

# **“PERFORMANCE ANALYSIS AND OPTIMIZATION OF MIXED FLOW PUMP”**

## **Research Paper**

Author-1:-

(P.G.Student) Name- **Mehul P. Mehta<sup>1</sup>**

Mobile no. +918866801327

University- Gujarat Technology University

Branch- Mechanical engineering

Master of engineering in subject of Thermal Engineering

Address- B-16, Maitrinagar society, bholav, bharuch.-392202

College name-LDRP-ITR, Near ITI, KH-5 Circle, Gandhinagar, Gujarat -382015,

Author-2:-

Guide Name- **Assistant professor. Prajesh M. Patel<sup>2</sup>**

Mobile no. +919409065134

University- Gujarat Technology University

Department- Mechanical engineering (LDRP-ITR at Gandhinagar, Gujarat)

College name-LDRP-ITR, Near ITI, KH-5 Circle, Gandhinagar, Gujarat -382015,

---

## **ABSTRACT**

Mixed flow pump widely used in agricultural irrigation, flood control, urban water supply, the cooling water system of power plant, Dairies, Fire fighting systems, cooling water circulating systems other fields. When flow passes through the blades, it is always complicated to understand the behaviour of flow. The losses create like impeller entry losses, leakage loss, impeller losses and diffuser losses always decreases the efficiency of the mixed flow pump. Hence, by reduce the losses of mixed flow pump impeller have been improve the performance of mixed flow pump.

To improve the head and efficiency of mixed flow pump, various analytical software available which gives the information about complex flow inside the impeller. The models of the mixed flow pump impeller made in solidworks 2009 (made by Dassault system Compny). Performance analysis has been carried by experimental and ANSYS CFX software. For the given problem backward blade mixed flow pump with 8 number of blade is selected. Experimental readings have been collected from company and software analysis results compared. Now, the parameter like inlet blade angle, outlet blade angle, number of blades has been changed for analysis. From the results obtained by changed geometry has been optimized by Taguchi method.

**Key words:** Mixed flow pump, Computational Fluid Dynamics (CFD) analysis, and Optimization with taguchi method.

---

## **CHAPTER -1 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:-

In this pump, addition of energy to the liquid occurs when the flow of liquid in axial as well as radial direction. In this type of pump liquid through impeller is as combination of axial and radial direction the head is developed partly by the action of centrifugal force and partly by the propelling force. These pumps mostly suitable for irrigation purpose where large quantity of water at a lower head.

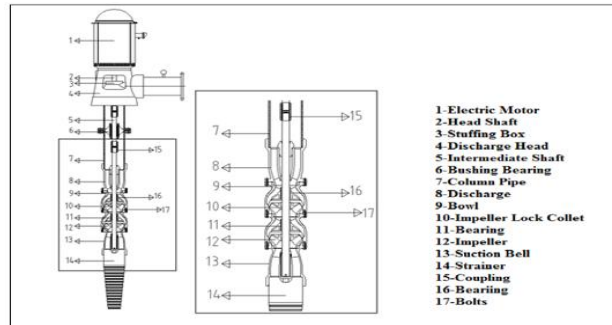


Fig 1 : Parts of the mixed flow Pump Assembly

#### MAIN PARTS OF A MIXED FLOW PUMP:-

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

#### APPLICATION:-

Submersible 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 have visit laffans petrochemical limited company and obtain information related my dissertation topic. Which is so helpful to achieve my final result.
- The Experimental Data collected from the laffans petrochemicals limited company to be say that low head and efficiency that are the major problem of mixed flow pump.
- There are different types of losses occurs in this mixed flow pump like friction losses, pressure drop, impeller losses.
- Also optimize the performance of Existing mixed flow pump impeller.
- I have visit Laffans Petrochemical Limited Company and obtain information related my dissertation topic. Which is so helpful to achieve my final result.
- The Experimental Data collected from the laffans petrochemicals limited company to be say that low head and efficiency that are the major problem of mixed flow pump.
- There are different types of losses occur in this mixed flow pump like friction losses, pressure drop, impeller losses.
- Also optimization the performance of Existing mixed flow pump impeller by Taguchi method.

## CHAPTER -2 LITERATURE SURVEY

**kiran patel (2008) et al, in his studied** of CFD analysis of mixed flow 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.

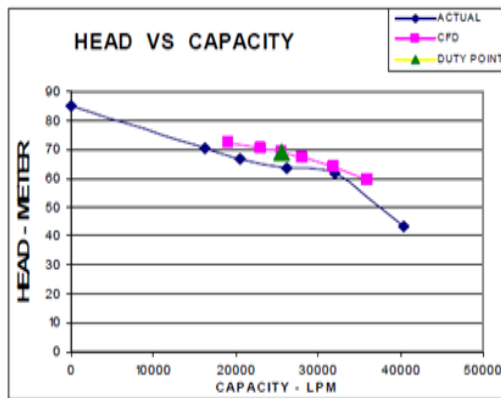


Fig 2: Head versus Capacity Curve

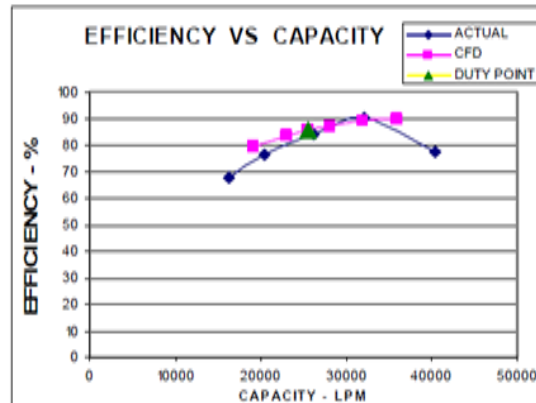


Fig 3 : Efficiency versus Capacity Curve

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]

**A Manivannan (2010) et al, in his studied** of CFD analysis of mixed flow pump derived that the mixed flow 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

**Mandar TABIB\* (2009) et al, in his study** of CFD analysis of mixed flow 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]

## OBJECTIVE 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 mixed flow pump impeller having 8 number of blade. I have collects experimental reading from the company and analysis of mixed flow pump impeller in software. First, I have completed modelling and meshing of mixed flow pump impeller and I have been completed CFD analysis of mixed flow 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 of mixed flow 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.

