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Research Article

Effects of Splitter Blades on Centrifugal Pump Performance - A Review

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Abstract

In turbomachinery design like pumps and compressors impeller is a crucial part. Centrifugal pump design is well facilitated by the use of Computational Fluid Dynamics (CFD). Opportunities do exist to improve the pump performance. This improvement can be achieved by making geometrical changes in design of an impeller like blade inlet & outlet angles, impeller inlet & outlet diameter and number of blades. Increase in number of blades increases the head and in addition causes the efficiency to decrease. This decrease in efficiency is due to the blockage of the fluid due to reduced area and increased friction inside the casing. Addition of splitter blades decreases the clogging at impeller inlet resulting in increase in pump performance. In this paper overview of various works by previous researches & their finding about study of effect of splitter blades on the centrifugal pump performance are done. And it is observed that as the splitter blade length increases; the flow rate and power increases, the efficiency decreases as well as hydraulic performances are improved, pressure fluctuations are reduced, and operating range is extended.On the other hand, the additional splitter blades will have positive effect on the cavitation performance due to the changes at the impeller inlet channel.

Keywords: *Splitter Blades, Centrifugal Pump Performance, Impeller, Cavitation.*

1. Introduction

A pump is energy consuming machine that expends energy from some source to increase the pressure of the liquid, in order to rise and/or transport it through a piping system. Pumps are also called fluid movers. Centrifugal pumps are probably among the most often used machinery in industrial facilities as well as in common life. After their invention, they passed long evolutionary way until they became accessible for various applications. Physical principle of pump is given by Euler centuries ago through a well-known equation named after him called Euler's equation for turbo machinery. During the last few years, the design and performance analysis of turbo machinery have experienced great progress due to the joint evolution of computer power and the accuracy of numerical methods and this is because of design analysis tools like CFD. This tool made possible flow field analysis of complex field problems. In a centrifugal impeller, increasing or decreasing the blade number will cause the disruption of flows. From the basic study of impeller it is expected that as the number of blades increases, head and efficiency increase whereas due to the increased blockage effect from the blade thickness and surface friction in the impeller passage, a loss of efficiency also occurs. This decrease inefficiency occurs especially with the increase in congestion in the impeller inlet area. As the inlet region gets crowded due to addition of splitter blades. Therefore, a high blade number will cause a decrease in efficiency and when the blade number is lowered, the liquid flow in the impeller will not obey the one-dimensional flow laws, which in turn increases the local losses.

Therefore, hydraulic losses will increase and performance will get decreased. This is where the splitter blades come into picture. It is observed that by placing a splitter blade between two adjacent blades hydraulic losses are observed to be decreased. And that is why splitter blades design has become one of the main methods of improving the performance of centrifugal pumps. It can reduce the congestion and incidence losses in the impeller inlet area in addition to this also improves the pressure and velocity distribution within an impeller and prevents emergence and development of secondary flow. Mustafa Golcu (2005), carried out experimentation on impellers of a deep-well pump with different number of blades and different length of splitter blades. Numerical simulations and performance tests was conducted by Liting YE(2012), on a single stage pump with a shrouded impeller and analyzed the effects of splitter blades on the performance of whole unsteady flow field of a centrifugal pump impeller. The result showed 2 – 12% increase in head with addition of splitter blades approximately.

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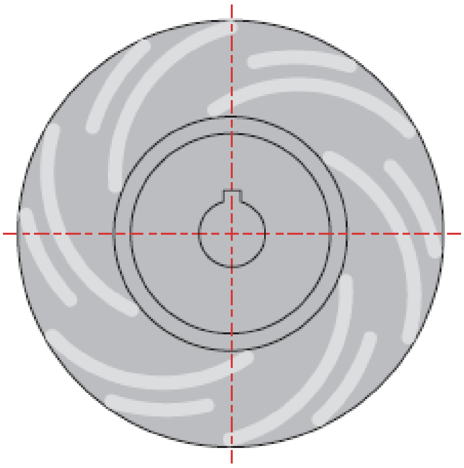

Fig.1 An Impeller with Splitter Blades

Pranit M. Patil (2015)discussed different techniques for improving centrifugal pump performance by changing impeller geometry. T. Shigemitsu (2013)carried out the performance analysis of mini centrifugal pump with and without splitter blades and the flow conditions are clarified with the results of the experimental and the numerical flow analysis. The experimental results showed that the performance of the mini centrifugal pump is improved by the effect of the splitter blades. And also the flow becomes uniform and backflow is suppressed to some extent in case of splitter blades. Y L Zhang(2014) carried out the Numerical simulations to investigate the characteristics of internal flow and the pump cavitation performances at different *NPSHA* with the CFD technique. Results showed some positive effects on cavitation performance if the inlet diameter of the splitter blade is properly selected. By considering all above facts, this paper tries to cover literature which deals with an effect of splitter blades on the centrifugal pump performance. In this paper overview of various works are done.

