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Effect of blade shape on the performance of radial flow centrifugal pump designed with concentric circular ARC method and Point by Point method

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ABSTRACT

Centrifugal pumps are the most widely used pumps due to their simple construction and ease of installation. As use of centrifugal pumps is very common they need to be efficient and low power consuming. Performance of a centrifugal pump depends on various factors like blade angle, blade thickness, number of blades, blade shape, blade outlet diameter etc. In the present analysis the effect of blade shape on the performance of centrifugal pump is shown by designing the blade profile using Concentric Circular Arc Method and Point by Point Method. For both the methods design parameters are kept same and CFD analysis is done to obtain the performance of pump at different flow conditions. Various results are evaluated and compared through charts and graphs.

Introduction

Centrifugal pumps are rotodynamic pumps which are capable of pumping large volume of liquids at moderate pressure to low and medium heights. In centrifugal pumps discharge is continuous and as it has large liquid handling capacity they are widely used in industries as well as in domestic households. Therefore, it is necessary that centrifugal pumps should be efficient and high performance machines. The shape of blade has great effect on the performance of pump and the blade profile needs to be designed properly. To see the effect of blade shape on the performance of pump various studies are done by different researchers e.g. Nyiri and Gahlot (1993) discussed detailed design procedures of blade profile in Centrifugal and Axial flow pumps (Theory and Design) [1]. Kyparissis et. al.(2009) conducted parametric study performance of a centrifugal pump based on simple and double-arc blade design methods [2]. Sri and Syamsundar (2010) performed computational analysis on performance of a centrifugal pump impeller [3]. A simplified 3d model approach in constructing the plain vane profile of a radial type submersible pump impeller using 3D CAD software was developed by Gundale et.al.(2013) [4]. Singh and Natraj (2014) performed design and analysis of pump impeller using SWFS [5]. Improving the hydraulic efficiency of centrifugal pumps through computational fluid dynamics based design optimization was studied by Moussa and Yunhao (2014) [6].

Methodology

For analysing the effect of blade shape on the performance of centrifugal pump the blade profile is first developed with Concentric Circular Arc Method and Point by Point Method keeping all the parameters same. After designing the blade profile with both the methods two impellers, casing and pipe are modelled in ICEM CFD. The two pumps are simulated in Ansys CFX Solver 14.0 commercial package for different discharge conditions to obtain head and efficiency. The design parameters used for designing the pump are as follows.

Impeller diameter, vane angle and blade height at inlet and outlet are D1 = 66 mm, D2 = 173 mm, β1 = 23° β2 = 29o, B1 = 15mm and B2 = 6mm respectively.

Number of blades Z = 7, Shaft diameter Dsh = 25mm, blade thickness = 5mm, mass flow rate Q =7.4 kg/s, Head H = 30m, Rotation N = 2870 rpm.

Figure 1 and 2 shows impeller model and impeller mesh. The meshing data are given in table-1 and table-2 respectively.

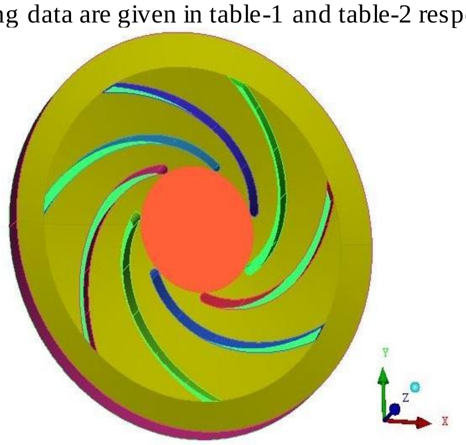

Figure 1. Impeller model

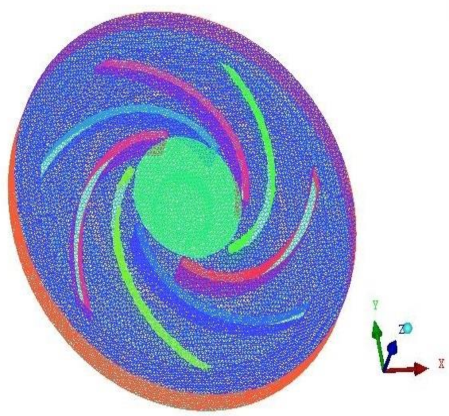

Figure 2. Impeller mesh

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Table 1. Meshing data for impeller

Blade design methods	No of nodes	No of elements
Concentric circular arc method	104169	580944
Point by point method	100316	559317

Table 2. Meshing data for casing and inlet pipe

Part	No of nodes	No of elements
Casing	126017	682403
Inlet pipe	120460	708151

Table 3. CFD numerical results

Blade Design Method	Discharge (lps)	Inlet Pressure (N/m^2)	Outlet Pressure (N/m^2)	Torque (N-m)	Input Power (W)	Total Head (m)	Overall Efficiency (%)
Concentric Circular Arc Method	5.8	102864	497572	9.31833	2800.59	40.2353	81.774
	6.3	103140	494145	9.94924	2990.2	39.8578	82.3801
	6.9	103503	487044	10.6143	3190.08	39.097	82.9583
	7.4	103830	478577	11.1053	3337.64	38.2005	83.0865
	8	104252	465631	11.6273	3494.54	36.8378	82.7299
	8.5	104629	449364	12.0078	3608.88	35.1411	81.1954
Point By Point Method	5.8	102864	492082	9.21421	2769.29	39.6756	81.5177
	6.3	103140	494654	9.95804	2992.85	39.9097	82.4144
	6.9	103503	489934	10.7009	3216.12	39.3916	82.9067
	7.4	103830	482615	11.2135	3370.16	38.6121	83.1715
	8	104251	468832	11.7626	3535.19	37.1642	82.5031
	8.5	104629	455622	12.1555	3653.28	35.7791	81.6645

Meshing of the impeller with different blade design methods is done in ICEM CFD. Data obtained from meshing are shown in table-2. In the tetrahedral meshing of impeller for concentric circular arc method and point by point method number of nodes are 104169 and 100316 similarly number of elements are 580944 and 559317 respectively.

