

EFFECT OF GEOMETRICAL CHANGES OF IMPELLER ON CENTRIFUGAL PUMP PERFORMANCE

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Abstract - Centrifugal pumps are probably among the most often used machinery in industrial facilities as well as in common life. After being invented they passed long evolutionary development until they became accessible for various applications. Centrifugal pump design is well facilitated by the use of Computational Fluid Dynamics (CFD). But still some problems are arising to improve the pump performance. This improvement can be achieved by making geometrical changes in design of an impeller. In this study, different techniques for improving centrifugal pump performance by changing impeller geometry are discussed.

Key Words: Pump performance, splitter blades, diffuser, tip clearance

1. INTRODUCION

Centrifugal pump is widely used in rural area, for pumping underground water, field irrigation as well as geothermal utilization. The pump performance parameters are expressed in the form of various characteristics such as head, discharge and power consumption, and efficiency are important for pump design. 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. Increase in performance will lead to increase the head and discharge of the pump, but this improvement affects the power consumption. As per costumers demand of pump performance for limited power consumption is difficult to achieve. There are various techniques developed for improvement of pump performance which are discussed in this paper.

- i. Impeller trimming
- ii. Varying blade angles
- iii. Addition of diffuser
- iv. Tip clearance
- v. Splitter Blades

2. IMPELLER TRIMMING

Mario Savar et.al [1] performed the testing on the centrifugal pump used in desalination plant where the electricity consumption used for centrifugal pump drives is significant part. Due to the high capacity of modern desalination plants optimizing of every component becomes an important task is a result of conservative approach the pump head is often less than expected while the flow rate is greater and to cause the operation of pump become energy inefficient because of flow rate is usually regulated. Energy efficient operation of the centrifugal pump saves energy and reduces operating cost. This was achieved by impeller trimming as shown in fig 1.



Fig 1. Impeller after trimming to final diameter

This idea is based on affinity laws that say pump impellers are considered to be similar if they satisfy geometric and kinematic similarity conditions. A general conclusion about the disregarded geometry similarities of the trimmed pump impeller of low specific speed will be possible.

3. BLADE ANGLES

E.C. Bachroudís et.al [2] described the simulation of flow into impeller of the laboratory pump in parametric manner. In this study, the performance of impeller with same outlet diameter having different outlet blade angles is reported thoroughly evaluated. The one dimensional approach along with empirical equations is adopted for the design of each impeller. The performance curves are

the results through calculation of internal flow field and successful correlation of local and global parameters. 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.

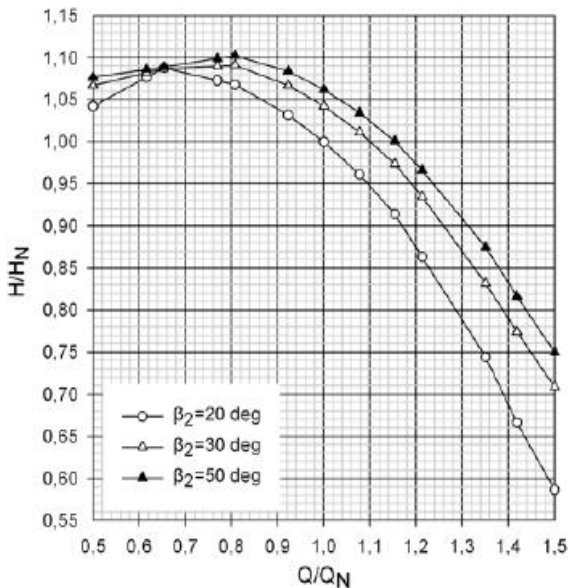


Fig 2. Predicted head curves for the examined pump impellers.

The gain in the head is more than 6% when the outlet blade angle increase from 20 to 50 degree. the results of the numerical prediction of the H-Q curves for the examined impellers, which are shown in Fig. 2.

T. Kumaresan et.al [3] 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) has been 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 (N_{OS}/N_{OP}) 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.

4. ADDITION OF DIFFUSER

Ling Zhou et.al [4] presented the design methodology for new type of three dimensional surface return diffuser (3DRD) as shown in fig 3, where the hydrodynamic

performance of the deep well centrifugal pump (DCP) was improved.

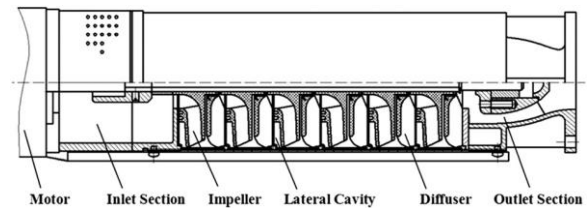


Fig 3. Cross section of investigated DCP with 3DRD

A two stage DCP equipped with two different type of diffusers was simulated employing the commercial computational fluid dynamics (CFD) software and ANSYS-fluent to solve the Navier-Stokes equations for three dimensional steady fluid flow. The two stage whole flow field was meshed with the structured mesh in ICEM and simulated in ANSYS- fluent. The detailed surface static pressure distribution was obtained by arranging the monitoring line at the same location of two diffusers.

