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A COMPARATIVE STUDY OF MIX FLOW PUMP IMPELLER CFD ANALYSIS AND EXPERIMENTAL DATA OF SUBMERSIBLE PUMP

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ABSTRACT

The present paper describes an improve the head of mixed flow pump impeller, Computational Fluid Dynamics (CFD) analysis is one of the advanced CAE tools used in the pump industry. From the results of CFD analysis, the velocity and pressure in the outlet of the impeller is predicted. The optimum inlet and outlet vane angles are calculated for the existing impeller by using the empirical relations. The CAD models of the mixed flow impeller with optimum inlet and outlet angles are modelled using CAD modelling software Solid Works 2009. By changing the outlet angle and the No. of blade of impeller the head of the impeller is improved to 86.75m. From this analysis it is understood that the changes in the inlet blade angle and No. of blade change the head of the impeller. From the CFD analysis the head of the impeller with optimum blade angles is calculated as 76.46m. Thus, head of the mixed flow impeller is improved by 10.29m by changing the inlet and outlet blade angles and No. of blade.

KEYWORDS: Mixed Flow Pump, Computational Fluid Dynamics (CFD) Analysis, Impeller Design, Submersible Pump

INTRODUCTION

The increasing performance levels and operating conditions requirements make the task of designing a pump impeller very challenging. The role of internal flows and the viscous effects in submersible impellers are fundamental and must be taken properly into account in the design process in order to obtain optimum performance. Formerly it was sufficient for a designer to analyze the steady state operation of a pumping system but nowadays with the increasing complexity of pumping systems, a wide variety of Submersible pump types have been constructed and used in many different applications in industry and other technical sectors.

However, 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. For this reason CFD analysis is currently being used in the design and construction stage of various pump types. WORLD PUMPS [1] has presented the head obtained by mixed flow pump is higher than radial & axial flow pump. Efficiency of mixed flow pump was between radial and axial flow pump. Mixed flow pump used where the high delivery rates are required against moderate heads. The different factors used in design of mixed flow pump like selection of casing (tubular casing, volute casing), effect of backflow, cavitations, pre-rotation of water are discussed in design aspects.

Vasilios et al [2] describes the flow domain is discredited with a polar, unstructured, Cartesian mesh that covers a periodically symmetric section of the impeller. The numerical results are compared to the measurements, showing good agreement and encouraging the extension of the developed computation methodology for performance prediction and for design optimization of such impeller geometries. J.Manikandan et al [3] shows the study of mixed flow pumps the leakage loss contributes about 7 percent of the total flow. From the Computational Fluid Dynamics analysis the internal flow pattern, Pressure and Velocity contour are predicted which will be useful for further enhancement of the pump. S.Rajendran1 et al [4] describes the simulation of the flow in the impeller of a centrifugal pump.

The numerical solution of the discredited three-dimensional, incompressible Navier-Stokes equations over an unstructured grid is accomplished with an ANSYS-CFX. The flow pattern, pressure distribution in the blade passage, blade loading and pressure plots are discussed in this paper. Gundale et al [5] presents the purpose of the analysis is to verify the performance at duty point or BEP (Best Efficiency Point). Nataraj et al [6] studied the Taguchi's parametric design concept for performance enhancement of centrifugal pump. For the experiment eight virtual model of impeller was selected by varying four parameters. After doing the simultaneous optimization the optimum condition of four operating parameter was found. Miner et al [7] presents the Non dimensional impeller results & Non dimensional stator a result was compared to get the final result show that the shapes and magnitudes of the velocity & static pressure profiles were correctly predicted. The largest error found in predictions of the total pressure and differences in the tangential velocity profile. Karanth et al [8] shows an optimum radial gap which could help providing maximum energy transfer by the impeller blades as well as maximum energy conversion by diffuser vanes. The static pressure recovery and total pressure loss for the diffusing components of the fan change with the radial gap. The larger is the radial gap, the smaller are the pressure fluctuations at the exit flange of the fan.

Manivannan et al [9] described the efficiency of the existing impeller is calculated by the empirical relations. The calculation of head, power rating & efficiency of existing impeller was found to be 19.24 m, 9.46 KW, & 55% respectively.

PUMP SPECIFICATIONS

Impeller Geometry

In this work, the mixed flow pump detailed geometric feature of the impeller was studied and parameterization of impeller geometry was done. Parameterization was done by reducing number of controlling geometric variables, facilitating the investigation of their individual or combined effects on the flow and the impeller performance. A typical submersible pump consists of impeller, diffuser, riser, discharge adapter, intermediate bowl and shaft is shown in Figure 1. The performance of a pump depends on active pump components. The active pump components of a mixed flow pump are mixed flow impeller and guide vanes. These parts are important while analysing a pump because mechanical energy (rotation) is transferred into fluid energy (pressure, velocity) by the active pump components.