In the tetrahedral meshing for casing number of nodes and number of elements obtained are 126017, 682403 and that for inlet pipe are 120460 and 708151 respectively.

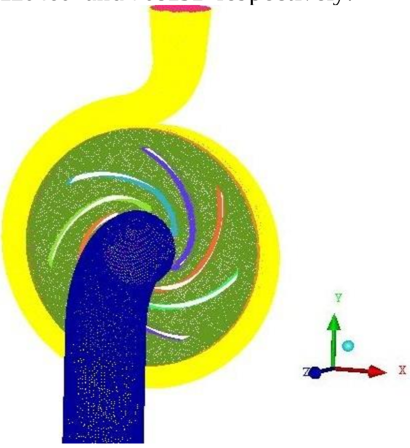

Figure 3. Pump assembly meshing

Numerical Results and Simulations

In the present analysis the pump is tested for six different discharge conditions and the results obtained are tabulated in table-3. The table shows the various results obtained by numerical simulation of pump by changing the impeller designed with concentric circular arc and point by point method keeping the same casing and inlet pipe. Here, various results are obtained by changing the mass flow rate at the casing outlet for each of the impeller and tabulated below:

Figure 4 and 5 shows the variation of head and efficiency with respect to discharge. It is observed from fig. 4 that for point by point method as the discharge increases head increases initially till 6.3 lps discharge and after that if discharge is increased head starts decreasing, total head obtained at 6.3 lps discharge is 39.097 m. For concentric circular arc method total head decreases with increase in discharge, maximum head obtained is 40.2353 m at 5.8 lps discharge.

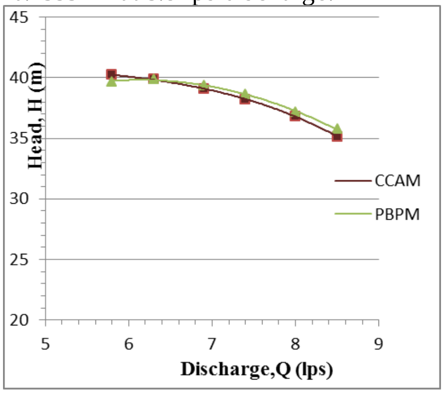

Figure 4. Variation of Total Head v/s Discharge

For both the methods the change in efficiency with respect to discharge is shown in fig. 5 it is seen from figure that as the discharge increases efficiency first increases than decreases. It is also observed that minimum efficiency is 81.1954 obtained at 8.5 lps with concentric circular arc method and maximum efficiency is 83.1715 obtained at 7.4 lps with point by point method.

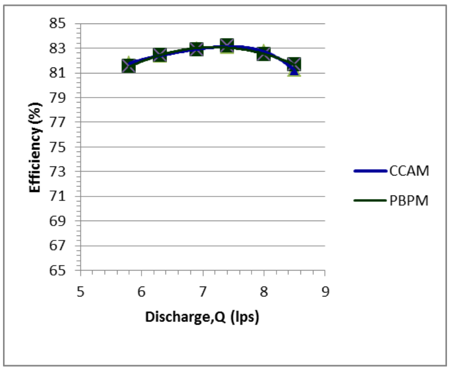

Figure 5. Variation of Efficiency v/s Discharge

Conclusion

The performance of a centrifugal pump is affected by various geometrical parameters. In this study, the effect of blade shape on the total head developed and efficiency of the pump have been investigated by designing the blade profile with concentric circular arc and point by point method, keeping the design parameters same for all the methods. From the results, following conclusion can be drawn:

- The flow pattern in the flow passage of impeller and casing is affected by blade shape and mass flow rate.
- For both the blade design methods velocity at inlet pipe is constant but when it enters the impeller it increases and it has been also seen that as discharge decreases flow is detached from the impeller.
- It is observed that as the discharge increases, efficiency first increases then it decreases after attaining maximum value. Maximum efficiency of 83.1715 % is obtained at 7.4 lps discharge with point by point method.
- In the present analysis it is found that for point by point method initially as the discharge increases head also increases but after attaining a maximum value it starts decreasing. On the other hand for concentric circular arc method head continuously decreases with increase in discharge.
- The maximum total head developed is 40.2353 m and it is obtained with concentric circular arc method at a discharge of 5.8 lps.
- At 8.5 lps discharge maximum total head developed is 35.7791 m and it is obtained with point by point method.
- Further on comparing the performance curve of concentric circular arc method and point by point method it is found that they have similar curves having marginal difference between them. The efficiency obtained with concentric circular arc method is 83.0865 and that of with point by point method is 83.1715 % at 7.4 lps discharge. The difference in efficiency increase is of 0.085 % only by point by point method.

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