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Review Article

Performance investigation of centrifugal pump by varying blade angles of the Impeller–A Review

Ajinkya Sonune*, Akshay Dudhe and Mahesh R. Chopade

†Department of Mechanical Engineering, Savitribai Phule Pune University, MIT College of Engineering, Pune, India

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Abstract

Centrifugal pumps are probably among the most often used machinery in industrial facilities as well as in common life. Centrifugal pump is widely used as a universal machine, so improving hydrodynamic performances of the centrifugal pump is important for energy saving. With the development of computational fluid dynamics (CFD), numerical simulation has become the main method for performance prediction and structure design of the pump. The impeller is the most important part in a centrifugal pump since it is the place where the mechanical energy is converted into hydraulic energy. Hence the parameters related to the impeller are directly affecting the performance of the pump. One of them is the blade exit angle; if it is not correctly designed, it can negatively affect the head and the hydraulic efficiency of the pump. The previous research suggests that a larger blade angle is suitable. Also, exit blades angle variation contributes more in the performance.

Keywords: *Exit blade angle, Pumps Performance*

1. Introduction

Pumps are the mechanical devices that convert mechanical energy into hydraulic energy. They are generally used to raise the water or other fluids from lower elevation to higher elevation. So pumps are generally classified into centrifugal pump and positive displacement pump. Centrifugal pumps are non-positive displacement pumps. They work on the principle of centrifugal action.

Centrifugal pumps are used to transport fluids by the converting rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits.

The performance of a centrifugal pump largely depends upon the geometrical parameters of the impeller. In rural area, for pumping underground water, field irrigation as well as geothermal utilization, the centrifugal pumps are quite common. The pump performance parameters are expressed in the form of various characteristics A centrifugal pump converts mechanical energy from a motor to energy of a moving fluid. A portion of the energy goes into kinetic energy of the fluid motion, and some into potential energy, represented by fluid pressure (hydraulic head) or by lifting the fluid, against gravity, to a higher altitude. Improvement in performance of centrifugal pump gives rise to increase in the head and discharge of the pump, but this partly affects the total power consumption. The customers always demand for a pump with minimum power consumption and maximum discharge, which is difficult to achieve under design conditions. A very limited research has been carried out for improving the performance of pump on the basis of flow behavior, influence of geometric parameters etc.

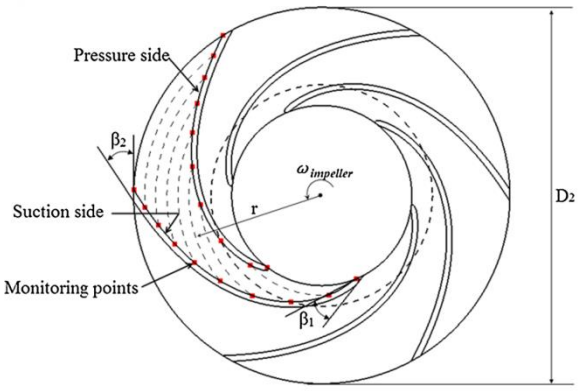

Fig. 1 Impeller Geometry

There are various techniques developed for improvement of pump performance.

i. Varying blade angles

*Corresponding author: **Ajinkya Sonune**

ii. Impeller trimming
iii. Addition of diffuser
iv. Tip clearance
v. Splitter Blades

All above various techniques can be implemented for improving centrifugal pump performance. All the above modifications in impeller geometry gives rise to the improvement in performance of the centrifugal pump. However, changing the inlet and exit blade angle is relatively easy by the design point of view. This review paper concentrates on the performance of pump by varying the blade angles (inlet and exit blade angles) denoted by β_1 and β_2 in fig. 1.

2. Influence of blade angles on the performance of Centrifugal Pump

In recent years, centrifugal pump have been increasingly utilized for various purposes, such as irrigation, water supply, steam power plants, oil refineries, air conditioning systems. Due to the vast application, it is very important that centrifugal pump should work efficiently.

Many researchers reported that modifying the geometrical parameters of an impeller will have an effect on the performance of the pump, as impeller is the only power driving element in the pump. There are still many unknown issues associated with increasing the efficiency in these pumps, which need to be investigated. If we make any change in the impeller geometry, it will have a direct effect on the impeller inlet or exit velocity triangles, which may result in significant performance change. The blade exit angle have very important role in the performance of the centrifugal pump.

