Proceedings of the International Conference on Applied Mechanical Engineering Research (IC-AMER2019)
NIT Warangal, India – May 02-05, 2019
Paper No. XXX (The number assigned when the paper is accepted)

Numerical study on the effect of impeller geometry on pump performance

Arshdeep Singh 1[a,*] , Siga Satya Sekhar 2[b*] , Jayavel S 3[c] , Sudhir Varadarajan 4[d]

[a,b,c,d] *Department of Mechanical Engineering, Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram Chennai 600 127, Tamilnadu, India*

*Corresponding author Email: mds17m003@iiitdm.ac.in, mds17m010@iiitdm.ac.in

---

Abstract. Blade thickness and blade height are the most influencing parameters on the performance of pump. The fluid flow passage can be optimised by the blade thickness. Energy consumption by pump is reduced by employing appropriate blade height. The objective of the present study is to optimise the blade geometry, *viz*. thickness and height. The duty parameters considered in the present study are flow rate (*Q*) 5000 LPH, Head (*H*) 28-26 m, speed 6000 rpm. Numerical simulations are carried out to study the pump performance. Three-dimensional, steady-state flow equations are solved in ANSYS CFX along with Reynolds-Averaged Naiver- Stokes. (RANS) equations with standard SST (Shear Stress Transport) turbulence models. The results showed that energy consumption decreases with blade height.

Keywords: Submersible pump, Blade thickness, Blade height, CFD

1. Introduction

The submersible pump is used in many applications, *viz*. domestic purposes, irrigation, wells and water tanks. To achieve best performance geometric parameters such as the impeller outlet diameter (D_2), impeller blade height, impeller blade outlet angle (β_2) and impeller blade thickness (e) as shown in Fig 1 are need to be modified. These parameters greatly influence the pump performance.

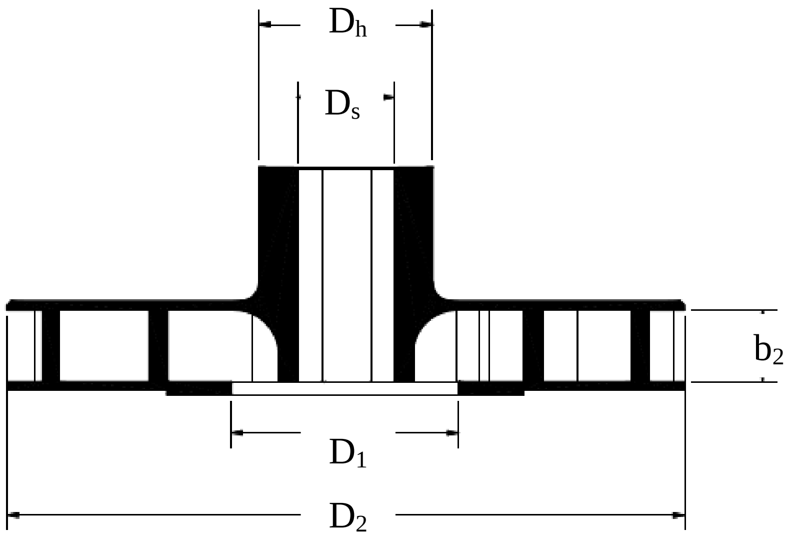


Figure 1. Sectional view of a closed radial impeller with geometric parameters

The minimum and uniform thickness required to achieve good casting qualities must be observed in casting of impellers; it depends on the casting process and it is 3 to 5 mm [7.2.1]. The speed is concerned with inlet diameter (D_1) and outlet diameter (D_2) of the pump impeller as shown in Fig 1. Pump inlet diameter is related to the flow and outlet diameter is related to the head. Generally D_2/D_1 value is larger. By controlling the blade thickness and blade height, D_2/D_1 ratio can be reduced

[7.3.1]. Impeller design for example, impeller blade-width, inlet and outlet blade angle, vane velocity, inner and outer diameter, diameter of hub and shaft diameter are appropriately selected from [7.1.1]. The influence of inlet and outlet angles on the geometry of the impeller of centrifugal pump and the hydraulic efficiency are reported in [7.3.2]. To reduce the shaft input power, control the passage volume by controlling the blade thickness and blade height [7.2.2].

2. CAD Model

Different impeller designs are modelled using Blade-Gen of Vista-CPD for blade thickness and Autodesk inventor for blade height.

2.1. Blade Thickness

Four different impeller designs are modelled by varying the blade thickness from the leading edge to trailing edge of the blade.

2.2. Blade height

Four different impeller designs are modelled in Autodesk inventor for blade height. Blade height is also a main parameter which directly influences the performance of the centrifugal pump.