2. Influence of Splitter Blades on the Flow Field of a Centrifugal Pump

Liting YE studied a single stage pump with a shrouded impeller (diameter = 160mm, 4 blades, specific speed = 47). Considering this as original impeller, 5 impellers with different splitter blades parameters were designed (detailed in Table 1) and all the numerical simulations were carried out by using the commercial software ANSYS CFX 12.1 based on standard *k-ε* turbulence model and the no-slip boundary condition with a specified wall roughness imposed over the impeller blades and sidewalls, the volute casing and the inlet and outlet pipe walls. It was observed that the head increased nearly 2 – 12% with addition of splitter blades at any flow rate. N-Q curves show that best efficiency increases by about 15% and is highest for impeller C (Fig. 2). Also pressure fluctuations are reduced which might improve jet-wake flow structure.

Table No. 1. Impeller Designs

Impeller	A	B	C	D	E
Number of Long Blades	4	4	4	4	4
Number of splitter blade	-	4	4	4	4
Splitter blade inlet diameter *Dsi*/（mm)	-	96	106	106	116
Splitter blades deviation θ/°	-	5	5	No deviation	5

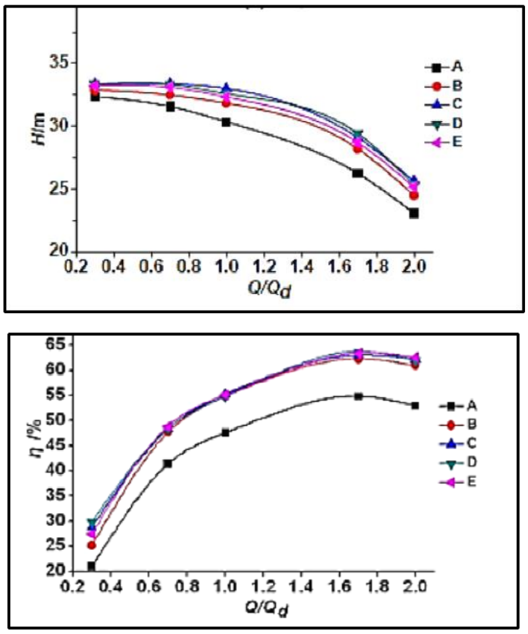

Fig No. 2 Comparison of Performance Curves for different Impellers

T. Shigemitsu adopted a semi-open impeller for the mini centrifugal pump with 55mm impeller diameter for research. A three dimensional steady numerical flow analysis is conducted to carry out the analysis of rotor thorough. Experimentation confirms that the performance of the mini centrifugal pump is improved by the effect of the splitter blades. Flow condition at outlet of the rotor becomes uniform and back flow regions are suppressed in the case with the splitter blades. Also increase in volute efficiency is observed with decrease in vortex loss.

3. Prediction of Head, Efficiency and Power Characteristics for Varying Length of splitter blades

Mustafa Golcu experimentally conducted a test on total of 18 impellers with impellers having different numbers of blades (z = 5, 6, 7) and low blade discharge angle, without and with a splitter (25, 35, 50, 60 and 80% of the main blade length), in a deep well pump keeping other parameters same. Results showed negative effect when blade number is 6 or 7 but addition of splitter blades seems useful for blade number equal to 5 that too with large discharge angles for better results.

