

Improving The Head And Efficiency of A Pump

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Abstract - Pump widely used in agricultural irrigation, flood control, urban water supply, the cooling water system of power plant, Dairies, Firefighting systems, cooling water circulating systems and other fields. When the flow passes through the blades, it is always complicated to understand the behaviour of the flow. The losses created like impeller entry losses, leakage loss, and impeller losses always decreases the efficiency of the pump. Hence, by reducing the losses of pump, Performance of pump has been improved. To improve the head and efficiency of pump, various analytical softwares are available which gives the information about complex flow inside the impeller. The models of the pump impeller made in solidworks 2009. Performance analysis has been carried out by experimental and ANSYS CFX software. For the given problem backward blade pump with 8 number of blade is selected. Experimental readings have been collected from company and software analysis results compared. Now, the parameters like inlet blade angle, outlet blade angle, number of blades have been changed for analysis. From the results obtained by changed geometry has been optimized by Taguchi method. Performance Improved has been seen in the head and efficiency of the pump.

Key words - Pump, Computational Fluid Dynamics (CFD) analysis, and Optimization with taguchi method.

I. INTRODUCTION

A pump is a device used to move liquids by mechanical action. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps. A wide variety of pump types have been constructed and used in many different applications in industry. Pumps must have a mechanism which operates them, and consume energy to perform mechanical work by moving the fluid. The activating mechanism is often reciprocating or rotary. Pumps may be operated in many ways, including manual operation, electricity, an engine of some type, or wind action. Mixed Flow Pump:-

Main Parts of A Pump

- Impeller blade
- Electric motor
- Stuffing box
- Coupling
- Head shaft

Application

Pumps are found in many applications. Single stage pumps are used for drainage, sewage pumping, general industrial pumping and slurry pumping. They are also popular with aquarium filters. Multiple stage submersible pumps are typically lowered down a borehole and used for water abstraction, water wells and in oil wells.

Problem Of Definition

- I obtain information with the research paper A. Manivannan related my topic. Which is so helpful to achieve my final result.
- The Experimental Data collected from the A. Manivannan research paper to be say that low head and efficiency that are the major problem of pump.
- There are different types of losses occurs in this pump like friction losses, pressure drop, impeller losses.
- Also optimization the performance of Existing pump impeller by Taguchi method.

II. LITERATURE SURVEY

Amanivannan (2010) et al, in his studied of CFD analysis of pump derived that the pump the best efficiency point of the pump is found. The existing impeller, the head, power rating and efficiency are found out to be 19.24 m, 9.46 kW and 55% respectively. The impeller 1, the percentage increase in the head, power rating and efficiency are 3.22%, 3.9% and 7.27% respectively. The impeller 2, the percentage increase in the head, power rating and efficiency are 10.29%, 7.61% and 10.91% respectively. The impeller 3, the percentage increase in the head, power rating and efficiency are .66%, 12.16% and 18.18% respectively. Viscous flow analysis of mixed flow pumps impeller. [2]

Impeller design	Inlet angle (deg)	Outlet angle (deg)
Existing	75	55
Impeller 1	75	60
Impeller 2	65	60
Impeller 3	55	65

Table 1- Vane angle of modified impellers

Kiran patel (2008) et al, in his studied of CFD analysis of pump derived that the head predicted by CFD analysis is higher than the test result at rated point. It also concluded that power predicted by CFD analysis is higher at rated point to compare with the test result.

