

Enhancing the Submersible Pump Efficiency by Impeller Design Modification through CFD Analysis

¹M.Prem Kumar, ²B.Logesh, ³B.Mohan, ⁴Muthuselvan, ⁵Nethaji, ⁶Karthick

^{1,2} Assistant Professors, ^{3,4,5,6} U.G Scholars,

^{1,2,3,4,5,6}Department of Mechanical Engineering,

^{1,2,3,4,5,6}Sree Sakthi Engineering College, Coimbatore, India.

Abstract: This paper deals with improving the pump efficiency by modifying the impeller design parameters of existing design. The most important design parameters are diameter, the inlet and exit angle of impeller, and width of impeller. In this paper the width of the impeller is changed by theoretical calculations for selecting the optimal discharge. 3D Modelling of impeller is done in the solid works software. The outlet characteristics like velocity, volume flow rate, pressures are determined by using the ansys CFX software. The materials considered are manganese bronze, cast steel, Nickel Aluminium.

Index Terms – Submersible pump Efficiency, CFD Analysis, Ansys, Impeller design.

I. INTRODUCTION

A pump is a hydraulic machine which converts a mechanical energy into hydraulic energy through rotation of impeller. The submersible pump is one of the pump in centrifugal pump. The submersible pumps are widely used to irrigation, flood removing, and rescuing operations. In order to reduce the power consumptions it is necessary to improve the pump efficiency. The efficiency of pump can be increased by changing the volute design of the impeller and by increasing the number of blades. But their design and performance prediction process is still a difficult task, mainly due to the great number of free geometric parameters, the effect of which cannot be directly evaluated. The significant cost and time of the trial-and-error process by constructing and testing physical prototypes reduces the profit margins of the pump manufacturers. For this reason CFD analysis is currently being used in the design and construction stage of various pump types. From the CFD analysis software and advanced post processing tools the complex flow inside the impeller can be analysed.

II. CFD

“Computational Fluid Dynamics” is defined as the methodology used for obtaining a discrete solution of real world problems. Discrete solution is obtained at a finite collection of a space points and at discrete time levels.

2.1 Importance of CFD

- Better prediction in short time.
- Design better and shorter, economical, meet environmental regulations and ensure industry compliance.
- By using CFD analysis we can make shorter design cycles and products get to market faster.
- Equipment improvements are built and installed with minimum down time.
- CFD is a tool for compressing the design and development cycle allowing for rapid prototyping.

2.2 The existing impeller dimensions

- I. Eye Diameter of Impeller (D_e) = 0.036 m
- II. Inlet Diameter of Impeller(d_i) =0.06 m
- III. Outlet Diameter of Impeller(d_o)=0.195 m
- IV. Blade width at inlet = B_i m
- V. Blade width at outlet = B_{om}
- VI. Thickness of blade = 7.36×10^{-3} m
- VII. Blade inlet angle = β_i = 30degree
- VIII. Blade outlet angle = β_o = 40degree
- IX. Head developed = H m
- X. Inlet height of blade =0.064 m
- XI. Outlet height of blade =0.053 m
- XII. Discharge = Q m^3/sec
- XIII. Acceleration due to gravity g = 9.81 m/sec^2
- XIV. Velocity co efficient C_v =0.98
- XV. Speed of impeller η_s = 2800 rpm
- XVI. No of blades Z = 3,4,5
- XVII. Density of water ρ =1000 kg/m^3
- XVIII. Overall efficiency = η_o

2.3 Formulae used for calculations

$$\text{Inlet area } A = \pi/4 * d_i^2 \quad \text{m}^2$$

$$\text{Inlet width } B_i = A_i / \pi d_i - (z * t / \sin \beta_i) \quad \text{m}$$

$$\text{Head } H = 2.79 * 10^{-4} * \eta_s^2 * [d_o^2 - d_i d_o * \tan \beta_i / \tan \beta_o]$$