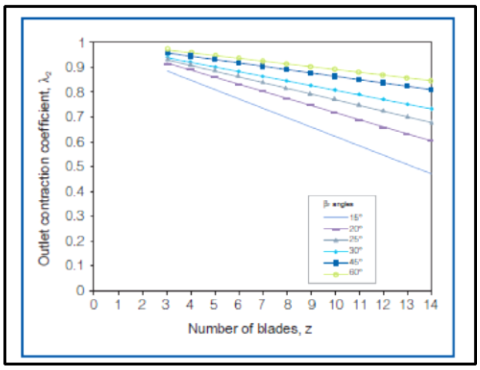

Fig No. 3. Variation of the outlet contraction coefficient (λ2) versus blade number (z) at different discharge angles (β2)

The outlet contraction coefficient (λ2) depends on the blade number (z) and the blade discharge angle (β2) which in turn depends upon the blade thickness and outlet diameter of impeller. The blade number in the outlet diameter zone of the impeller is doubled with respect to the value of z (= 5, 6 or 7) due to the addition of the splitter blades of different lengths. The deep well pump without splitters and having z = 5 consumed 1.8329 kW of power at the BEP while running with an efficiency of 58.364%. Results showed that when splitter blades with a length of 80% of the main blade length were added to the same blade number (z = 5), the power consumed by the deep well pump at the BEP decreased to 1.7089 kW, resulting in an energy saving of 6.765%. Also 1.138% increase in overall efficiency was obtained.

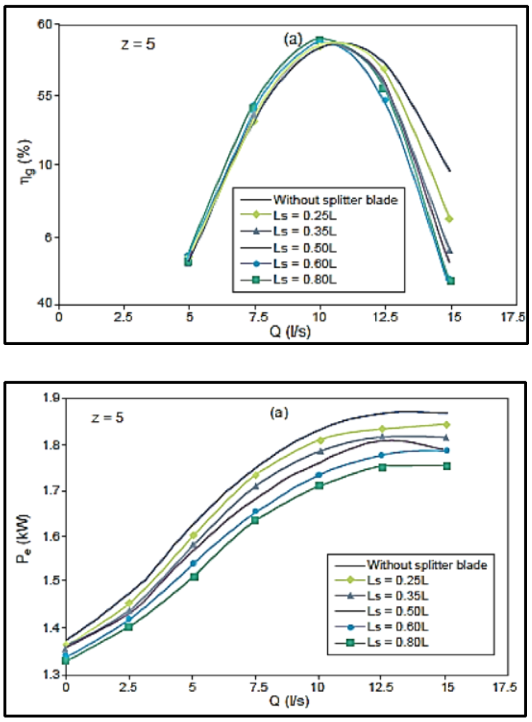

Fig No. 4. Efficiency and input power as a function of discharge with varying splitter blade length

By addition of splitter blades pressure fluctuations are reduced this improves the Jet-Wake flow structure.

4. Impeller Treatment using Splitter Vanes

Madhwesh N.examined the effect of splitter vanes to various geometrical locations on the impeller. He designed the impellers with the splitter vanes at different locations.

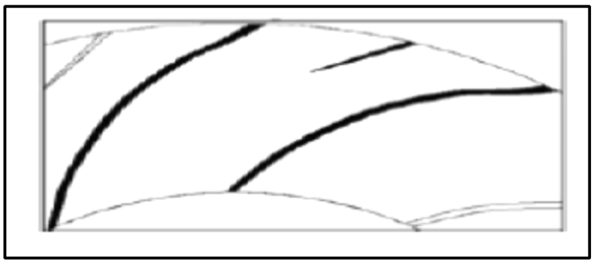

Fig No. 5. Splitter vanes at mid span of trailing edge

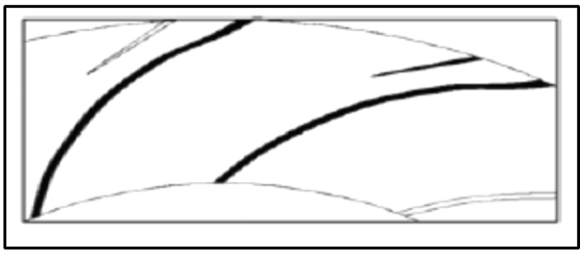

Fig No. 6. Splitter vanes at trailing edge at pressure side of impeller

Fig No. 7. splitter vanes at mid span of leading edge

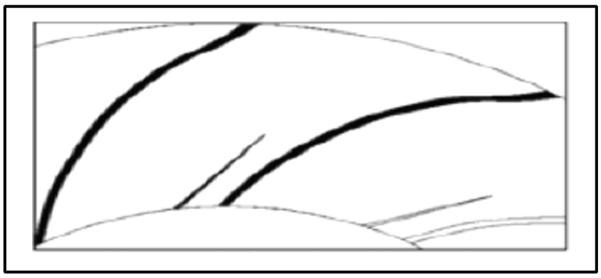

Fig No. 8. Splitter vanes at leading edge at pressure side of impeller

This modeling was analyzed using sliding mesh method in CFD. Splitter vanes provided at the impeller trailing edge (shown in figure 6.) produce significantly lower static pressure which gives poor performance. Splitter vanes provided at the impeller leading edge (shown in figure 8.) provide relatively large static pressure recovery of the fan gives good performance.