Ohta *et al* examined different blade exit angles to investigate its effect on the performance of the centrifugal pump. The authors stated that changing some geometric characteristic of the impeller in centrifugal pumps improves their performance. For investigation of the impeller blade exit angle effect on the performance of the centrifugal pump various blade exit angle were examined. For pump of specific speed 28.91, the designed blade angle is 35˚. Thus, the blade angle is varied around 35˚ and the results are recorded. For pump of specific speed 38.47 and 53.48, designed blade angle is 23˚. Both pumps were investigated for the blade exit angles 20˚, 30˚ and 40˚. They found that both head and efficiency of centrifugal pump increases with increasing in blade exit angle.

Modifying the inlet and outlet angles of the impeller gives better performance. But, it should not differ way too much from the design blade angles. There is a need to research upon the limiting values of the changes or simply saying, a tolerance value is essential so as to set the limits upon deciding how much change in the blade angle will have a positive effect on the performance of the pump. Bigger value of blade angles creates vacuum in the impeller and smaller value increases the clogging of water inside the impeller, this degrades the performance. The investigation shows that the blade angles have significant influence on the head, input power and efficiency of the impeller. Performance characteristics of a pump greatly depend on geometry and surface property of an impeller. Many researchers reported analysis of centrifugal pump for the flow behavior, influence of geometric parameters, etc. The works on inlet and exit blade angle shows that the performance can be altered, when the angles are modified. A higher exit blade angle was suggested by the researchers. Reports on centrifugal pump handling viscosity liquids shows that that the large exit angle exhibits an improvement in head and efficiency. The inlet blade angle modification provides performance enhancement of the pump.

Y. Nagendra Babu and K. Aparana, in their study, analysed the effect of vane angle change in systems of impeller pumps. They analyzed different models of the centrifugal impeller of a single stage pump by changing the vane angle 16˚, 18˚ and 20˚. Static analysis was performed on the impeller to determine stresses by applying the rotational velocity using different materials such as Structural Steel, Aluminum alloy, Glass Fiber Reinforced Plastic and Borosilicate Glass. The comparison of Velocity, Pressure and Mass-Flow Rate at different vane angles as analyzed, are shown in figures 2, 3, 4.

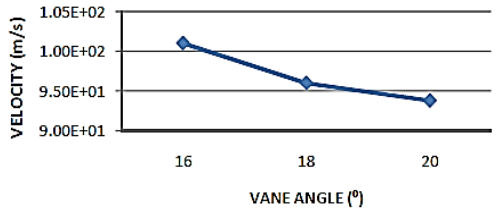

Fig. 2 Deviation in velocity at different vane angles

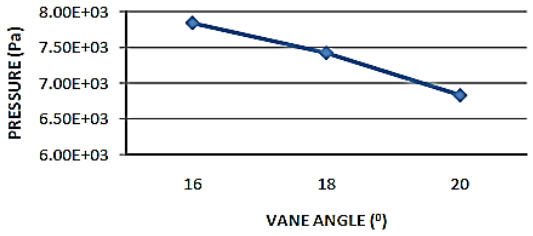

Fig. 3 Deviation of pressure at different vane angles

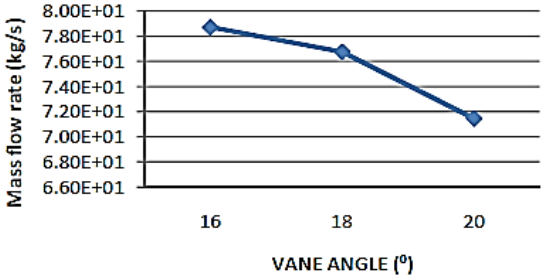

Fig. 4 Deviation of mass flow rate at different vane angles

The results obtained by the researchers clearly concluded that the pressure, velocity and mass flow rates are decreasing by increasing the vane angle. The investigation shows that the blade angles have significant influence on the head, input power and efficiency of the impeller. The works on inlet and exit blade angle shows that the performance can be altered, when the angles are modified. A higher exit blade angle was suggested by the researchers. For a double suction centrifugal pump, the head increment can be achieved by increasing exit blade angle and an improvement in efficiency by varying exit blade angles can be obtained. The blade exit angle has higher influence on the head, shaft power and hydraulic efficiency while the inlet blade angle has lower effect on the parameters. Large exit blade angle always augments head generation with increased input power consumption. Increase in exit blade angle increases the hydraulic efficiency till the design point. At off-design points, the efficiency decreases for higher exit blade angles because of different losses.