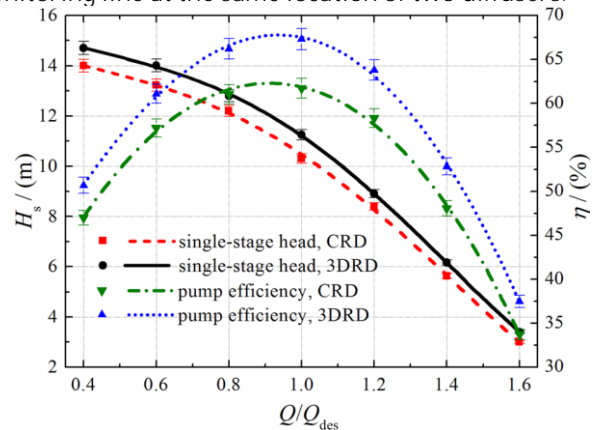


Fig 4. Comparison of performance characteristic

The result showed that the performance of the pump with 3DRD is better than that of the traditional cylindrical return diffuser (CRD). Comparison of performance characteristics as shown in fig 4.

Seralathan S et.al [5] analyzed the effect of extended shroud by 10% with impeller exit diameter on flow diffusion and performance and compared with stationary vane less diffuser. Efficient, compact centrifugal compressors with higher pressure ratios along with adequate surge margins are required. Achieving these necessitates development of newer non-conventional diffuser designs and rotating vane less diffusers is one such concept. One method of reducing the shear losses on the stationary vane less diffuser side walls, with probable improved efficiency and flow range of low-to-medium specific speed stages, is the use of rotating diffuser. A particular type of rotating vane less diffuser is forced to rotate the vane less diffuser, in which the rotational speed equals that of the impeller and the rotating vane less diffuser is integral with the centrifugal impeller which is created by extending the impeller disks beyond the blades. A higher static pressure rise with reduced losses is achieved by Impeller with extended shrouds by 10% of

the diameter at exit of the impeller (ES10) compared to Stationary vane less diffuser (SVD), which indicate that the rate of diffusion is higher in the shroud extend configuration. Also, shorter flow path with higher relative flow angle causes reduced frictional losses in shroud extend configuration in comparison with SVD. The efficiency as well as energy coefficient of ES10 is higher than SVD.

5. TIP CLEARANCE

Tahsin Engin et.al [6] designed and fabricated three semi-open centrifugal fan impellers using ceramic materials to provide high resistance to temperature. Centrifugal fans are being widely used in many industrial applications. However, when handling gases with temperatures exceeding 800°C, the use of centrifugal fan impeller is of particular interest since the conventional steel impellers would not be operated at such elevated temperatures. Experiments have been conducted to investigate the performance characteristics of these impellers and the deteriorations in their performance due to varying tip clearance. Factors have been determined to estimate the tip clearance losses. Results showed that the simple impeller geometries of ceramic materials were less sensitive to the varying tip clearance. In addition, the gas temperature has been found to have almost no influence on the performance degradation due to the tip leakage flow. The effect of impeller geometry, shaft speed, gas temperature, and the tip clearance on the overall performance of the tested impellers have been studied experimentally.

6. SPLITTER BLADES

M Golcu et.al [7] used impeller with splitter blades as shown in fig 5, in turbo machinery for both pump and compressors. In this case study impellers having different number of blades (Z = 3,4,5,6 & 7) with and without splitter blades (25, 35, 50, 60, and 80% of the main blade length) were tested for a deep well pump. The effects of the main blade number and lengths of splitter blades on the pump performance have been investigated.

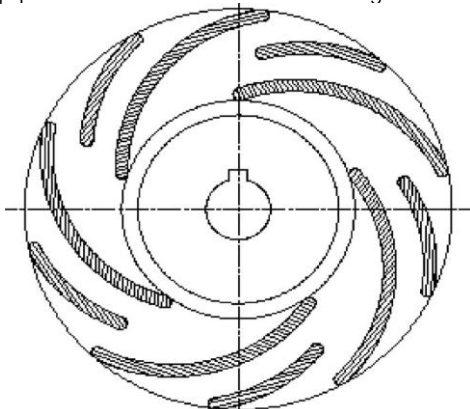


Fig 5. An impeller with splitter blades While the number of main blades and the lengths of the splitter blades of a principal impeller were changed, the

other parameters such as pump casing, blade inlet and outlet angles, blade thickness, impeller inlet and outlet diameters, were kept the same. It showed that increase in number of blades increases the head of pump however it causes a decrease in efficiency due to blockage effect of the blade thickness and friction. Characteristic curves of impellers with different number of blades as shown in fig 6. Splitter blades with different length are analyzed and the performance characteristics are shown in fig 7.

