the rotor in order to decelerate the fluid by transforming part of the kinetic energy into pressure energy. The process of using the volute is to collect the fluid leaving the rotor and direct it to the turbo machinery outlet with the greatest possible uniformity and efficiency. The design of the volute structure is characterized by a gradual increase as it is directed towards exit, this increase being responsible for reducing the losses by shock and turbulence. For the dimension of the volute, certain geometrical considerations were made: the angular velocity of the rotor is constant; there is no internal partition in the volute; between rotor and volute there is no diffuser system; and the volute has a logarithmic spiral shape, excluding the tongue and the outlet nozzle. As for the flow: the analysis of the flow in the volute was made in the transverse plane, and the flow in the volute was considered permanent.*

***Key Words*: pump volute, centrifugal pump, casing, BEP, Volute design**

1. INTRODUCTION

A hydraulic pump, according to Mataix (1986), is a machine that provides or absorbs mechanical energy and transfer it to the fluid. This component is also called hydraulic machine of operation and has a widely range of uses in industries. Among the several components that construct a pump, the rotor and the volute are the responsible for present an important role in transfer of mechanical energy into pressure energy for the fluid. Thus, they are very important for the mechanical engineering field.

The rotor is a rotating component that has blades, which prosecute the force into the liquid resulting in an acceleration of the fluid. Rotor spins at high speed in a continuous movement due to the force of the motor. That results in the suctioning of the liquid which causes a vacuums zone at the center and a zone of high pressure at the peripheries. There are classification of rotors, which can be about its stages, whereas multiples stages is necessary for reduce the dimensions and improve the efficiency. The other classification is about if the rotor is opened or closed. Wherein, opened rotor is used for fluid that presents impurities, while the closed one is for fluids without particles.

The casing is as shown in “Figure - 1”. So it makes as to produce an equal velocity of flow at all sections around the circumference and also to gradually reduce the velocity of the water as it flows from the impeller to the discharge pipe. A centrifugal pump volute increases in area from its initial point until it encompasses the full 360 degrees around the impeller and then flares out to the final discharge opening.

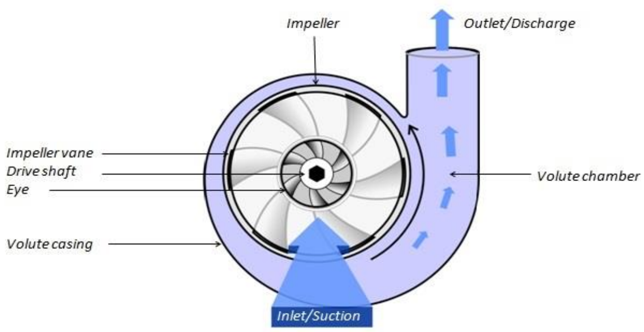


FIG (1)

In sum, the goal of the rotor is to improve the speed of the fluid. The volute is usually a component that is located around the rotor, its function is decelerate the fluid by transforming part of the kinetic energy into the pressure energy.

Thus, the role of the volute is to transport the fluid out of the rotor through a designed path until the turbo-machine outlet with greater efficiency and uniformity (Quintero, 2013). The design of the volute structure is, mainly, characterized by a gradual increase in diameter as it head for the exit. Due to this enlargement, it results in reduces the loss caused by turbulence shocks, as Guimarães(1991) said. In this paper, it will be discuss how to design and scale out a rotor and a volute of a centrifugal-type hydraulic turbine generator.

Moreover, the working fluid will be water, which will be considered incompressible. In addition,because it is an approximately radial pump, the width of its blades will not be constant, it will be equally spaced with the exit edge parallel to the rotor axis ignoring possible manufacturing defects. The turbo-machine will be considered as:diffuser, rotor, and volute (Quintero, 2013 Bruna R. Mariano, Leonardo R. Queiroz, Matheus S. C. Fonseca, Ruben A. M. Carrillo and Carlos E. C. Rodrigues

1.1 Purpose:

This work has as main purpose to design a impeller and a volute of high efficiency, based on the equation that the literature has. In addition, as a secondary objective, it is expected to develop the design of the projected elements as well as its Application , which will be done via 3D modeling.