$$\text{Discharge } Q = 0.1644 * d_i^2 * B_i * \eta_s * \tan \beta_i$$

$$\text{Input power} = \rho * g * Q * H / \eta_0$$

III. MODELLING OF IMPELLER IN SOLID WORKS



Fig.1. 3D Model of Impeller

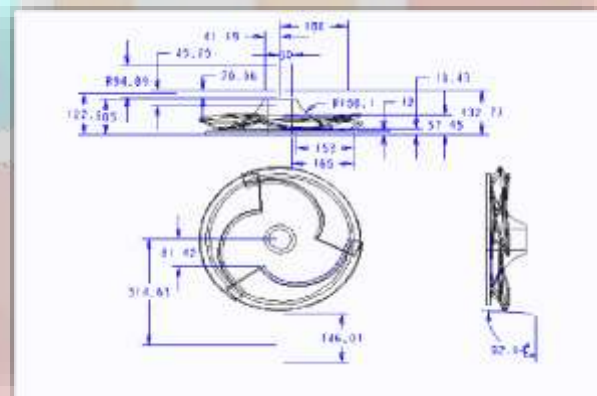


Fig.2. 2D Model of Impeller

IV. CFD ANALYSIS OF SUBMERSIBLE PUMP IMPELLER

4.1 Boundary Conditions

The submersible pump impeller is analysed in CFD by applying the velocities are taken from the above calculations and the structural analysis is done by applying the internal pressure values obtained from CFD analysis.

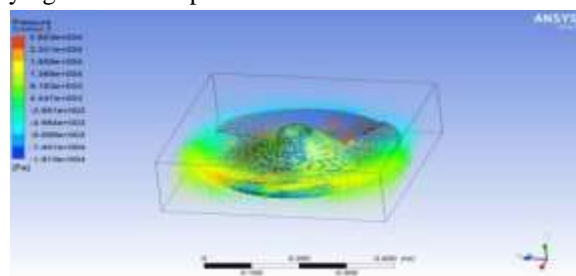


Fig.3 static pressure contours.

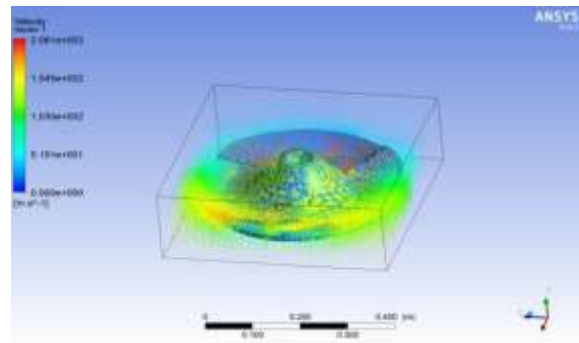


Fig.4 Velocity magnitude.

Table 1 –CFD analysis result for 3 blades.

Blade Angle	Pressure (Pa)	Velocity (m/s)	Mass Flow Rate (kg/sec)
40	2.803e ⁺⁰⁰⁴	2.061e ⁺⁰⁰²	- 0.027032852
45	2.804e ⁺⁰⁰⁴	1.876e ⁺⁰⁰²	- 0.029628754
50	2.922e ⁺⁰⁰⁴	1.973e ⁺⁰⁰²	- 0.035345078

Table 2-CFD analysis results for 4 blades.

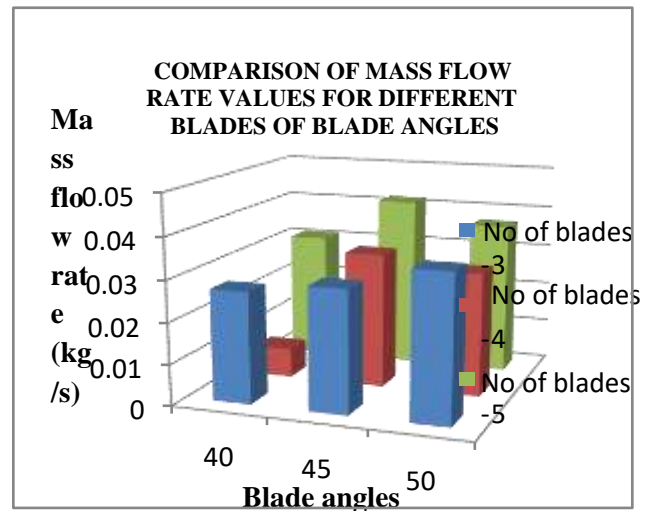
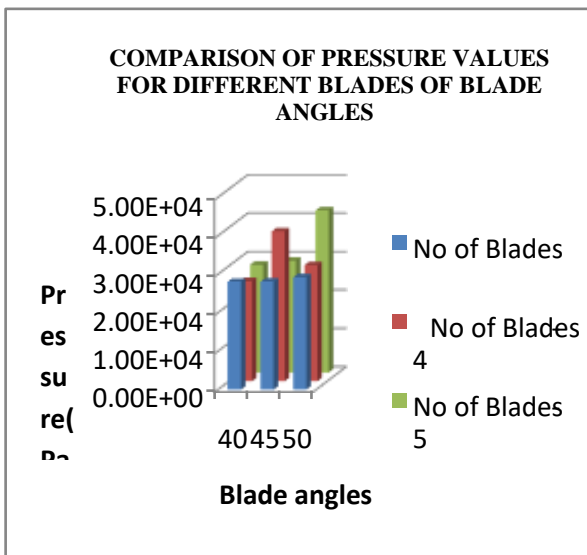
BLADE ANGLE (°)	Pressure(Pa)	Velocity (m/s)	Mass flow rate (kg/s)
40	2.603e ⁺⁰⁰⁴	1.939e ⁺⁰⁰²	- 0.007174491
45	3.894e ⁺⁰⁰⁴	2.508e ⁺⁰⁰²	0.032692002
50	3.014e ⁺⁰⁰⁴	2.063e ⁺⁰⁰²	- 0.029935837