3. Meshing

The fluid domain of the impeller is divided into sub-domains as shown in Fig. 2. The mesh size is given in Table-1. The grid independence study has been conducted the result is shown in Fig.3.

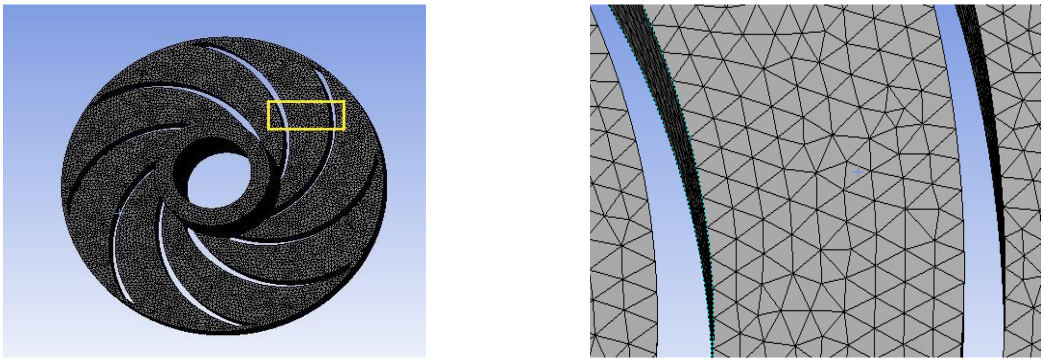


Figure.2. Tetrahedron Meshing of Impeller fluid domain

Table 1. Meshing Detail

Mesh type	No. of Nodes	No. of Elements	Element Size
Tetrahedron	651296	449180	0.95

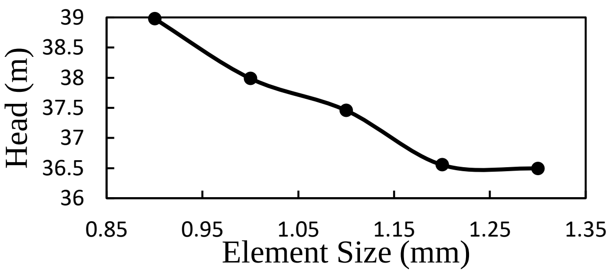
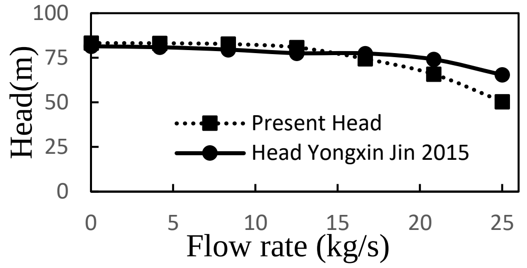


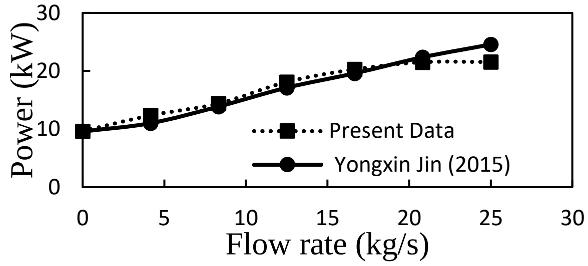
Figure.3. Effect of mesh element size on the output result (Head)

4. Results and discussion

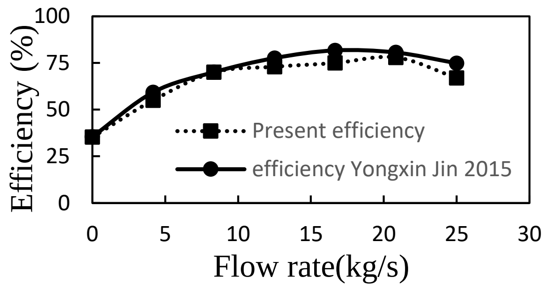
Computations are performed using ANSYS-Software with appropriate boundary conditions. Present computational results are validated using the results from Jin (2015). The present results are found to satisfactorily match with the results of Jin (2015). The results are shown in Fig. 4.



(a)



(b)



(c)

Figure.4. Comparison of the present simulated data and the data from "Yongxinjin 2015"
(a) Effect of flow rate on the head.
(b) Effect of flow rate on the input shaft power.
(c) Effect of flow rate on the efficiency.

4.1. Effect of Blade Thickness

For blade thickness simulation complete single stage of submersible pump was simulated i.e. Impeller, casing and return guide vane. Results are shown in Fig. 5.