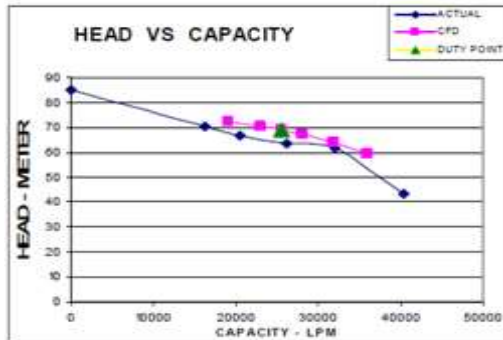


Fig1: Head versus Capacity Curve

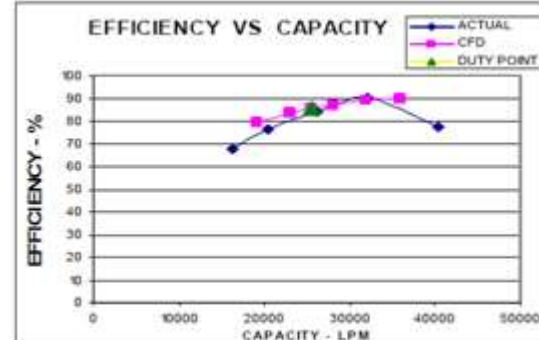


Fig2: Efficiency versus Capacity Curve

Power predicted by CFD analysis is 5 to 10% higher at rated point. The volumetric efficiency is determined. Pump efficiency considering disc friction loss and leakage-loss was predicted and it was found within +5% ranges, at duty point. Efficiency predicted by CFD analysis is higher than the test result. Leakage-loss was predicted using. Efficiency was improved by 1% after matching stator angle and changing hub curve profile. Stator blade loading at hub and shroud has improved. [1]

Mandar TABIB*(2009)et al, in his study of CFD analysis of pump derived that the computational simulation of the mixed flow pump impeller was implemented. A CFD code, the ANSYS® CFX® 12.1, was used to obtain the head and pressure, velocity streamlines. The analysis results show the head of 7.45m and the head achieved by the experimental work in industries was 8.08 m. The efficiency find by experimental result was 53.27 % and by CFD analysis 49.6 %. Because in CFD analysis there is no influence from the diffuser, so the friction losses are smaller, affecting the pressure fields and increasing the head values. This fact represents the necessity to introduce the friction losses due to coupling between the diffuser and impeller. Result shows pressure in the impeller channels increases from the entrance to the discharge in successive ranges. [3]

III. FUNCTION OF WORK

A survey of the previous research work has shown that various authors have carried out investigations under completely different conditions. I have selected backward-swept pump impeller having 8 number of blade. I have collected experimental reading from the research paper and analysis of pump impeller in software. First, I have completed modelling and meshing of pump impeller and I have been completed CFD analysis of pump. Then experimental readings from company and analysis results from ANSYS CFX software compared. The parameter like inlet and outlet blade angle, number of impeller blade have been changed for analysis. So I have been get different result for different parameter. The results of different parameter pump impeller are optimized by Taguchi method. Finally, Results of Taguchi method have been achieved maximum head, power consume and efficiency. On the basis of optimization, the final conclusion has been predicted.

IV. METHODOLOGY

Table 2: DATA COLLECTED FROM RESEARCH PAPER

Sr. no.	Parameter	Size
1	Blade inlet angle (α)	40°
2	Blade outlet angle (β)	29°
3	Number of blade	8
4	Blade thickness (t)	3mm
5	Impeller inlet Diameter (D_i)	50mm
6	Impeller outlet Diameter (D_o)	112mm
7	Impeller Rotation speed	2800rpm
8	Casing inlet diameter	NOT POSSIBLE BECAUSE FLUID IS ENTER FROM IMPELLER
9	Casing outlet diameter	27.75 mm
10	Casing width	92 mm

Boundary Condition

Table 3: Boundary Condition

Inlet boundary condition	Pressure	1.948×10^4 pa
	Velocity	8.083 m/sec

Outlet Boundary condition	Temperature	298 k
	Mass flow rate	7 kg/sec
	Pressure	1.382×10^5 pa
	Velocity	23.162 m/sec
	Temperature	305 k
Wall Boundary condition	Mass flow rate	7 kg/sec
	Heat transfer	adiabatic
	Mass and Momentum	No slip well
	Wall Roughness	Smooth wall
Blade Boundary condition	Wall motion	Rotating
	Heat transfer	adiabatic
	Mass and Momentum	No slip well
	Wall Roughness	Smooth wall
	Surface Roughness on blade	10micron
Heat transfer Model		Total Energy
Turbulence Model		K-Epsilon
Fluid		Water (1000 Density)
Element		Tetrahedral Element

Table 4- CHANGED PARAMETERS OF IMPELLER

Sr. no.	Parameters	Existing data	Case-1	Case-2
1	Number of blade	8	6	10
2	Blade inlet angle	40°	38°	42°
3	Blade outlet angle	29°	27°	31°