### CHAPTER -3 METHODOLOGY

Table 2: DATA COLLETED FROM LAFFANS PETROCHEMICALS LIMITED

Sr. no.	Parameter	Size
1	Blade inlet angle ( $\alpha$ )	40°
2	Blade outlet angle ( $\beta$ )	29°
3	Number of blade	8
4	Blade thickness (t)	3mm
5	Impeller inlet Diameter (Di)	50mm
6	Impeller outlet Diameter (Do)	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 x 10 <sup>4</sup> pa
	Velocity	8.083 m/sec
	Temperature	298 k
	Mass flow rate	7 kg/sec
Outlet Boundary condition	Pressure	1.382 x 10 <sup>5</sup> pa
	Velocity	23.162 m/sec
	Temperature	305 k
	Mass flow rate	7 kg/sec
Wall Boundary condition	Heat transfer	adiabatic
	Mass and Momentum	No slip well
	Wall Roughness	Smooth wall
	Wall motion	Rotating
Blade Boundary condition	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**

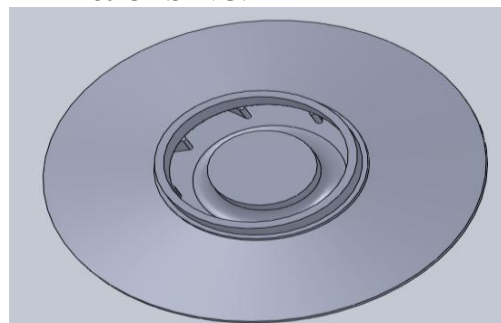
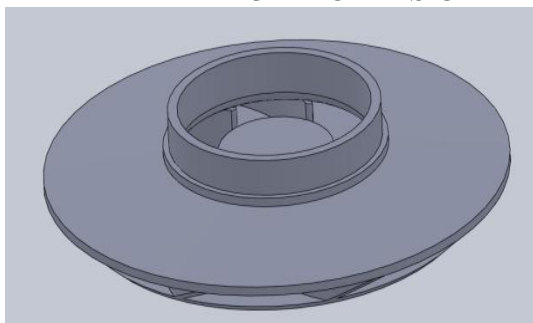
Sr. no.	Parameters	Existing data	Case-1	Case-2
1	Number of blade	8	6	10
2	Blade inlet angle	40°	38°	42°
3	Blade outlet angle	29°	27°	31°



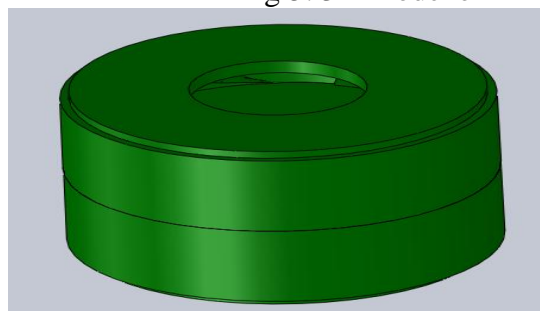
**Fig 4: - Experimental picture of mixed flow pump at laffans petrochemicals limited**

## **CHAPTER -4 MODELLING OF MIXED FLOW PUMP**

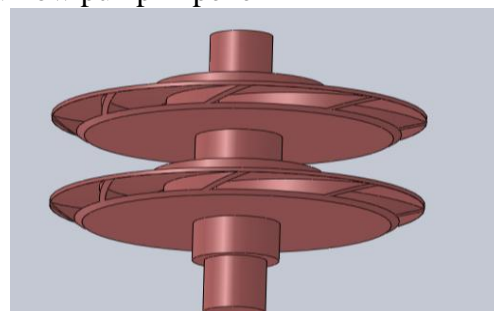
### **3D MODELS OF IMPELLER & CASING:-**



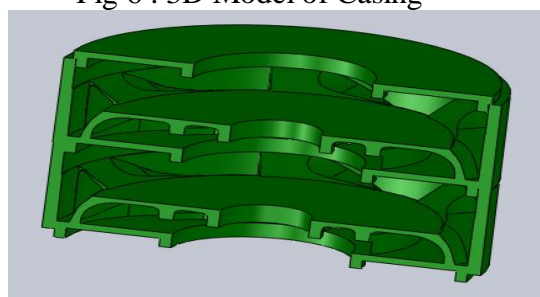
**Fig 5: 3D Model of mixed flow pump impeller**



