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Study on Overall Performance of Low Specific Speed Centrifugal Pump - A Review

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Abstract- **Since the olden times, the man has been trying to find some convenient ways of lifting water to higher levels and thus, the need of pumps arises. A pump which raises water or a liquid from a lower level to a higher level by the action of a centrifugal force is known as a centrifugal pump. Centrifugal pump finds its applications in sectors like HVAC, Chemical, Petroleum, Pharmaceutical industries. In this paper, the main focus is to study the overall performance of low specific speed centrifugal pump. For the study of overall performance, Throat area, Inlet width of volute and Rotation angle volute are taken into consideration.**

Index Terms- **Centrifugal Pump; Efficiency; CFD; Specific Speed.**

1. INTRODUCTION

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. Or in other words, a pump may also be defined as a machine, which converts mechanical energy into pressure energy. The pump which raises water or a liquid from a lower level to a higher level by the action of a centrifugal force is known as a centrifugal pump.

1.2 PUMP TYPES:

Depending on the direction of the flow at the impeller exit impellers are distinguished as radial, semi-axial and axial. Accordingly the terms radial, semi-axial and axial pumps are used; the latter are also called "propeller pumps". "Closed impellers" are the impellers with front shroud, those without a front shroud are termed "semi-open impellers" and those with large cut-outs in the rear shroud are designated as "open impellers". According to the flow direction at the diffuser inlet there are radial, semi-axial and axial diffusers. Vaneless diffusers are rarely built. The most frequent type of diffusing element for a single-stage pump is a volute. Sometimes there is a concentric annulus or a combination of annulus and volute.

1.3CENTRIFUGAL PUMP: SCHEMATIC, CONSTRUCTION AND WORKING

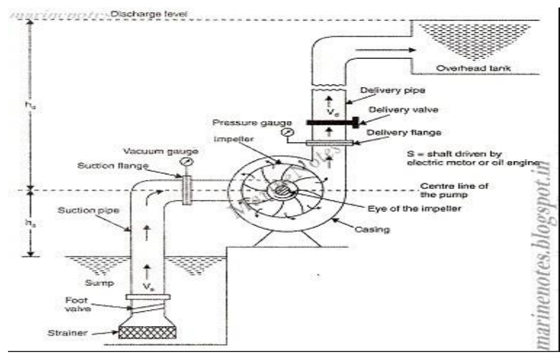

Fig. 1.1 Schematic diagram of centrifugal pump

Strainer prevents large particles from entering the pump. Foot valves are the valves to make sure that the pump is always primed. A pipe whose one end is connected to inlet of the pump and other end dips into water in sump is known as Suction pipe. The value of suction pressure is always below the atmospheric pressure in order to suck the water from lower level to higher level and hence Vacuum gauge is installed. Impellers are basically of 3 types. Viz. Open impeller, Semi-open impeller and closed impeller. Casing type can have a large impact on pump reliability and, to a lesser extent, pump efficiency when pump flow rates are above or below the best efficiency point (BEP). Single volute, double volute and vaned diffuser are the three basic types primarily used for centrifugal pumps. Delivery flange is the flange to connect the pump with the delivery pipe. A pipe whose one end is connected to the outlet of the pump and other end is to the overhead tank where the water is to be delivered is the Delivery pipe. Delivery valve is the Non-return valve which is provided at the position where the water comes out of the casing.

2. LITERATURE REVIEW

Reti characterized the first machine that could be used as a centrifugal pump was a mud lifting machine which appeared as early as 1475 in a treatise by the Italian Renaissance engineer Francesco di Giorgio Martini. It is believed that the idea of lifting water by Centrifugal force was given by L.D.Vinci (Italian scientist and engineer) in the end of 16th century. In 17th century, Denis Papin built the actual centrifugal pump using straight vanes. However, later it was found that straight vanes are not giving expected results. The curved vane was introduced by British inventor John Appold in 1851.

E.C.Bacharoudis et al. [1] did the parametric study of a centrifugal pump impeller by varying outlet blade angle. 3 impellers were taken into consideration for the study. All impellers were having same diameter in suction and pressure side, same blade leading edge angle (β1= 14o) and they vary in blade's trailing edge angle (β2= 20o, 30o and 50o resp.). Through this study it has been concluded that when pump operates at design condition or nominal capacity, gain in the head is more than 6% when angle increases from 20o to 50o and ηH decreases by 4.5%. When pump operates at off-design condition, % rise of head curve due to increment of β2 is larger for high flow rates and becomes smaller for Q/Q_N < 0.65 and there is significant improvement in ηH.