V. MODELLING OF PUMP

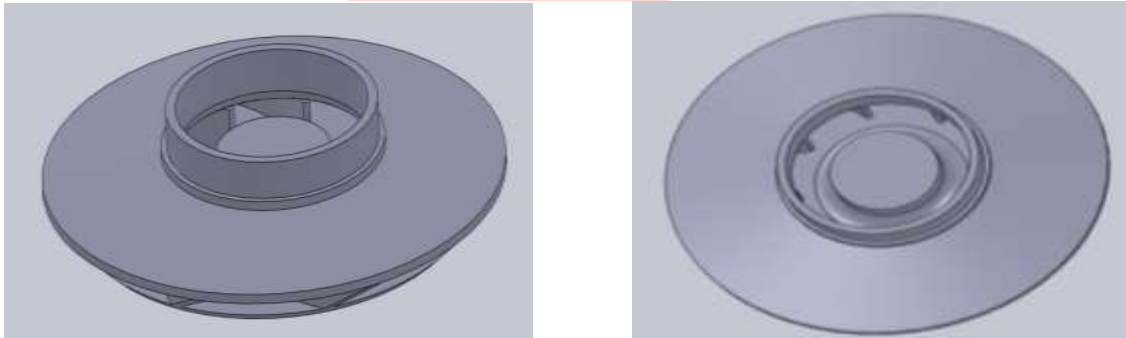


Fig 3: 3D Model of pump impeller

Our CFD Analysis method is Cavity Patten so we have to create Cavity model of above impeller. Save below Cavity model in *.IGES Format for Importing into ANSYS Workbench Mesh Module for Meshing.

Cavity Model of Impeller

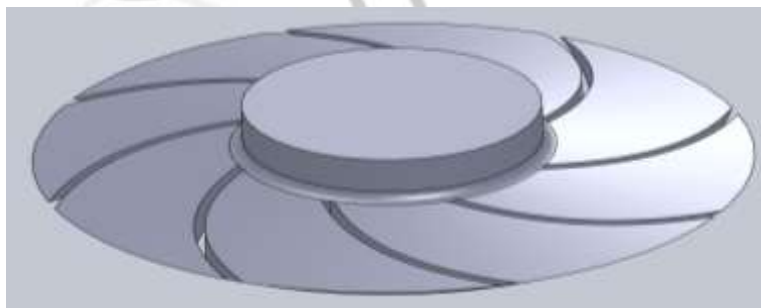


Fig 4-Create Cavity Model of pump impeller

CFD ANALYSIS OF PUMP

Techniques for numerical discretization

- (1) Finite difference method
- (2) Finite volume method
- (3) Finite element method

Procedure of CFD Analysis

- (1) 3D Model of Impeller is generated in SOLIDWORKS 2009 as per above given Drawing.
- (2) Our CFD Analysis method is Cavity Patten so we have to create Cavity model of below impeller.

- (3) Save above Cavity model in *. IGES Format for Importing into ANSYSWorkbench Mesh Module for Meshing.
- (4) Import above Cavity model in ANSYS Workbench Mesh Module.
- (5) Meshing of Impeller:-

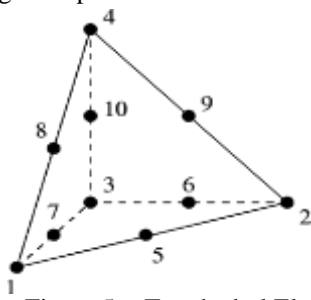


Figure 5: - Tetrahedral Element

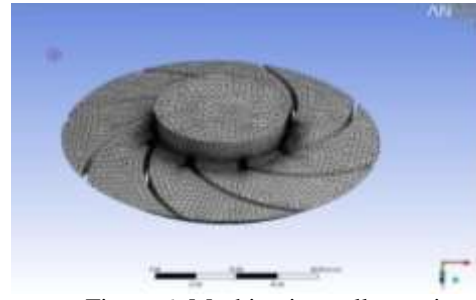


Figure 6: Meshing imepeller cavity

Table 5: Meshing of impeller

Domain	MESHING TYPE	TYPE OF ELEMENT	No. OF Nodes	NO. OF Elements
Impeller	3D	TETRAHEDRAL	61847	319895

- (6) Save Above model in *.CMDB Format for importing into ANSYS CFX Pre.
- (7) Import above .CMDB File in ANSYS CFX Pre:-
- (8) Define Water Domain:-
- (9) Define Heat Transfer and Turbulence model:-

The continuity Equation is then

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho U) = 0$$

The momentum equation becomes:-

$$\frac{\partial \rho U}{\partial t} + \nabla \cdot (\rho U \otimes U) - \nabla \cdot (\mu_{eff} \nabla U) = \nabla P' + \nabla \cdot (\mu_{eff} \nabla U) T + B$$