1.2 Theoretical background:

Volute:

According to Quintero (2013) "Generating radial turbo-machinery (pumps and fans) generally have a volute around the outer periphery of the rotor" p.28, which aim to receive the fluid from the rotor outlet (in the design in question, there was no use of diffuser) and thus, to conduct this fluid to the pump outlet, uniformly. Non-uniformity may appear when the nominal flow is changed, resulting in non-uniformity of flow, radial forces on the machine axis and pressure oscillations. The volute is in the shape of a spiral or a curved funnel which increases its area as nearer to the discharge area as illustrated in Fig. 2 (Medeiros, 2009),

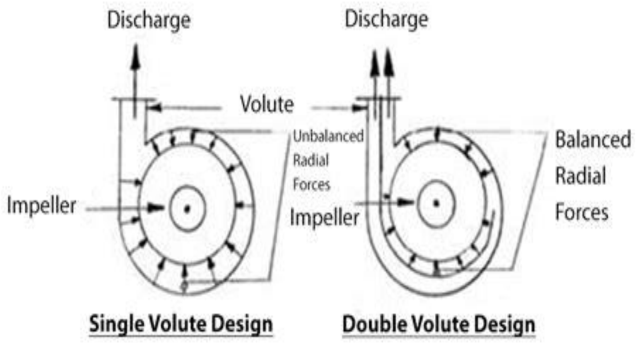


FIG (2)

There by reducing the velocity of the fluid and increasing its pressure. After the beginning of its spiral the volute grows uniformly so that a balance of the radial forces acting on the rotor along its periphery occurs. However even due to such configuration of this component, there is an uneven distribution of the pressure there-in, when the pump is operating outside its nominal point giving rise to a reaction perpendicular to the axis.

Such a reaction, called radial thrust, can be avoided by using the double volute, which consists of dividing the flow into two ducts, in order to balance the reactions caused by the pressure difference along the same conduit, as shown in Fig. 3 (Medeiros, 2009).

Another benefit of using the volute is that in pumps with this system the rotor can be reduced by up to 20% of the maximum value without loss of efficiency (Brasil, 2010).

2. Volute Design:

Casting is manufacturing process in which liquid material is poured in to a mould. This setup is known as core. Generally cores are used for making interior surfaces. Which contains a hollow cavity of the desired shape and then allow to solidify and this solidify part is known as casting. Volute are made of casting and we can see volute core as shown in figure – 2.

Volute throat area is the one of most important geometric parameter in pump design. It is observe that there is slight drop of the heights efficiency with the increase of throat area. As we can see in figure – 2 the throat area of the following o.5 hp pump is 15.04mm. By which we get flowrate of 142 LPM at 11meter head after experiment.

By removing material from throat area in such a way that it does not change diameter of discharge pipe as shown in figure - 3. We improved throat area like we removed 0.75mm material and increase the area of throat from 15.04 mm to 15.79 mm, so we can get more discharge.

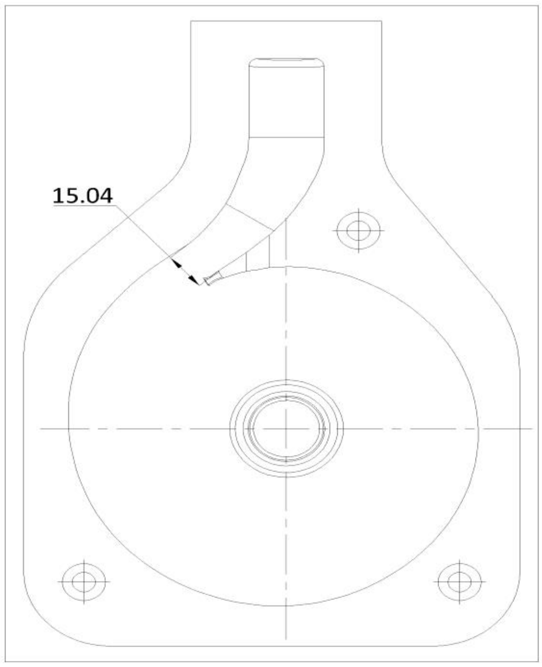


FIG (3) Volute core

3. DESIGN CALCULATION OF CENTRI-FUGAL PUMP VOLUTE CASING:

The known parameters from impeller calculation are:
Flow rate, Q = 0.16 m^3/min

Head, H = 11 m

Specific speed, Ns = 175.16 rpm

Suction pipe diameter, Ds = 25 mm

Impeller diameter at outlet, D2 = 123.5 mm

Shroud thickness, = 3 mm

Impeller outlet width, b2 = 4.2 mm

3.1.1 Calculation of Average flow velocity

$$V_v = Kv\sqrt{2gH}$$

V_v = average flow velocity in the volute casing (m/s)

k_v = experimental design factor = 0.41

g = gravitational acceleration (m/s^2) = 9.81

h = head required (m)

$$V_v = 0.41\sqrt{2 * 9.81 * 11}$$

$$= 6.02\ m/s$$

3.1.2 Calculation of Volute Areas

$$Av = \frac{Q_s}{V_s}$$

Where, A_v = volute area at throat (m^2)