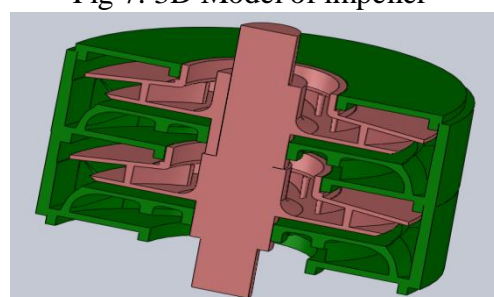
**Fig 6 : 3D Model of Casing**



**Fig 7: 3D Model of impeller**



**Fig 8: 3D Cutting Model of casing**



**Fig 9: 3D Cutting casing & 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:-

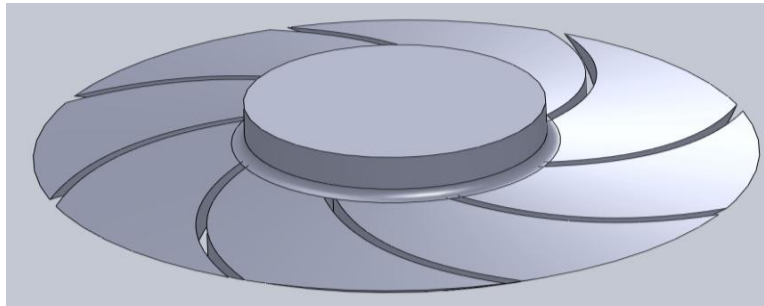


Fig 10- Create Cavity Model of Mixed flow pump impeller

## CHAPTER -5 CFD ANALYSIS OF MIXED FLOW 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.

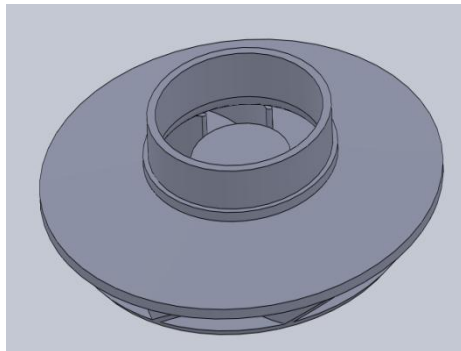


Figure11: 3D Model of Impeller

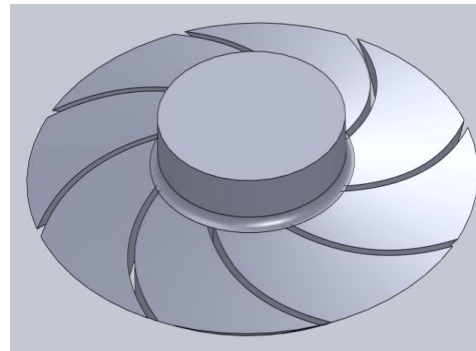


Figure12: Cavity Model of impeller

- (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:-

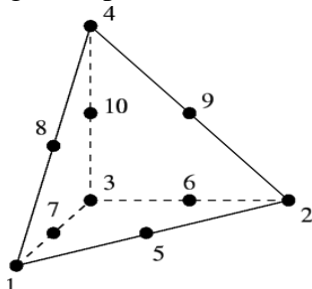


Figure13: - Tetrahedral Element

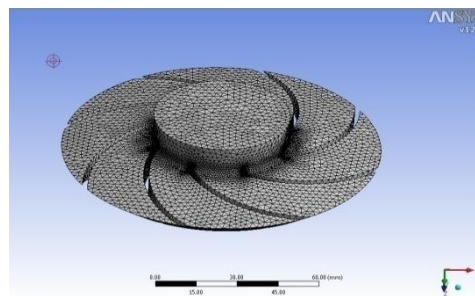


Figure14: Meshing imepeller cavity

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 OF ANALYSIS:-

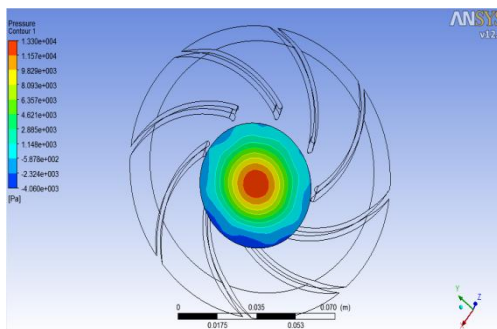


Fig 15 : Inlet pressure contour

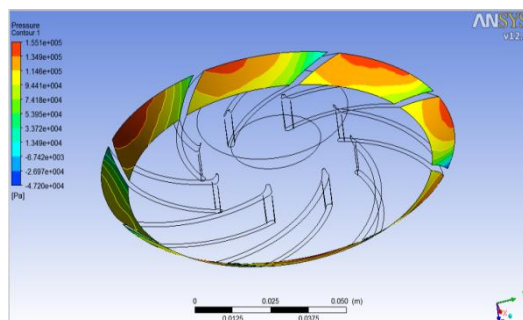


Fig 16: Outlet pressure contour

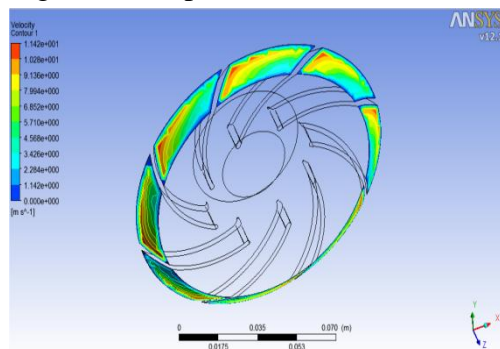


Fig 17 : Inlet velocity contour

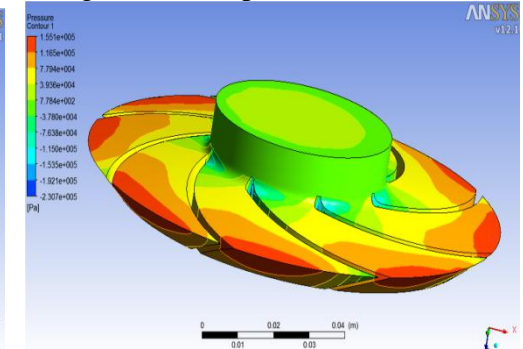


Fig 18: Full domain pressure contour

## COMPARISON OF EXPERIMENTAL WITH CFD RESULTS:-

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

Table 6- Head Comparison experimental with CFD Results

Sr No.	Description	Head (Experimental)	Head (CFD)	Percentage Variation
1	12T Pump	14.05m	14.45m	2.7681%

The use of ANSYS CFX software for CFD analysis of mixed flow pump impeller existing impeller head found out to be (14.45m). The Experimental reading of mixed flow pump impeller to be collected from Laffans Petrochemicals Limited at Panoli, the head is (14.05m). When experimental reading of mixed flow pump impeller compares with CFD Results the percentage of variation is 2.7681% to be achieved. The experimental and CFD Analysis is closer to design point conditions in mixed flow pump under study.