- (10) Define Hub as a Rotating Wall:-
- (11) Define Shroud as a Rotating Wall:-
- (12) Define inlet for Impeller:-
- (13) Define Outlet for Impeller:-
- (14) Define Solver Control Criteria:-
- (15) Run the Analysis:-
- (16) Get the Results:-

RESULTS ANALYSIS OF EXISTING IMPELLER

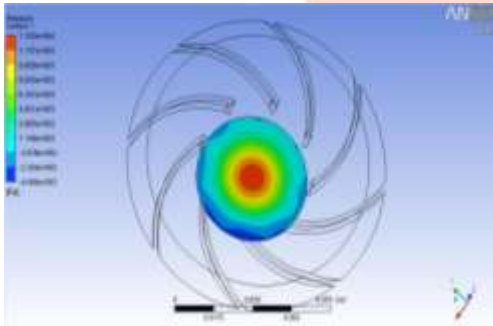


Fig 7 : Inlet pressure contour

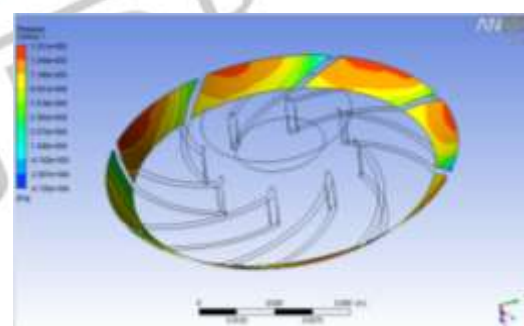


Fig 8: Outlet pressure contour

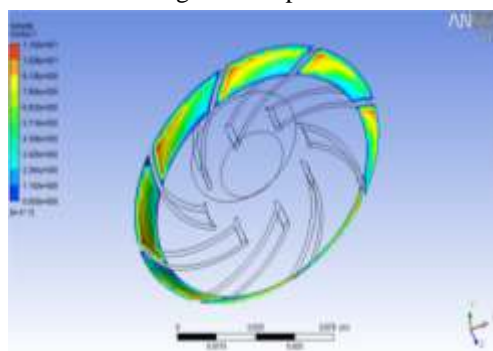


Fig 9 : Inlet velocity contour

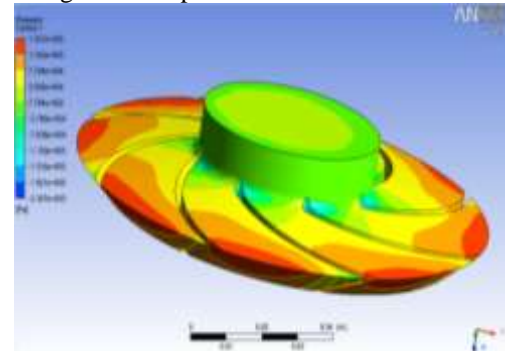


Fig 10: Full domain pressure contour

COMPARISON OF EXPERIMENTAL WITH CFD RESULTS

- Head Generated :- $\frac{P_{outlet}-P_{inlet}}{\rho \cdot g}$
 $\therefore (1.551 \times 10^5 - 1.330 \times 10^4) / (1000 \times 9.81)$
 $\therefore 14.45\text{m}$

Table 6- Head Comparison experimental with CFD Results

Sr No.	Description	Head (Experimental)	Head (CFD)	Percentage Variation
1	32B Pump	14.05m	14.45m	2.7681%

VI. OPTIMIZATION WITH TAGUCHI METHOD

Table 7: Orthogonal Array L9 of Taguchi Method using Minitab-16 software

Number of Modified impeller	Inlet Angle (degree)	Outlet Angle (degree)	Number of Blades
Modified Impeller-1	38°	27°	6
Modified Impeller-2	38°	29°	8
Modified Impeller-3	38°	31°	10
Modified Impeller-4	40°	27°	8
Modified Impeller-5	40°	29°	10
Modified Impeller-6	40°	31°	6
Modified Impeller-7	42°	27°	10
Modified Impeller-8	42°	29°	6
Modified Impeller-9	42°	31°	8

VII. RESULT ANALYSIS MODIFIED IMPELLER-1

Number of impeller	Inlet Angle (degree)	Outlet Angle (degree)	Number of Blades
Existing Impeller	40°	29°	8
Modified Impeller-1	38°	27°	6