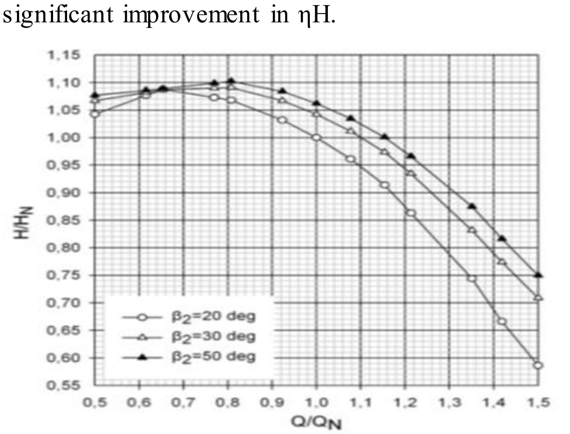

Fig. 2.1 Predicted head curves for the examined pump impellers

D. Ekardt [2] performed the detailed accurate measurements of velocities, directions, and fluctuation intensities with a newly developed laser velocity meter in the internal flow field of a radial discharge impeller, running at tip speeds up to 400 m/s.

Splitter blade design method was introduced by H. Chen et al [3] for low specific speed centrifugal pump. Splitter blade was set among the long blade to change the velocity and pressure distribution, and the pump performance is improved. It was showed that when the splitter blade is set, the circumferential velocity and pressure becomes even, the vibration and the radiated noise are improved, and the efficiency of the pump can be improved by 1-2% if the blades are set properly. A numerical study had been done by Raul Barrio et al [4] on the pulsating flow at the tongue region for a conventional centrifugal pump with a non-dimensional specific speed of 0.47 and an impeller–tongue gap of 11.4% of the impeller radius. The main focus was the relation between the pressure pulsations and the fluctuating velocity field. The simulations were performed by solving the equations for the modelled pump with the commercial code CFX, after proper analysis of the sensitivity of the results with respect to the mesh size and other numerical parameters. In addition, the predictions of the model were contrasted with experimental data previously collected at laboratory for the real pump

In 2015, Said A. E. Havash et al. [5] studied the reliability improvements to centrifugal pump performance in conjunction with the inducers. In this study, inducer was installed in the same shaft with the impeller of the pump, in front of the pump. It was observed that the reliability of the pumps gets improved when original stainless steel impeller and inducer is replaced by titanium. Inducer was mounted on the threaded area of the rotor assembly (taking the place of the impeller nut) and operated as a low (NPSH) axial flow impeller in series with the main pump impeller. Two types of impeller i.e. Axial and Helical were installed. (In helical inducer, blade consists of 3 turns of 17o angle while in axial inducer, 4 bladed inducer is taken with inlet blade angle, β1= 11.5o and outlet blade angle β2= 29.5o.)

Fig. 2.2 Axial and Helical inducers in conjunction with the tested pump, respectively

The percentage enhancement in efficiency and head of a pump by using an inducer is shown in the following table.

Table 2.1 Change in head and efficiency values by using Axial and Helical inducers

	Without Inducer	Using Axial Inducer	% change	Using Helical Inducer	% change
Efficiency (%)	53.07	68	21.96	71.59	25.87
Head (m)	36.59	44.63	18.01	45.75	20.02

In 2017, Zhenmu Chen et al. [6] did the research on Optimum design of volute tongue shape of a low specific speed centrifugal pump. In this study, 12 kinds of volute with same impeller were designed at impeller blade outlet angle 34o. Two types of volute geometries were studied shown as below. It was concluded that pump efficiency of volute type 2 (Fan-shaped areas) is higher than that of 1.

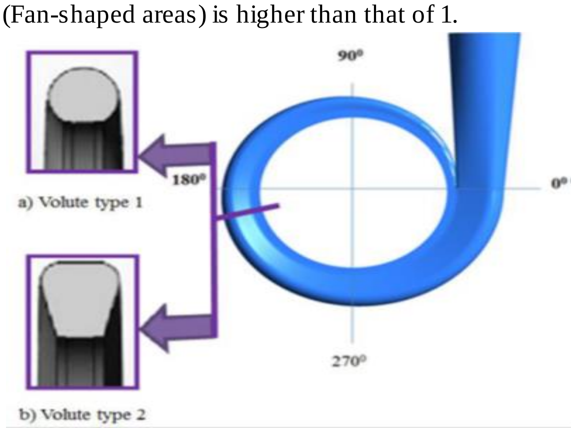

Fig. 2.3 Volute model types 1 and 2

The results were taken by changing the volute tongue angle and the gap between impeller and volute tongue. Post-optimisation was done once the results are obtained. It was concluded that efficiency of 74.4% is achieved when the volute tongue angle is 5o and the gap between volute tongue and impeller is 7.67 mm. But still there is percentage increase in efficiency after post-optimisation and it is described in the table below:

Table 2.2 Summary results in comparison

Parameters and Objective	Initial Design	Post-optimisation
X1 (Gap)	7.67 mm	7.67 mm
X2 (Angle)	5^o	0^o
η	74.4 %	75.01 %

From the above table, it can be seen that the volute tongue angle is more strongly effective on pump performance than the gap is.