5. Influence of Splitter Blades on the Total Flow Field of a Low Specific Speed Centrifugal Pump

CUI Baoling (2006) basedon the Navier-Stokes equations and the Spalart-Allmaras turbulence model calculated a three-dimensional flow field in four modelled impellers numerically and analyzed them by using commercial code FINE/TURBO^{tm}6.2 developed by NUMECA International. Modelled impellers were having short mid and long blades in addition to original blades. Results showed that the complex impeller with long, mid and short blades can improve the velocity distribution and reduce the back flow in the impeller channel. Further experimentation showed that pump performance is influenced by back flow in impeller and also flow rate instability of the low-specific-speed centrifugal pump can be reduced by using complex impellers with long, mid and short blades. Yuan carried out experimentation and proved that splitter blades with 70% length of its main blade length can solve three hydraulic problems of low specific speed centrifugal pumps.(relatively lower efficiency, drooping head-flow curve and easily overloaded brake horsepower characteristics) Results also showed that the effects of splitter blades on pump performance primarily depends on the circumferential position and then on the stagger angle. Pumping head increases as discharge increases. Splitter blades gives smoother pressure and velocity distribution at impeller exit and volute inlet and in turn reduces the pressure fluctuations.

6. Effect of Splitter Blade on the Cavitation Performance of a Centrifugal Pump

Y L Zhang based on a model pump IS50-32-160 modelled two more impellers with splitter blades of different inlet diameters and carried out Numerical simulations to investigate the characteristics of internal flow and the pump cavitation performances at different *NPSHA* with the CFD technique. The results show that the additional splitter blades will have some positive effect on the pump cavitation performance if the inlet diameter of the splitter blade is$0.725D_2$. The reason behind such improvement is that it helps to avoid the flow blocking at the impeller inlet and the vortex cavitation inside the blade passages effectively.

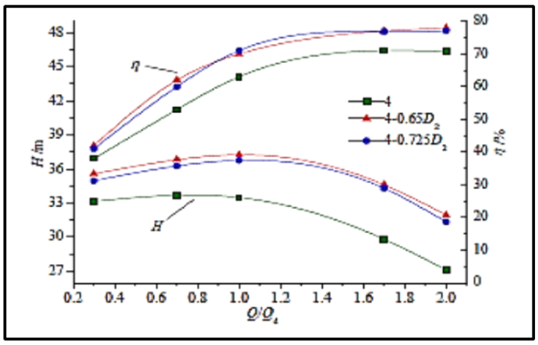

Fig No.9. Hydraulic performance curves at different Q/Qdof the three schemes

The degree of improvements on the pump cavitation performance depends on the proper selection of the inlet diameter of the splitter blade, the reason behind is that it helps to avoid the blocking at the impeller inlet and cavitation vortex inside the water passage efficiently.

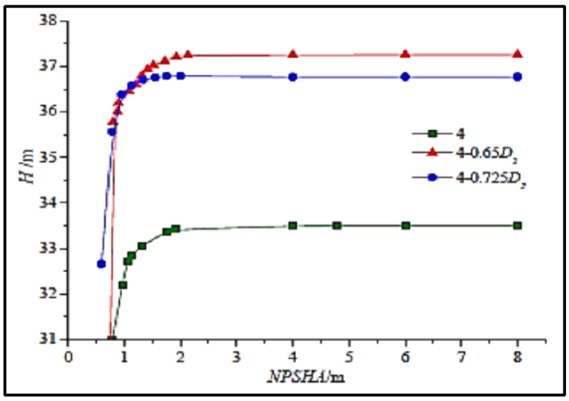

Fig No.10. Cavitation performance curve (the head at different NPSHA) at the design flow of the three schemes

Conclusion

This paper gives a review of the recent developments in the implementation of splitter blades in centrifugal pumps. Addition of splitter blades smoothens pressure and velocity fluctuations as compared to impellers without splitter blades. Also shows positive effect on pump cavitation at inlet diameter of splitter blade is 0.725 of impeller outlet diameter. Head also increases due to splitter blades addition.

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