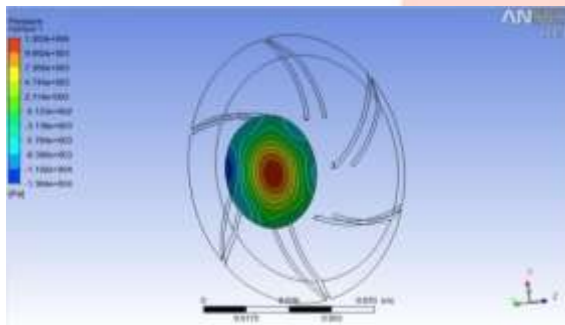


Fig 11: Inlet Pressure Impeller-1

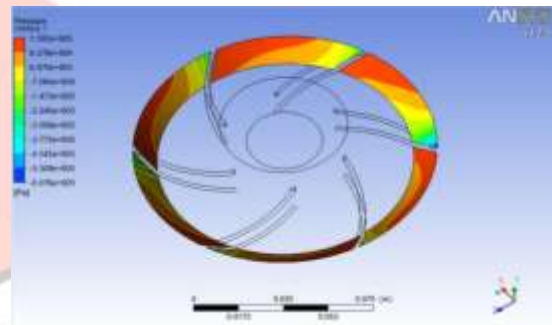


Fig12: Outlet Pressure Impeller-1

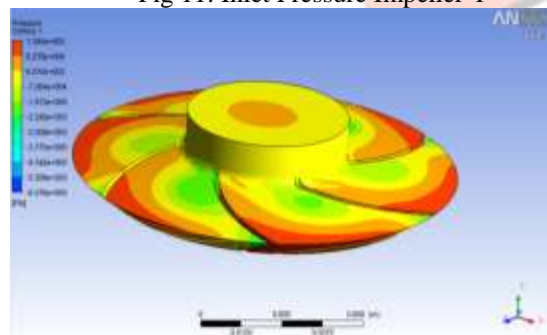


Fig 13: Full domain pressure Impeller-1

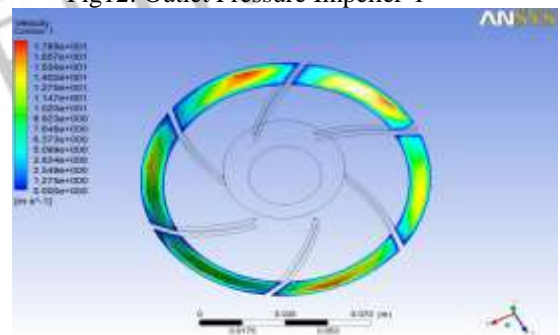


Fig 14: Outlet Velocity Impeller-1

VIII. RESULT AND ANALYSIS MODIFIED IMPELLER-2

Number of impeller	Inlet Angle (degree)	Outlet Angle (degree)	Number of Blades
Existing Impeller	40°	29°	8
Modified Impeller-2	38°	29°	8