3. Effects of varying blade angles on different parameters of pump

Osman Babayigit *et. al* analyzed the performance of centrifugal pump by using numerical analysis tools. During the study, they conducted numerical analyses for the blade exit angle values of 18˚, 20˚, 25˚, 30˚ and 35˚. In consequence of the performed analyses, it is determined that hydraulic efficiency of the pump impeller value is changed between 81.0-84.6%. The most convenient blade exit angle that yields 84.6% hydraulic efficiency at is 18˚. The obtained results show that the blade exit angle range has an impact on the centrifugal pump performance describing the pump head and the hydraulic efficiency. The effect of different blade exit angles is well described by figures 5, and 6.

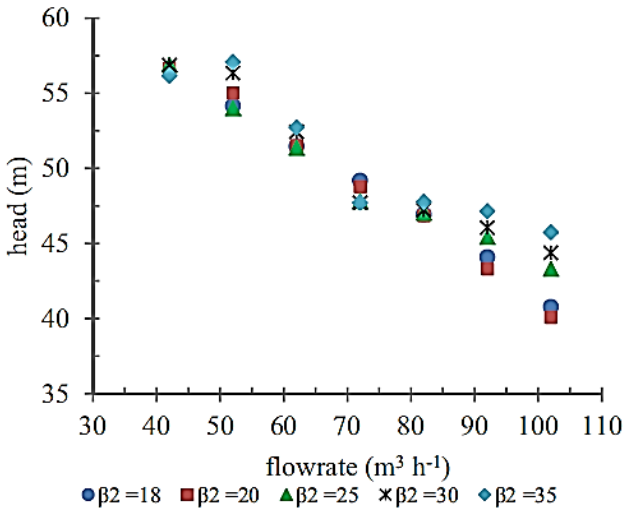

Fig. 5 The effect of blade exit angles on the head

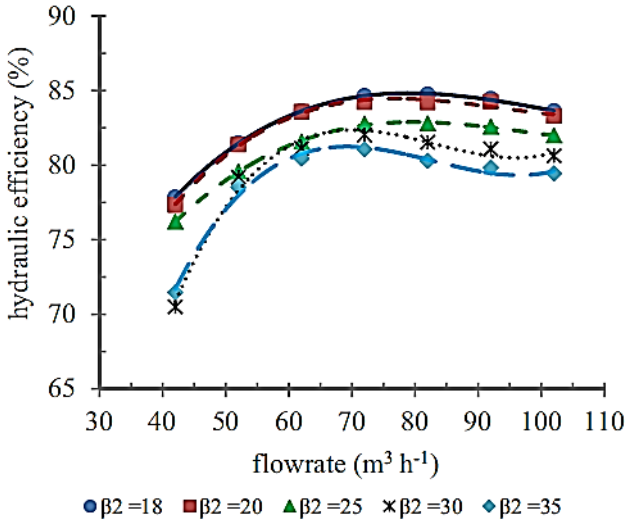

Fig. 6 The effect of blade exit angles on hydraulic efficiency

Sanda and Daniela expressed that variation of blade inlet angles had an effect of 1-2 % on hydraulic efficiency, which might be very important when considered the total energy consumption of the pump in the world.

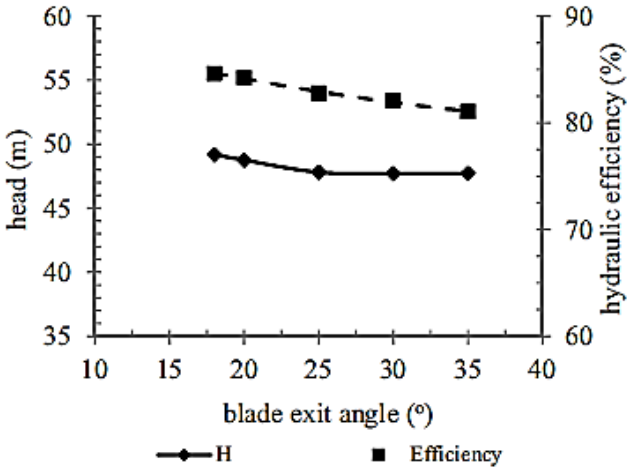

Fig. 7 The effect of blade exit angle variation on head and hydraulic efficiency

Bayraktar and Eralp used a computer-aided design method based on experimental techniques for centrifugal pump design in their study. They obtained 3- D model of the design with data transmission to CAD/CAM programs. They confirmed validation of their developed program according to the pump design method in the literature. Their results showed that the method is reliable.