Q_s = flow rate per second (m^3/min)

V_v = average flow velocity in the volute at the throat (m/s)

$$A_v = \frac{0.16}{6.02 * 60}$$

$$= 4.4296 * 10^{-4}\ m^2$$

$$= 44296\ mm^2$$

Since the volute casing is divided into eight sections Av is the volute area at the throat and it is denoted by A_v8 representing the area of volute section 8. Then, other volute sections are estimated by,

$$A_{vi} = A_v * \frac{i}{8}$$

$$= 44296 * \frac{1}{8}$$

$$= 5537\ mm^2$$

Calculation of volute width

$$b_v = 2b_2$$

$$= 2 * 4.2$$

$$= 8.4\ mm$$

3.1.3 Overall efficiency (η_o)

η_o = (head (H)* Discharge/6.2*power) * 100

$$= \frac{11 * 160}{6.2 * 1061} * 100$$

$$= 26.75\ \%$$

4. Results and Discussion

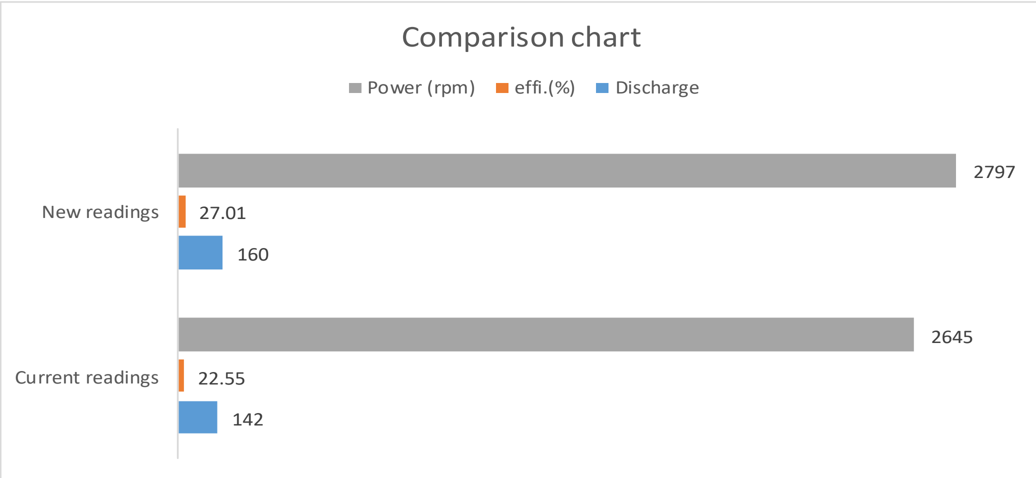
In this paper, the casing is designed for the end-suction single stage centrifugal pump for fresh water.

The design pump is 0.5 hp motor drive single state centrifugal pump. The designed pump can develop a head at 2645 rpm. The designed impeller has 31.8 mm inlet diameter, 123.5 mm outlet diameter, the number of vanes is 5. And then, the outlet width is 4.2 mm. The diameter of discharge flange is 25 mm. The maximum efficiency of this pump may be obtained in 26.75%.