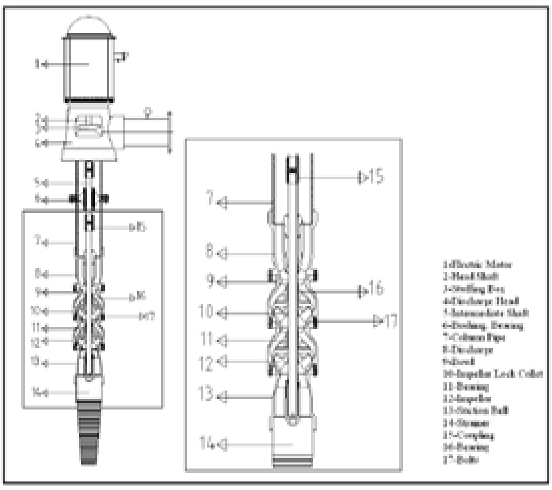

Figure 1: Part of the Pump Assembly

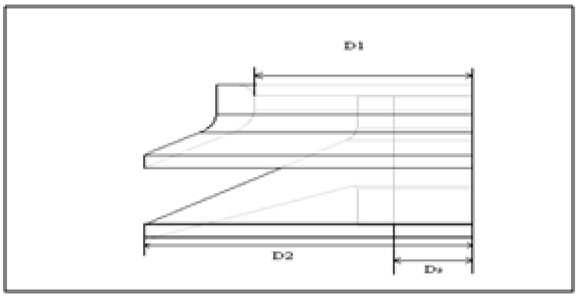

Figure 2: Layout of Impeller

The geometry of a mixed flow pump impeller is highly complex in nature. The mixed flow geometry consists of several features among those following geometric features are important as they have direct effect on overall pump performance.

Table 1: Existing Mixed Flow Impeller Dimensions

Parameter	Size
Impeller inlet diameter(D_1)	345mm
Impeller outlet diameter(D_2)	606.5mm
Number of blades(N_b)	6
Number of stages	Single
Shaft Diameter(D_s)	78mm
Blade Inlet Height(B_1)	64mm
Blade Outlet Height(B_2)	53mm
Rotation(N)	2850rpm
Inlet Blade Angle	29^0
Outlet Blade Angle	40^0

Geometric feature of the impeller was studied in detail and parameterization of impeller geometry was done. Parameterization was done by reducing number of controlling geometric variables (inlet angle, outlet angle), to investigate their individual or combined effects on the flow and the impeller performance. After parameterization mixed flow impeller can be represented using a relatively small number of parameters; some of them are shown in Figure 2.and their values are given in Table 1. The rotation speed and the main impeller dimensions, namely the exit diameter $D2$ as well as the blade inlet and exit angles, $\beta 1$ and $\beta 2$, respectively, determine the nominal head.