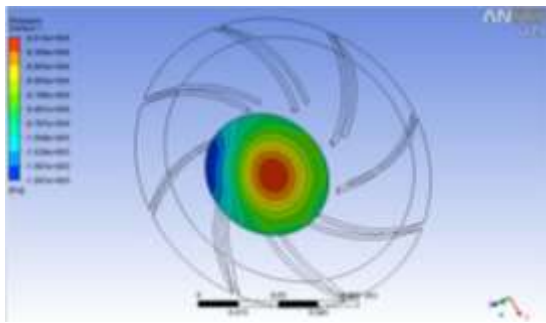


Fig 15: Inlet pressure Impeller-2

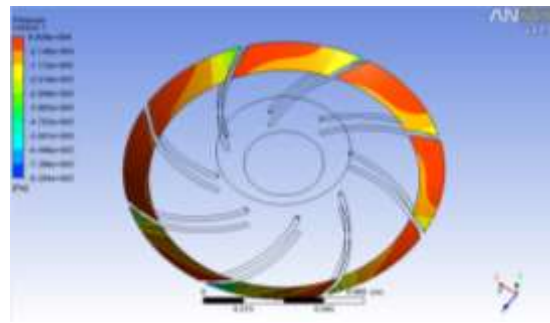


Fig 16: Outlet pressure Impeller-2

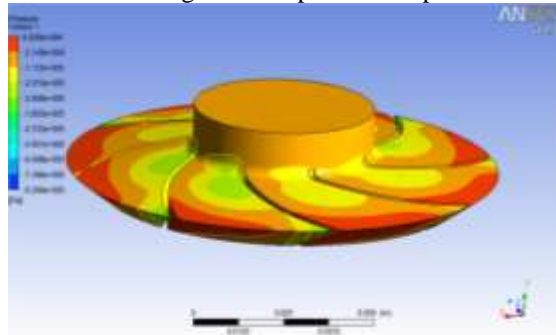


Fig 17: Full pressure domain Impeller-2

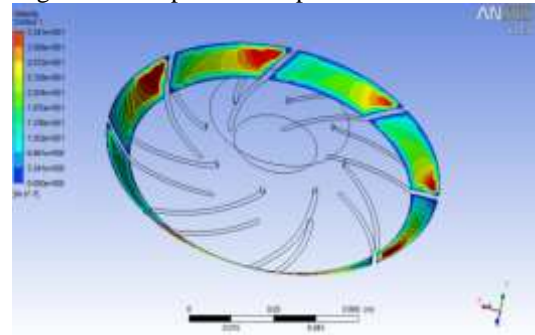


Fig 18: Outlet Velocity Impeller-2

Same method we analysis of Modified impeller 3 to 9 and we get the results below table.

IX. OPTIMIZATION TAGUCHI RESULT TABLE

TABLE 8:Optimization Result Table

Number of Modified Impeller	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades	Outlet Pressure (Pa)	Inlet Pressure (Pa)	Head (m)	Velocity (m/sec)	Torque (N.m)	Power Consumed (Watt)	Efficiency (%)
Impeller-1	38°	27°	6	1.60×10^5	1.29×10^4	14.94	16.37	10.95	3208.92	81.39
Impeller-2	38°	29°	8	6.83×10^4	-8.04×10^4	15.16	20.04	11.91	3490.54	79.83
Impeller-3	38°	31°	10	1.21×10^5	-4.20×10^4	16.64	16.37	9.88	2896.72	83.63
Impeller-4	40°	27°	8	9.95×10^4	-5.22×10^4	15.46	23.50	11.05	3237.16	82.00
Impeller-5	40°	29°	10	1.61×10^5	-2.52×10^3	16.62	15.26	9.01	2640.94	85.19
Impeller-6	40°	31°	6	6.44×10^4	-7.93×10^4	14.65	22.18	10.99	3219.67	80.40
Impeller-7	42°	27°	10	1.31×10^5	-4.98×10^4	18.46	15.40	9.06	2655.10	84.61
Impeller-8	42°	29°	6	6.47×10^4	-8.74×10^4	15.50	24.35	9.56	2800.78	86.22
Impeller-9	42°	31°	8	7.56×10^4	-6.20×10^4	14.02	20.22	11.18	3277.33	80.24

There are different 9 cases of modified impeller analysis. (Shown in above table 6.15) The result of Taguchi optimum head is 18.46m, Power consumed is 2655.10w, and efficiency is 84.61% at 42° inlet angle and 27° outlet angle, 10 no. of blade of pump impeller.

X. CONCLUSION

- The 9 number of analysis are done for those sets of parameters. Analysis values of performance are put in the Minitab software 16 and the set of parameter 42° inlet angle, 29° outlet angle and 10 number of blade predicated. The Minitab software predicated head is 18.46m, power consumed is 2655.10w, and efficiency is 84.61%
- These analysis values of pump head, power consumed and efficiency are very closer to the predicated by Minitab software 16 values.

- Set of parameter 42^0 inlet angle, 29^0 outlet angle with 10 number of blade is successfully used in the pump by changing parameters level.
- By this method in the pump impeller is increases the number of blade which gives the maximum head, efficiency and minimum power consumed. Also outlet angle is same, inlet angle is increases so, that maximum head and efficiency.

XI. SCOPE OF THE FUTURE WORK

- By this method, we will optimize other parameters which are not used in this CFD analysis.
- Same CFD Analysis will be done to achieve total pressure characteristics.
- This method will be also used for other pumps.
- This CFD analysis and modelling will be done for pump by other analytical softwares. (Like Catiya, Solid edge, Auto-cad, C++ etc.)
- This analysis will be done with other parameters like impeller diameter, diffuser, impeller casing interaction etc.,
- This analysis will be done for same pump by other DOE method or other optimization techniques.

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