## CASING EFFECT ON MIXED FLOW PUMP:- RESULT ANALYSIS OF CASING:-

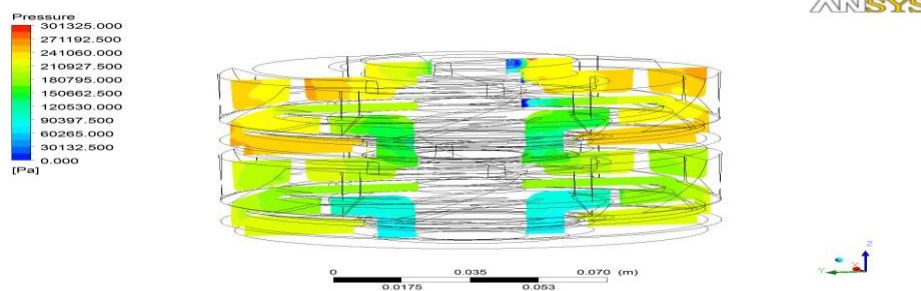


Fig 19: Full Casing Pressure Contour

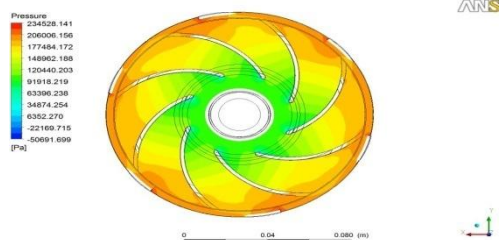


Fig 20: Pressure contour Impeller-1

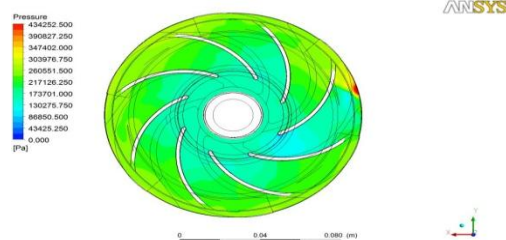


Fig 21: pressure contour impeller-2

## FULL CASING RESULT DATA:-

Table No 7 : Casing Result Data

Total Pressure at inlet	101338.00	Pa
Total pressure at outlet	265752.00	Pa
Total pressure develop	164414.00	Pa
Head	16.81	m
Velocity at inlet	8.07	m/s
Velocity at outlet	15.21	m/s
Average Torque	10.08	N.m
Power required	2781.85	Watt
Efficiency	84.78	%