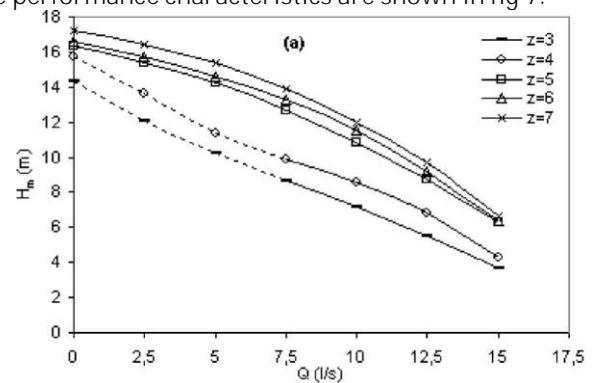


Fig 6. characteristics of impellers with different number of blades

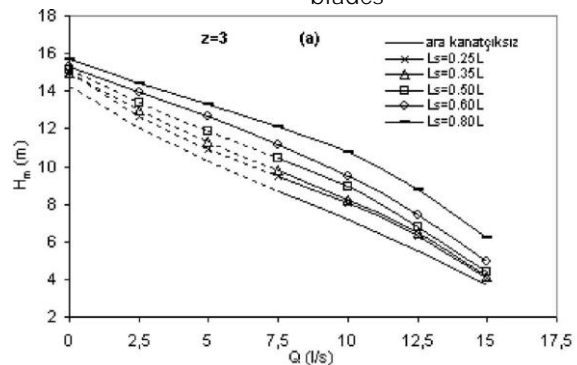


Fig 7. Characteristics of the impeller with different lengths of splitter blades

G. Kergourlay et.al [8] have discussed the influence of adding splitter blades on the performance of a centrifugal pump. The studied machine is an ENSIVAL-MORET MP 250.200.400 pump (diameter = 408 mm, 5 blades, specific speed = 32), with an impeller is designed with and without splitter blades. Velocity and pressure fields are computed using unsteady Reynolds-Averaged Navier-stokes (URANS) approach at different flow rates. The sliding mesh method is used to model the rotor zone motion in order to simulate the impeller-volute casing interaction. The flow morphology analysis shows that, when adding splitter blades to the impeller, the impeller periphery velocities and pressures become more homogeneous. An evaluation of the static pressure values all around the impeller is performed.

It shows the effect on radial thrust. Global and local experimental validations are carried out at the rotating speed of 900 rpm, for both the original and the splitter blade impellers.



Fig 8. Original (left) and splitter (right) impellers.

The head is evaluated at various flow rates: 50%, 80%, 100%, and 120% of the flow rate at the best efficiency point (BEP). The pressure fluctuations are measured at four locations at the BEP using dynamic pressure sensors.

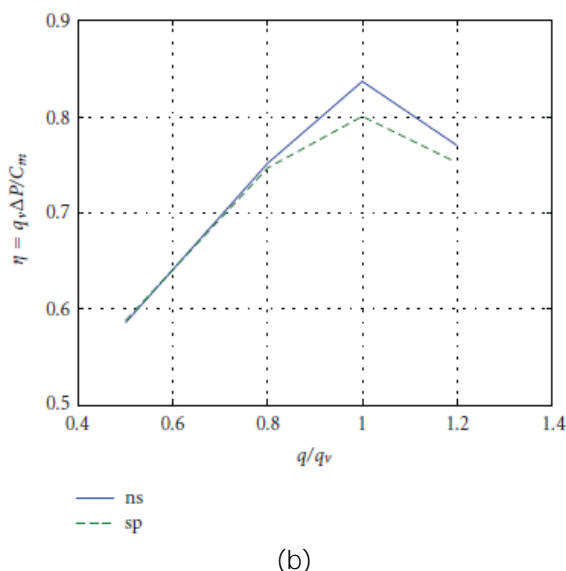
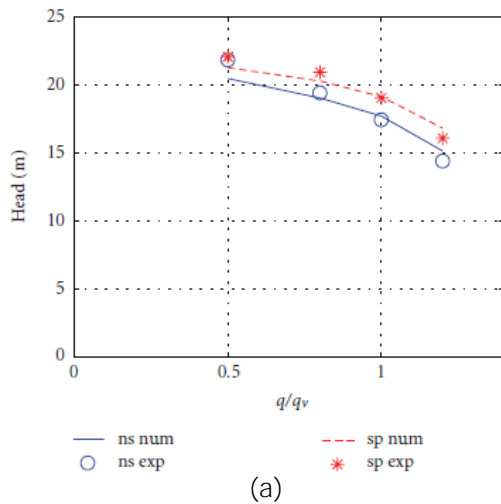


Fig 9. Head against flow rate (a) comparison with test (b) mechanical efficiency (ns = nonsplitter, sp = splitter).

The experimental results match the numerical predictions, so that the effect of adding splitter blades on the pump is

acknowledged. Addition of splitters has a positive effect on the pressure fluctuations which decrease at the canal duct.

7. CONCLUSION

All above various techniques can be implemented for improving centrifugal pump performance.

1. Impeller trimming will lead to affect the strength of the impeller.
2. 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.
3. Use of diffuser also gives improvement in performance. But number of diffusers is needed to use for specific value of head and discharge but this may leads to increase the weight.
4. Change in tip clearance shows better performance in case of centrifugal fans.
5. Splitter blades reduces the pressure fluctuation hence decreases vibration and noise. It also reduces the clogging of fluid at inlet of impeller.

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BIOGRAPHIES



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