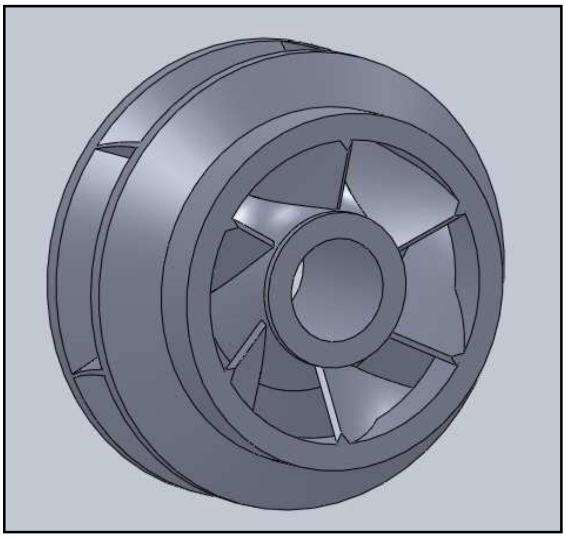

Figure 3: Model of Mixed Flow Impeller

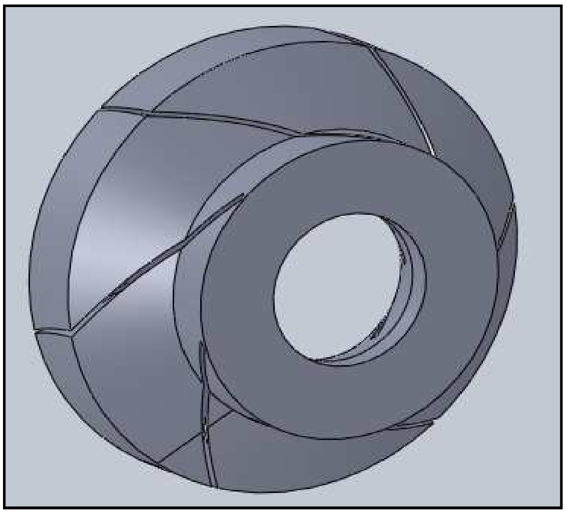

Figure 4: Cavity Model of Mixed Flow Impeller

ANALYSIS OF MIXED FLOW IMPELLER

Meshing of Impeller

Meshing Type: 3D

Type of Element: Tetrahedral

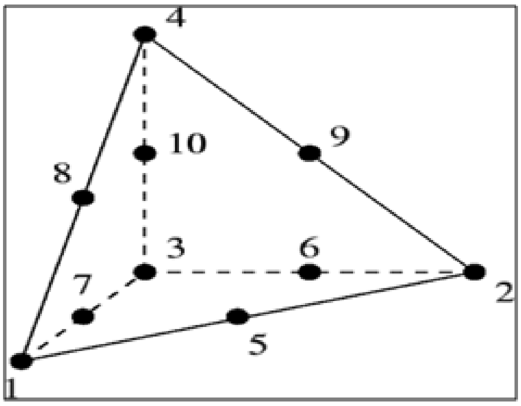

Figure 5: Mashing Type

No. of Nodes: 111637

No. of Elements: 1 49456

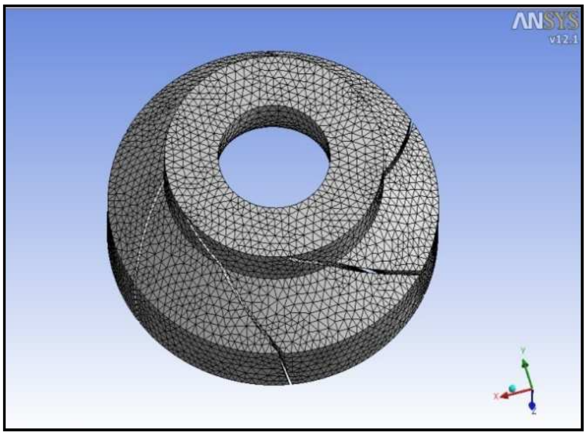

Figure 6: Meshed Model of Impeller Cavity

Boundary Conditions

Centrifugal pump impeller domain is considered as rotating frame of reference with a rotational speed of 2850 rpm. The working fluid through the pump is water at 25o C. k-ε turbulence model with turbulence intensity of 5% is considered.

RESULTS

Velocity Stream Contour

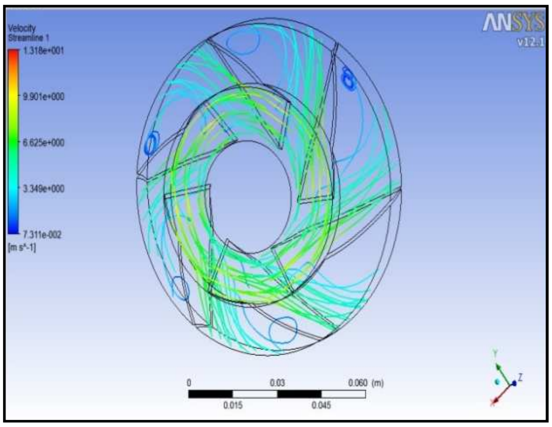

Figure 7: Velocity Contours

Pressure Contour

Inlet

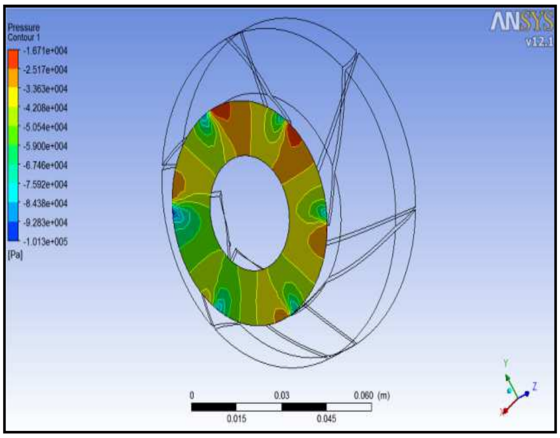

Figure 8: Inlet Pressure Contour

Outlet

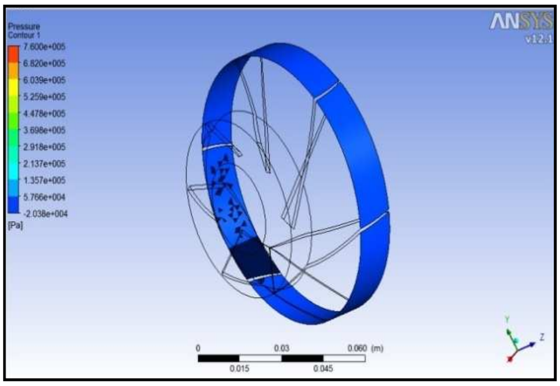

Figure 9: Outlet Pressure Contour

Head Generated = (Output Pressure – Input Pressure)/ρ*g

= (7.67e5 – (-1.67e4))/(1000*9.81)