Table 3-CFD analysis results for 5 blades.

BLADE ANGLE (°)	Pressure(Pa)	Velocity (m/s)	Mass flow rate (kg/s)
40	2.807e ⁺⁰⁰⁴	1.937e ⁺⁰⁰²	- 0.031002045
45	2.912e ⁺⁰⁰⁴	2.030e ⁺⁰⁰²	- 0.041711807
50	4.218e ⁺⁰⁰⁴	3.419e ⁺⁰⁰²	- 0.036879539

V. COMPARISONS OF CFD RESULTS FOR DIFFERENT NO OF BLADES

Comparative values of pressures, velocity, and mass flow rate of fluid are given follows to select the optimum values for pumps.



- Maximum pressure is obtained at outlet of pump $2.803e^{+4}$ and maximum pressure is $4.43e^{+4}$.
- Maximum velocity is obtained at outlet of pump $2.061e^{+2}$ m/sec and minimum velocity is $5.151e^{+1}$ m/sec at walls of pump.
- Maximum velocity is obtained at blade angle 50° and having 5 blades.
- Maximum velocity is obtained at blade angle 50° and having 5 blades.
- Maximum mass flow rate is obtained at blade angle 45° and having 5 blades.

Table.4. Comparison of new design with Existing design

Content	Mass flow rate(m^3/sec)	Efficiency (%)
Existing design	0.0348	64
New design	0.0371	83

VI. CONCLUSION

By studying the CFD results, the pressure and velocity and the mass flow rates are increasing by increasing the number of blades. From the CFD and theoretical calculation results the inlet blade angle is chosen as 45° and chosen out let blade angle is 60° and 6 blades for its optimum discharge rate and head. And hence the efficiency of impeller is increased by 29 % from its previous overall efficiency.

REFERENCES

- [1] Gundale V.A., Joshi G.R., "A Simplified 3d Model Approach in Constructing the Plain Vane Profile of A Radial Type Submersible Pump Impeller", Research Journal of Engineering Sciences, Vol. 4, July 2013, PP. 33-37.
- [2] Ankurkumar. H. Vyas, Performance, optimization and CFD analysis of submersible pump impeller, IJSRD International Journal for Scientific Research & Development| Vol. 1, Issue 4, 2013 | ISSN (online): 23210613
- [3] V. Ramkumar, Study of the existing design of impeller of 4" submersible pump and improving its efficiency using cfd a through theoretical analysis, ISSN 0976 – 6340, Volume 6, Issue 5, May (2015), pp. 51-55, IAEME
- [4] Krishna Kumar Yadav, V.K. Gahlot, and Performance improvement of mixed flow pump impeller through CFD analysis, IJRET: International Journal of Research in Engineering and Technology eISSN: 2319-1163 | pISSN: 2321-7308.
- [5] ShyamKaranth, Design, modeling & analysis of a submersible pump and to improve the pump efficiency, International Journal of Latest Trends in Engineering and Technology (IJLTET), Vol. 4 Issue 2 July 2014, ISSN: 2278-621X
- [6] N. Ramasamy, K. Ganesan, an Investigation on Design And Performance Optimization Of Pump Impeller, 2016
- [7] IJEDR | Volume 4, Issue 1 | ISSN: 2321-9939
- [8] Shardul Sunil Kulkarni, "Parametric Study of Centrifugal Pump and its Performance Analysis using CFD", International Journal of Emerging Technology and Advanced

- [9] Engineering, Vol. 4, July 2014, PP: 155-161.M. Shojaeefard, M. Tahani, et al. Numerical study of the effects of some geometric characteristics of a centrifugal pump impeller that pumps a viscous fluid. *Computers & Fluids*, 2012, 60: 61–70.
- [10] S R Shahaet al. CFD for centrifugal pumps stae of the art, Chemical, Civil and Mechanical engineeringTracks of 3rdNirma University International conference journal