## CHAPTER -6 OPTIMIZATION WITH TAGUCHI METHOD:-

Table 8: 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

### RESULT ANALYSIS MODIFIED IMPELLER-1

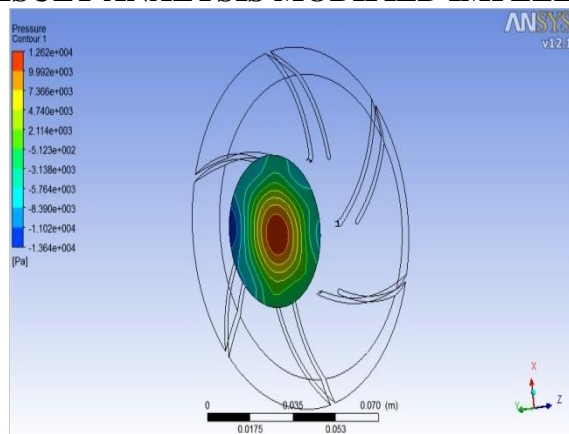


Fig 22 : Inlet Pressure Impeller-1

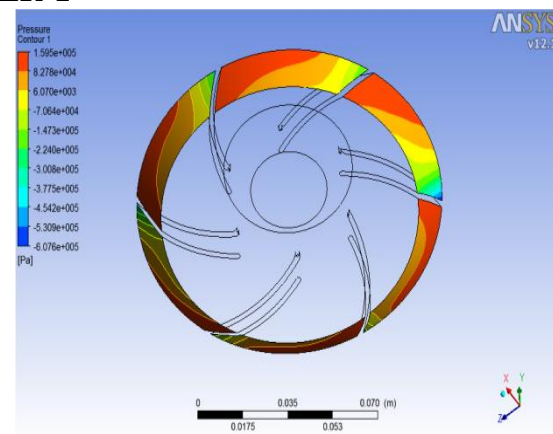


Fig 23 : Outlet Pressure Impeller-1

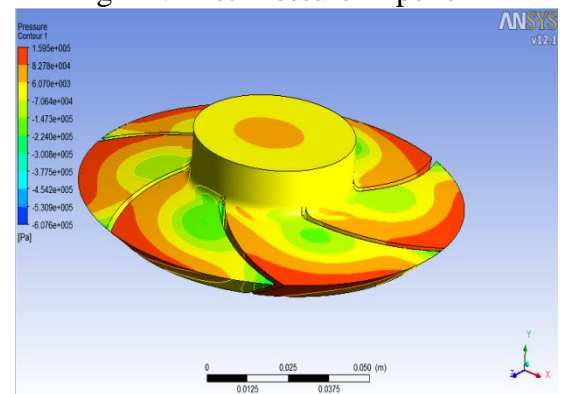


Fig 24: Full domain pressure Impeller-1

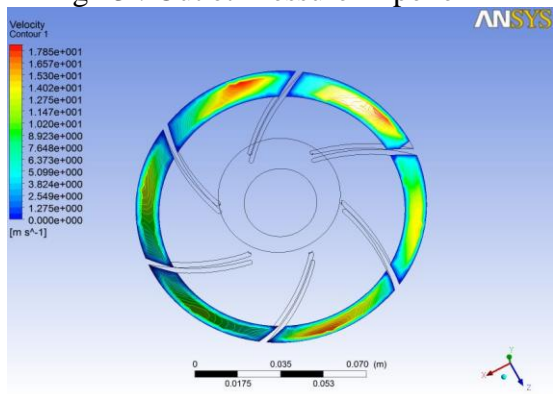


Fig 25 : Outlet Velocity Impeller-1

### 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

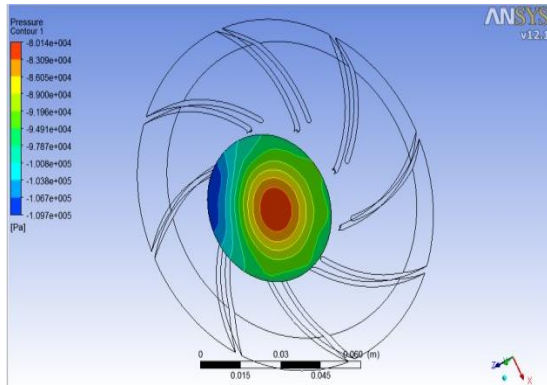


Fig 26: Inlet pressure Impeller-2

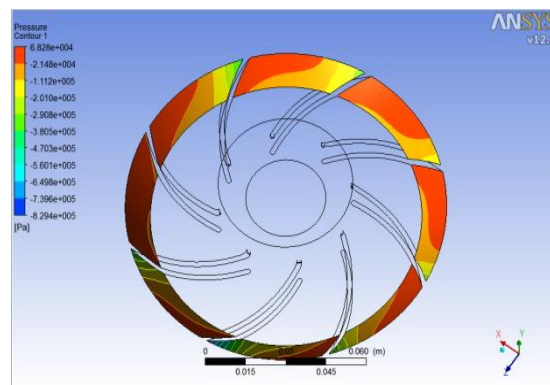


Fig 27 : Outlet pressure Impeller-2

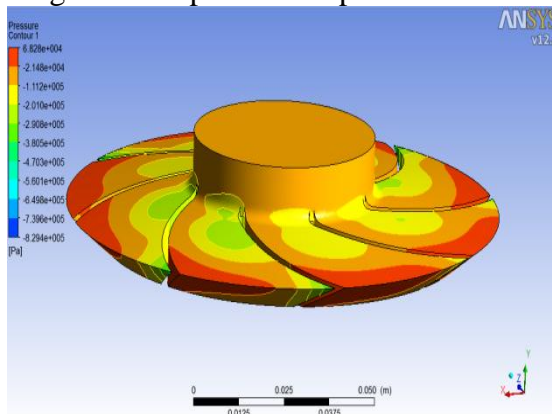


Fig 28: Full pressure domain Impeller-2

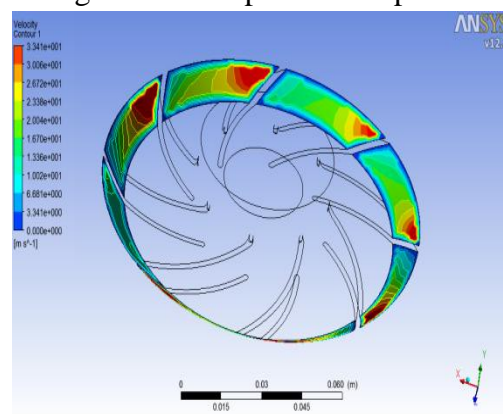


Fig 29: Outlet Velocity Impeller-2

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

### OPTIMIZATION TAGUCHI RESULT TABLE:-

TABLE 9: 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	$1.60 \times 10^5$	$1.29 \times 10^4$	14.94	16.37	10.95	3208.92	81.39
Impeller-2	38°	29°	8	$6.83 \times 10^4$	$-8.04 \times 10^4$	15.16	20.04	11.91	3490.54	79.83
Impeller-3	38°	31°	10	$1.21 \times 10^5$	$-4.20 \times 10^4$	16.64	16.37	9.88	2896.72	83.63
Impeller-4	40°	27°	8	$9.95 \times 10^4$	$-5.22 \times 10^4$	15.46	23.50	11.05	3237.16	82.00
Impeller-5	40°	29°	10	$1.61 \times 10^5$	$-2.52 \times 10^3$	16.62	15.26	9.01	2640.94	85.19
Impeller-6	40°	31°	6	$6.44 \times 10^4$	$-7.93 \times 10^4$	14.65	22.18	10.99	3219.67	80.40
Impeller-7	42°	27°	10	$1.31 \times 10^5$	$-4.98 \times 10^4$	18.46	15.40	9.06	2655.10	84.61
Impeller-8	42°	29°	6	$6.47 \times 10^4$	$-8.74 \times 10^4$	15.50	24.35	9.56	2800.78	86.22
Impeller-9	42°	31°	8	$7.56 \times 10^4$	$-6.20 \times 10^4$	14.02	20.22	11.18	3277.33	80.24

## CHAPTER -7 RESULT AND DISCUSSION:

### ➤ Analysis of pump head:-

- Calculation for head:-

$$\text{Head (H)} = \frac{P_{\text{outlet}} - P_{\text{inlet}}}{\rho * g}$$

Table 10 : Response Table for Means of Pump Head

Level	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades
1	15.58	16.29	16.60
2	15.58	17.33	14.88
3	17.56	15.10	17.24
Delta	1.99	2.33	2.36
Rank	3	2	1