= 76.46

Table 2: Variation of Head

Sr.No.	Description	750T Pump
1	Head (Experimental)	74.5
2	Head (CFD)	76.46
3	Percentage Variation	2.56343186

OPTIMIZATION OF RESULTS

Existing Impeller Data

Outlet Angle: 29°

Inlet Angle: 40°

9 Different Combination of Impeller is generated for Optimization

Optimization for Outlet and Inlet Blade Angle

Table 3: Optimization of Outlet and Inlet Blade Angle

Impellers	Outlet Blade Angle	Inlet Blade Angle	No. of Blades
Impeller 1	27	38	4
Impeller 2	27	40	6
Impeller 3	27	42	8
Impeller 4	29	38	6
Impeller 5	29	40	8
Impeller 6	29	42	4
Impeller 7	31	38	8
Impeller 8	31	40	4
Impeller 9	31	42	6

Results from Optimization

Table 4: Result Table

Impellers	Outlet Pressure (Pa)	Head (m)
Impeller 1	9.16E+04	80.60
Impeller 2	9.73E+04	84.25
Impeller 3	1.16E+05	86.75
Impeller 4	8.91E+04	78.53
Impeller 5	9.00E+04	76.46
Impeller 6	8.92E+04	75.42
Impeller 7	8.21E+04	72.38
Impeller 8	8.43E+04	73.36
Impeller 9	8.57E+04	74.45

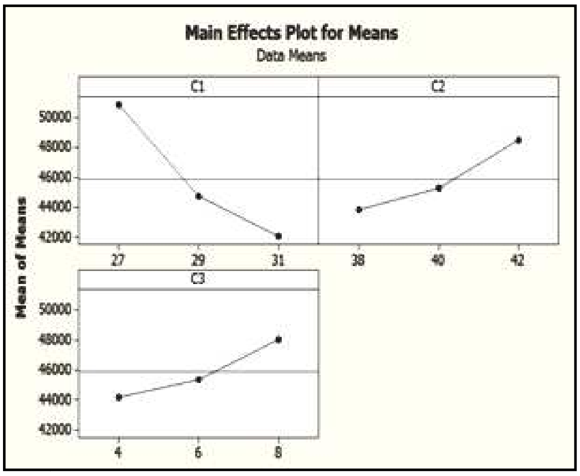

Figure 10: S-N Ratio Plot

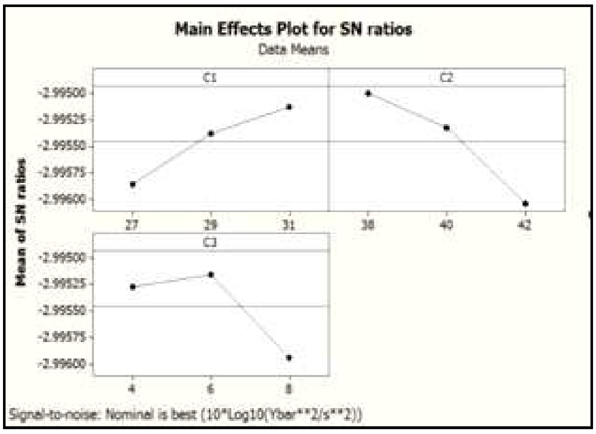

Figure 11: Main Effect Plot for SN Ratio

CONCLUSIONS

- By increasing the outlet Blade angle and decreasing the inlet blade angle improves the performance of pump that is simulated in this study
- Best head 74.50m and No. of blade 6 point of the pump (Impeller 3) simulated in this study increases total head from 76.46m to 86.75 m so increase the performance of pump.
- Outlet pressure also increases.
- No. of blade can also increase so efficiency of increase.
- Performance of the pump impeller also increases due to outlet blade angle decrease and inlet blade angle increase.
- Optimum head found at the 8 no. of blade impeller with 27^0 outlet blade angle and 42^0 inlet blade angle optimum head found.

Thus selecting suitable blade angles and head are important from the manufacturing point of view

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