The performance of the impeller had been studied [7] by keeping the outlet diameter same and varying the blade numbers. The main focus of the investigation was the performance characteristics of pump. The methods of numerical simulation and experimental verification were used to investigate the effects of blade number on flow field and performance of a centrifugal pump. 2-D steady numerical analysis was performed for centrifugal pumps with impeller blades 7, 8 and 9. It had been investigated that the efficiency is maximum for 7 bladed impeller centrifugal pumps.

In 2016, Fan Meng et al. [8] studied the effect of two diffuser types of volute on pressure fluctuation in centrifugal pump under part-load condition. In the study, the volute was tested with 2 types of diffuser viz. Radial diffuser and Tangential diffuser as shown in the figure below.

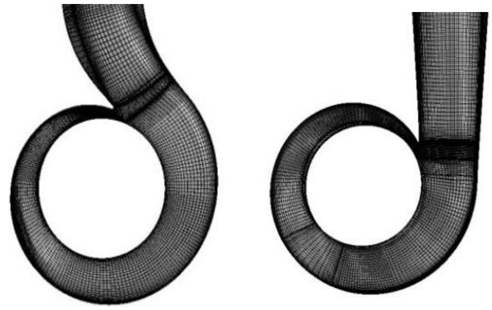

Fig. 2.4 Radial Diffuser (a) and Tangential Diffuser (b)

In this study, the following points are concluded:

1. In outlet of volute, the distribution of pressure fluctuation intensity is more average and pressure fluctuation gradient is bigger in Radial diffuser over Tangential diffuser.
2. Near the tongue, under part load condition (Q= 0.8QDES) the distribution of pressure fluctuation intensity is more average but gradient of pressure fluctuation is smaller in Radial diffuser over Tangential diffuser.

3. Near the tongue, under part load condition (Q= 0.8QDES) the change trend of pressure fluctuation are same for two diffuser types of volute. Furthermore, whether near the tongue or in the diffuser, pressure fluctuation frequency is based on blade pass frequency for two diffuser types of volute.
4. The comparison of performance of two types of volute is shown below where 330 m3/hr is a full load condition and two more readings are taken at 20% deviation of the full load [8].

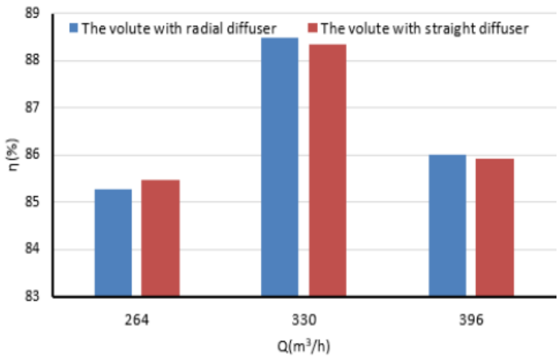

Fig. 2.5 Comparison of the efficiency

In 2015, Hamed Alemi et al. [9] conducted the research on Effects of volute curvature on performance of a low specific speed centrifugal pump at design and off-design condition. In this study, 3 volutes with different geometries and same cross sectional area are taken into consideration. It was seen that circular cross-sectional volute is the best considering head and efficiency. However, circular and trapezoidal cross sectional have higher radial force, at design point and low flow rate. At high flow rate, trapezoidal and circular volutes produce better condition. Hydraulic radii of circular and trapezoidal geometries are higher than rectangular one which causes reduction in pressure loss. In the same research, volute was designed with different diffuser shapes also. There are two alternatives for the selection of diffuser shape in volute design; namely, Radial and Tangential diffuser. Both diffusers provided more or less the same head but radial diffuser gives a slightly higher efficiency at design point and higher flow rate. Also radial diffuser produced lower radial force at design point and low flow rate. It was also concluded in the same research that in low Nq pumps, the generated radial force at high flow rate was significantly more than radial force at low capacity. Mou-Jin Zhang et al. [10] studied the complex 3-D flow field in a centrifugal impeller with low speed. Coupled with high Reynolds number k-ὲ turbulence model, the fully 3-D Reynolds averaged Navier-Stokes equations were solved.

3. CONCLUSIONS

From the review paper, it has been concluded that up to now, many studies have focused intensively on impellers. Fluid that obtains energy from an impeller is discharged through a volute. So the characteristics of a volute are an important factor if the goal is to discharge fluid with less energy loss. Thus study on the characteristics of the volute is absolutely a necessary process to improve the performance of centrifugal pumps. But most studies have focused on the impeller while study of the volute has drawn relatively lower attention. In order to improve the performance of a centrifugal pump, a more sophisticated study of volute is needed.

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