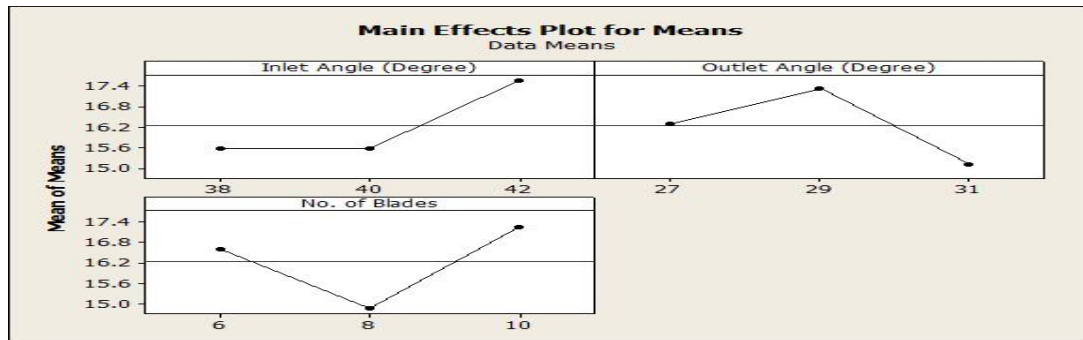


Figure- 30: Main Effects Plot for Means of Head

From above table, means is average value for reading taken for particular parameter. From graph, mean value is maximum (17.56m) for 42° inlet angle and minimum (15.58m) for (38° or 40°) inlet angles. Mean value is maximum (17.33m) for 29° outlet angle and minimum (15.10m) for 31° outlet angle. Mean value is maximum (17.24m) for 10 no. of blade and minimum (14.88m) for 8 no. of blade.

Delta is difference of maximum value and minimum value. Delta value is maximum for no. of blade parameter (2.36) and minimum (1.99) for inlet angle parameter. Delta value for outlet angle is between other two parameter it is (2.33). So that effect of no. of blade is maximum and effect of inlet angle is minimum on mixed flow pump head.

Table 11: Response Table for Signal to Noise Ratios Larger is better

Level	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades
1	23.84	24.20	24.31
2	23.84	24.71	23.44
3	24.79	23.56	24.72
Delta	0.95	1.15	1.28
Rank	3	2	1

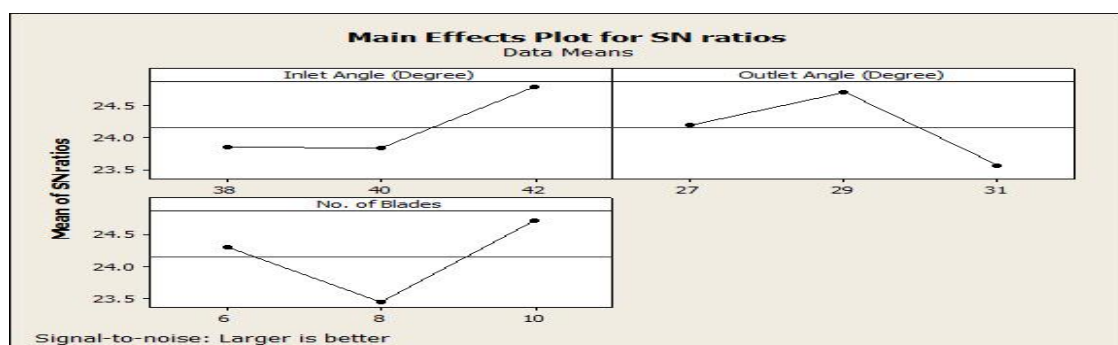


Figure- 31: Main Effects Plot for S/N ratios of Pump Head

The optimum setting is determined by choosing the level with the highest S/N ratio. Referring. The response curve for S/N ratio, the highest S/N ratio was observed at 42° inlet angle (24.79), no. of blade (10) and outlet angle (29°), which optimum parameters are setting for highest mixed flow pump head. The Delta values as mention above, maximum (1.28) for no. of blade and minimum (0.95) for inlet angle. Parameter no. of blade is most significant parameter and inlet angle is least significant for mixed flow pump head.