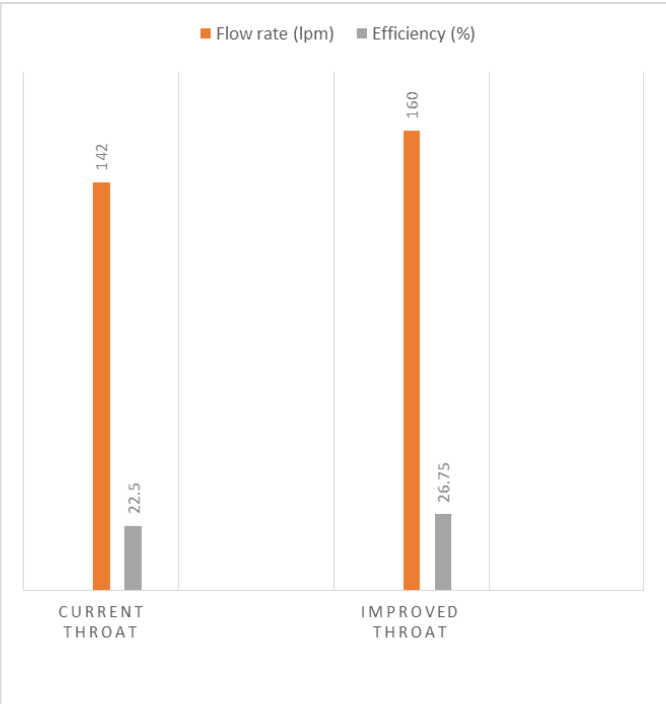
In this design, the volute casing is divided into eight volute sections of 45 angular spacing, which increase in proportion from cut-water to discharge nozzle. The design of volute areas or sections is very important in designing the volute casing. So, the volute area at the throat is calculated for eight volute sections from the value of average flow velocity in the volute casing. After design calculation procedure, the layout of pump casing is drawn with AutoCAD. The results of calculated and existing are not much different. These are expressed in the following “table - 1”.

	Volute throat area	Flow rate (lpm)	Efficiency (%)	Head (m)	Speed (rpm)	Watt
Current throat	39313 mm^2	142	22.50	11	2645	1158
Improved throat	44296 mm^2	160	26.75	11	2797	1061

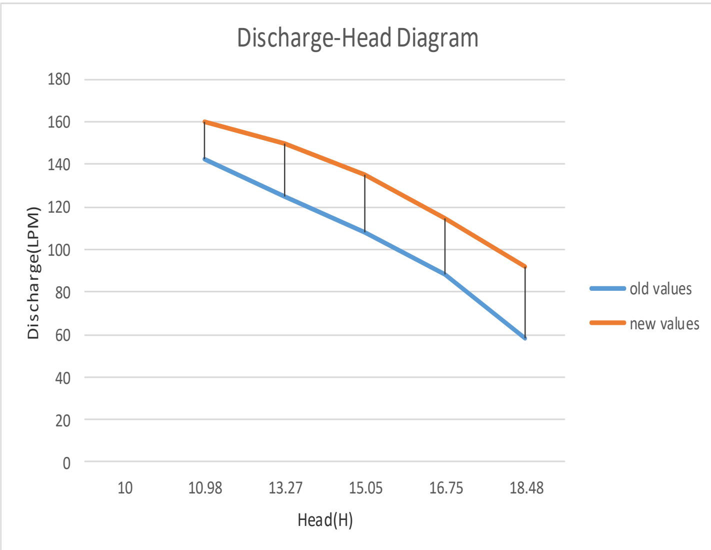
Table – (1)



Graph – (1)



Graph – (2)



Graph – (3)

5. CONCLUSIONS

We realize that several considerations must be made in order to determine the initial parameters of a design of a rotor and volute for centrifugal pumps. The considerations that the literature provides the directions of the calculation to be initiated, yet the experience of the designers is the one that allows the correct interpretation of the results, as well as exerts influence in the decision to continue along a path or to abandon it and to continue in other. Many challenges are encountered during manipulation of the variables involved in the calculation base, the relations that one exercises over the other, the iterative process that treats the error conditioned to the calculation process, in fact, many points that end up interrupting for some time the fluency of the project, but that in a way, allow the enrichment of the work as well as the increase of knowledge added to those that are part of this constructive process. The equation of exponential rise were used to determine the volute geometry. Through a simulation realized with the module Flow Simulation of Solid works, the behavior of the fluid was analyzed.

(a) To good distribution of mass (main function of the volute), the velocity through all the sections has to be the same.
As demonstrated, the Mach velocity along of all sections of volute remains constant.
(b) Generally, the recirculation mass zone is located almost at exit of volute. Meanwhile, because of not ideally location of tongue, this zone has moved to the spiral's begin.
(c) The exponential rise demonstrated to be an efficient method to design a volute.

However, considerations has to be carefully adopted, to avoid recirculation and decrease in flow

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