Liu *et al*. investigated numerically with a simulation of inner-flow in a multi-stage pump. They used Fluent software and standard k-Ɛ model for this study. They used three different types of impeller for the numerical analysis which are twisted type, cylindrical type and stopper type.

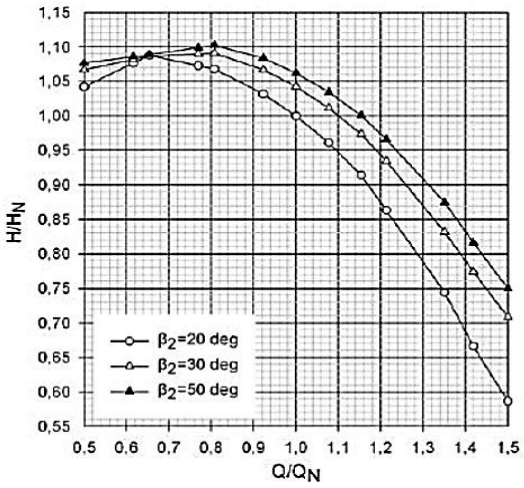

Fig. 7 H-Q curve for different exit blade angles

CFD is used to predict the increase of the nominal flow rate which causes reduction in the total head of the pump. As the blade outlet angle increases the performance curves become smoother and flatter for whole range of flow rates when pump operate at nominal capacity. The gain in the head is more than 6% when the outlet blade angle increased from 20 to 50 degree. The results of the numerical prediction of the H-Q curves for the examined impellers are shown in Fig. 7.

T. Kumaresan *et.al* The flow pattern in a vessel depend on the impeller blade angle, number of blades, blade width, blade twist, blade thickness, pumping direction and interaction of flow with the vessel wall. Measurements of the power consumption and flow pattern have been carried out in a stirred vessel of 0.5m diameter for the range of impellers to study the effect of blade shape on the flow pattern. The comparison of the flow pattern (average velocity, turbulent kinetic energy, maximum energy dissipation rate) can be presented on the basis of equal power consumption to characterize the flow generated by different impeller geometries. Comparisons of LDA (laser Doppler anemometer) measurements and CFD predictions have been presented. The good comparison indicates the validity of the CFD model. As the impeller angle increases from 30◦ to 60◦, the primary and secondary flow number ratio (NQS/NQP) was found to be 2.15 and 2.17 for 30° and 45° pitch, respectively, whereas it reduced to 1.73 for 60° pitched blade impeller.

Weng li examined the effect the various blade angles of the industrial oil pump by mathematical model. The result obtained from mathematical model is compared with experimental results. He found that the blade exit angle have equal effect on head, shaft power and efficiency. Moreover Weng li examined the effect of blade exit angle and viscosity as well as the roughness on the performance of the centrifugal pump with the use of CFD code. Shojaeefard *et al*. investigated the effect of impeller outlet angle for oil, experimentally and numerically. They conclude that increasing of impeller outlet angle causes improvement in the performance. Aoki *et al* and Ohta *et al* experimentally studied the influences of the discharge angle on the performance of a centrifugal pump when handling water.

Conclusions

Investigation of effect of impeller blade exit angle on the performance of the centrifugal pump has been done in this study. Head and efficiency have been found with the use of hydraulic loss model presented by Gulich. From light of above discussion following conclusions can be drawn:

1) The blade exit angle has significant and equal effect on the head and the efficiency.
2) With the increase in blade exit angle the performance of the centrifugal pump is increases.
3) There may be some inaccuracy due to the complication of the geometrical dimensions. This could be removed by investigating with numerical analysis by CFD code.
4) The blade exit angle has higher influence on the head, shaft power and hydraulic efficiency while the inlet blade angle has lower effect on the parameters. Large exit blade angle always augments head generation with increased input power consumption. Increase in exit blade angle increases the hydraulic efficiency till the design point. At off-design points, the efficiency decreases for higher exit blade angles because of different losses.
5) Changing impeller blade inlet and outlet angles gives better performance but blade angle should have in suitable value. Larger value creates vacuum or smaller value increases the clogging of water inside the impeller.

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