### ❖ RESULT ANALYSIS OF TAGUCHI PREDICTED IMPELLER

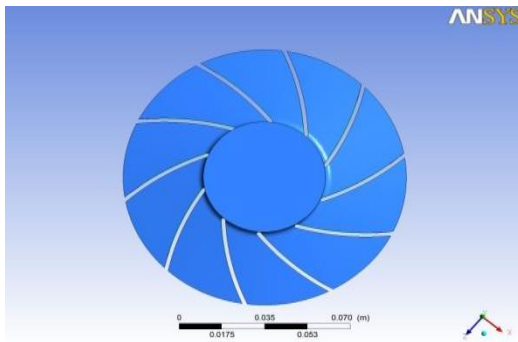


Fig 32: Cavity Model of Impeller-10

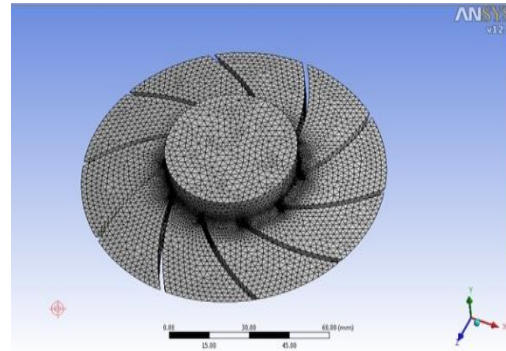


Fig 33: Mesh model of Impeller-10

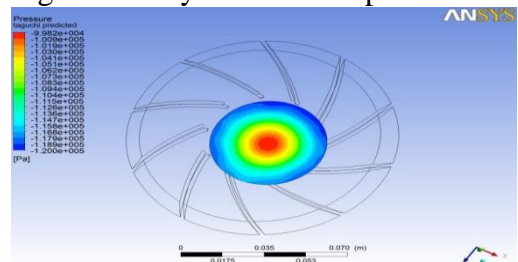


Fig 34: Inlet Pressure Impeller-10

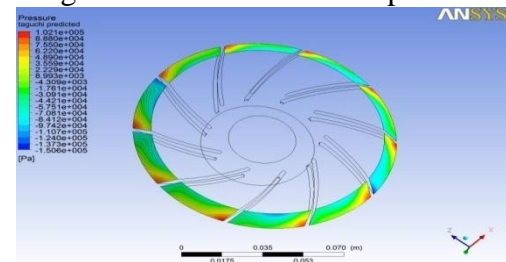


Fig 35: Outlet Pressure Impeller-10

Table 12: Taguchi Predicted Results for Pump Head

Head (m)	S/N Ratio
19.65	25.91

Table 13: Validation Results for Head

Taguchi Modified Impeller	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades	Outlet Pressure (Pa)	Inlet Pressure (Pa)	Head (m)
Validation-1	42°	29°	10	$1.021 \times 10^5$	$-9.982 \times 10^4$	20.58

Analysis has done for above set of parameter gives performance as shown in above table. The pump Head is (20.58m). This analysis value is nearer our predicted value is (19.65m). So, that our analysis going to a right way.

#### ➤ Analysis for pump power consumed:-

- Calculation for Pump Power consumed:-

$$\text{Power Consumed (P)} = \frac{2 * \pi * N * T}{60}$$

Taguchi Analysis of Pump Power consumed by Using Minitab Software:-

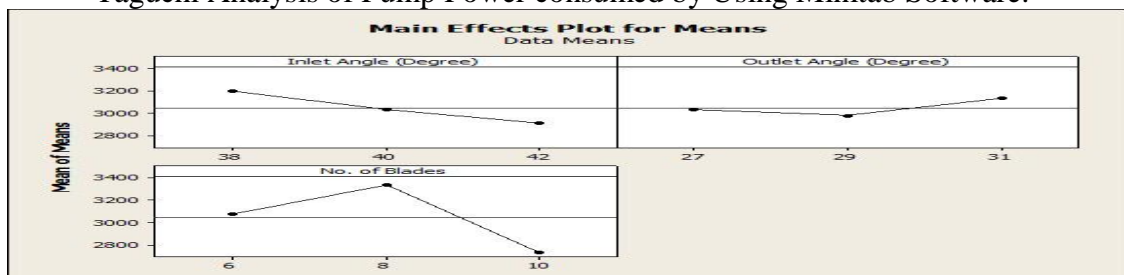


Figure 36: Main Effects Plot for Means of Pump Power Consumed

Table 14: Response Table for Means of Pump Power consumed

Level	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades
1	3199	3034	3076
2	3033	2977	3335
3	2911	3131	2731
Delta	288	154	604
Rank	2	3	1

From above table, mean is an average value for reading taken for particular parameter. From graph, mean value is maximum (3199) for 38° inlet angle and minimum (2911) for 42° inlet angle.

Mean value is maximum (3131) for 31° outlet angle and minimum (2977) for 29° outlet angle. Mean value is maximum (3375) for 8 no. of blade and minimum (2731) for 10 no. of blade.

Delta is difference of maximum value and minimum value. Delta value is maximum for no. of blade parameter (604) and minimum (154) for outlet angle parameter. Delta value for inlet angle is between other two parameter and it is (288). So that effect of no. of blade is maximum and effect of outlet angle is minimum on power consumed. (1.63).

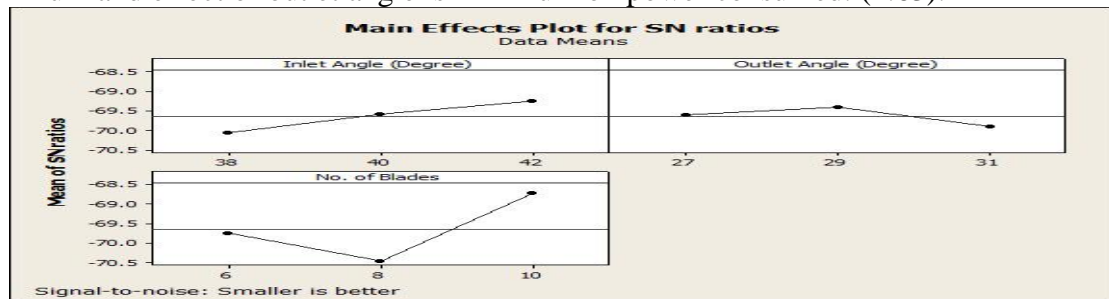


Figure 37: Main Effects Plot for S/N Ratio for Pump Power consumed

Table 15: Response Table for S/N Ratios for Means Pump Power Consumed

Level	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades
1	-70.07	-69.60	-69.74
2	-69.60	-69.41	-70.46
3	-69.25	-69.90	-68.72
Delta	0.83	0.49	1.74
Rank	2	3	1

The optimum setting is determined by choosing the level with the lowest S/N ratio. Referring, the response curve for S/N ratio, the lowest S/N ratio was observed at 38° inlet angle (-70.07), 8 no. of blade (-70.46) and 31° outlet angle (-69.90), which are optimum parameter setting for lowest pump power consumed. The delta values as mention above, maximum (1.74) for no. of blade and minimum (0.49) for outlet angle. Parameter no. of blade is most significant parameter and outlet angle is least significant for pump power consumed.