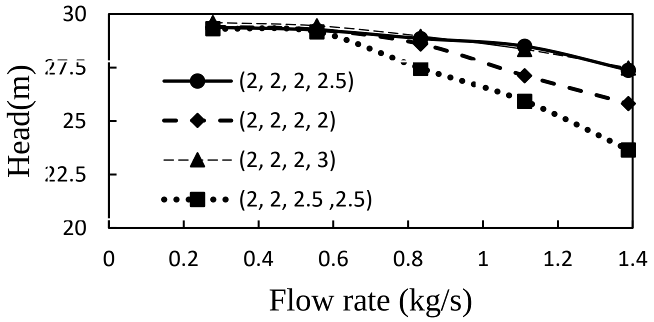
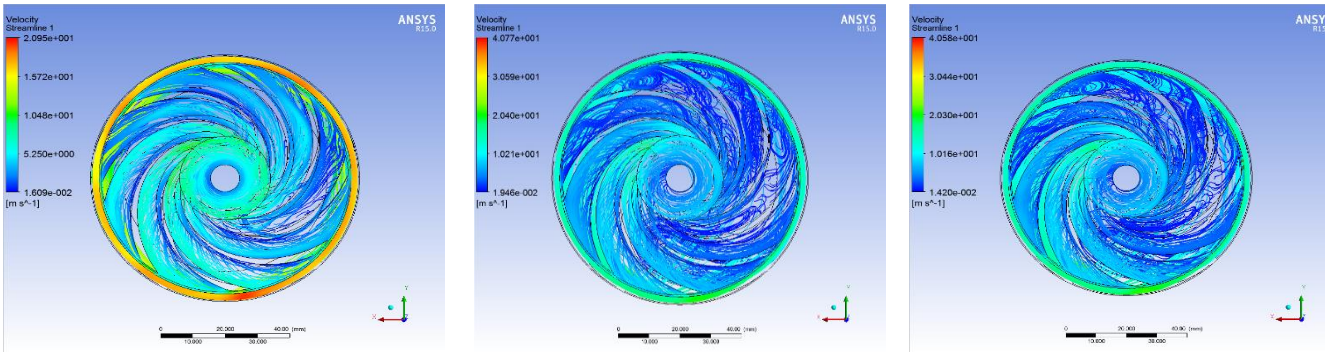


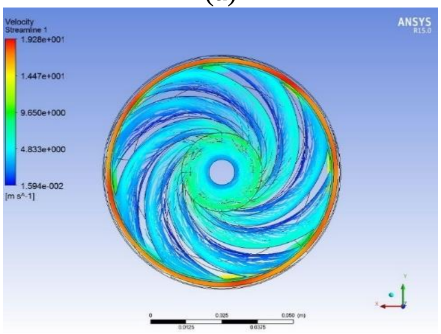
Figure.5. Head for different blade thickness value w.r.t flow rate condition

Head for impeller having blade thickness (2, 2, 2, 2) and (2, 2, 2.5, 2.5) is less than other two impeller with blade thickness (2, 2, 2, 2.5) and (2, 2, 2, 3) shown in Fig 9. Head for blade thickness (2, 2, 2, 2.5) and (2, 2, 2, 3) has same head approximately.

Flow in impeller passage is shown in Fig 6. Four channel flows are compared here to find which is more efficient. When operated under off-design condition flow separation and flow recirculation affect the performance. Flow separation is mostly observed near to the leading edge due to non-tangential inflow. If excessive deceleration of the flow occurs (Pressure increase) or if there is a sudden change in the direction of the profile of blade, the flow outside the boundary layer will no longer follow the direction of the wall but it will separate or leave the surface of the blade. Flow separation leads to flow losses. Suction recirculation can be seen in centrifugal pump at low flow.



(a) (b) (c)

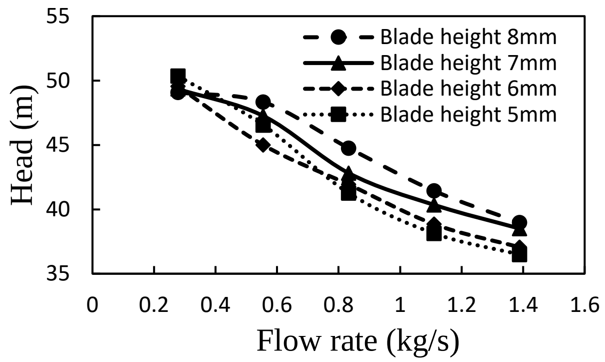


(d)

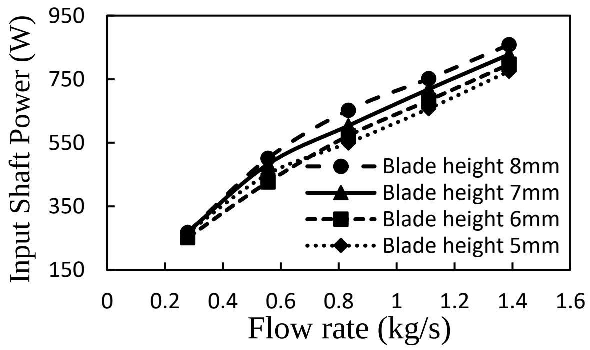
Figure .6. Streamline contour of four different blade thickness. (a) Blade thickness (2, 2, 2, 2.5). (b) Blade thickness (2, 2, 2, 2). (c) Blade thickness (2, 2, 2.5, 2.5). (d) Blade thickness (2, 2, 2, 3)

4.2. Effect of Blade Height

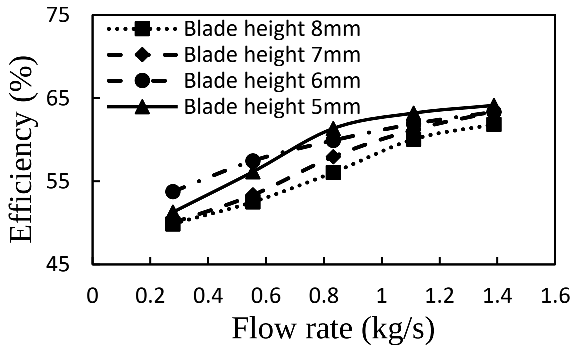
Blade height controls the passage volume. Input power requirement increases with flow passage volume. The results are shown in Fig. 7.



(a)



(b)



(c)

Figure .7. Comparison of head, input shaft power and efficiency of the impellers with different blade height.
(a) Effect of flow rate on the head correspond to different blade height.
(b) Effect of flow rate on the input shaft power correspond to different blade height.
(c) Effect of flow rate on the efficiency correspond to different blade height.

On the other hand, head decreases with blade height. Head for impeller with blade height 8 mm is 38.96 m but input shaft power and efficiency are 858.4 W and 61.8 %, respectively. But the head for impeller with blade height 5 mm is 36.48 m shaft input power and efficiency are 775.1 W and 64.13 %, respectively. Impeller with 5 mm blade height consumes less energy and shows better efficiency.

5. Conclusion

Numerical study has been carried out by varying the impeller parameters such as, blade passage width, blade thickness, blade height, flow rate of modified design of the impeller. Conclusions from the present numerical study are: the blade thickness of the impeller should be (2, 2, 2, 3) because it gives more head and has negligible flow separation and flow recirculation. Shaft input power decreases with blade height. Efficiency increases with decreasing blade height. Four different design impellers are studied. Among these impellers, the impeller with 5 mm blade height is more efficient.

6. Nomenclature

b	Blade height
D_1	Outer diameter
D_2	Eye diameter
D_s	Shaft diameter
H	Head
Q	Flow rate
Q_d	Design Flow rate
t	Blade thickness
$\beta 1$	Blade inlet angle
$\beta 2$	Blade outlet angle

Reference

1. Journal Articles

[1] Ravi Teggin, Shashank M Hebbal, M.S.Hebbal7, July 2016,*International Journal of Innovative Research in Science, Engineering and Technology*,Effect of Blade Geometry on Hydraulic Performance of the Centrifugal pump,**Vol. 5**

[2] Ji Pei, Shou-qi Yuan, Xiao-jun Li, Jian-ping Yuan, 2014, *Journal of Hydrodynamics*,Numerical prediction of 3-D periodic flow unsteadiness in a centrifugal pump under part load condition, **26**(2):257-263.

[3] Raghavendra S Muttlli, Shweta Agrawal,HarshlaWarudkar,august 2014, *The International Journal of Innovative Research in Science, Engineering and Technology*,CFD Simulation of centrifugal pump Using ANSYS-CFX,**Vol.3**,Issue8.

2. Books

[1] Johann Friedrich Gulich 2010Springer 2nd edition*Centrifugal Pumps*(Villeneuve (Switzerland).

[2] K.M. Srinivasan 2008 Newage international (p) limited, publishers,*Rotodynamic Pumps (Centrifugal and Axial).*

3. Conference Paper

[1] Yongxin Jin, Wenwu Song, Jie Fu,*Advanced Materials Research* A study on the effects of blade thickness on the performance of low specific speed centrifugal pump,**Vols. 1070-1072 (2015)** pp 1957-1962.

[2] Sanda budea, 2016Article *in Revista de Chimie–Bucharest,* Optimization of the Impeller Geometry and its Coating with PTFE to Improve the Hydraulic Performances, **67** (7).

[3] J F Zhang, Y F Wang and S Q Yuan, 2016, *IOP conf. series: Materials Science and Engineering, Experimental* research on internal flow in impeller of low specific speed centrifugal pump, **129.**