Table 16: Predicted Results for Pump Power consumed

Power Consumed (Watt)	S/N Ratio
2524.49	-68.09

Table 17: Validation Results for Pump Power Consumed

Taguchi Modified Impeller	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades	Torque (N.m)	Power Consume (Watt)
Validation-2	42°	29°	10	9.01	2546.62

Analysis has done for above set of parameter gives performance as shown in above table. The pump power consumed is (2546.62w). This analysis value is nearer our predicted value

(2524.49w). So, that our analysis going to a right way.

- Analysis of mixed flow pump efficiency:-
  - calculation of mixed flow pump efficiency:-

$$\text{Pump Efficiency } (\eta) = \frac{(P_{\text{outlet}} - P_{\text{inlet}}) * Q * 100}{P}$$

Table 18: Response Table for Means of Pump Efficiency

Level	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades
1	81.62	82.67	84.00
2	82.53	85.08	80.69
3	85.02	81.42	84.48
Delta	3.41	3.66	3.79
Rank	3	2	1

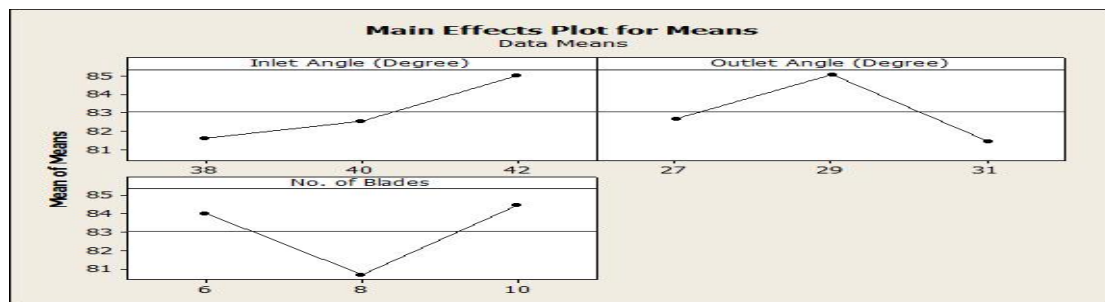


Figure-38: Main Effects Plot for Means of Pump Efficiency

From above table, mean is an average value for reading taken for particular parameters. From graph, mean value is maximum (85.02%) for 42° inlet angle and minimum (81.62%) for 38° inlet angle.

Mean value is maximum (85.08%) for 29° outlet and minimum (81.42%) for 31° outlet angle. Mean value is maximum (84.48%) for 10 no. of blade and minimum (80.69%) for 8 no. of blade.

Delta is difference of maximum value and minimum value. Delta value is maximum for no. of blade parameter (3.79) and minimum (3.41) for inlet angle parameter. Delta value for outlet angle is between other two parameter and it is (3.66). So that effect of no. of blade is maximum and effect of outlet angle is minimum on pump efficiency. Table 19: Response

Table for S/N Ratios for Means Pump Efficiency

Level	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades
1	38.23	38.35	38.47
2	38.33	38.59	38.14
3	38.58	38.21	38.53
Delta	0.35	0.37	0.40
Rank	3	2	1

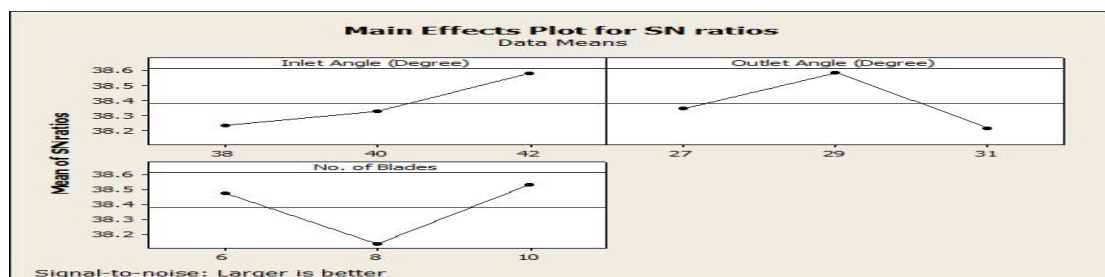


Figure- 39: Main Effects Plot for S/N Ratio for Pump Efficiency

The optimum setting is determined by choosing the level with the highest S/N ratio. Referring , the response curve for S/N Ratio, the highest S/N ratio was observed at 42° inlet angle (38.58), 10 no. of blade (38.53) and 29° Outlet angle (38.59), which are optimum parameter setting for highest mixed flow pump efficiency. The delta values as mention above, maximum (0.40) for no. of blade and minimum (0.35) for inlet angle. Parameter no. of blade is most significant parameter and inlet angle is least significant for mixed flow pump efficiency.

Table 20: Predicted Results for Pump Efficiency

Efficiency (%)	S/N Ratio
88.46	39.93

Table 21: Validation Results for Pump Efficiency

Number of Modified Impeller	Inlet Angle (Degree)	Outlet Angle (Degree)	No. of Blades	Outlet Pressure (Pa)	Inlet Pressure (Pa)	Head (m)	Torque (N.m)	Power Consumed (Watt)	Efficiency (%)
Validation-3	42°	29°	10	$1.021 \times 10^5$	$-9.982 \times 10^4$	20.58	9.01	2546.62	88.34

Analysis has done for above set of parameter gives performance as shown in above table. The Mixed flow pump efficiency is achieved (88.34%). This analysis value is nearer our predicted value (88.46%). So, that our analysis going to a right way.

## CHAPTER -8 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 19.65m, power consumed is 2524.49w, and efficiency is 88.46%
- The suggested set of parameter validation analysis has been done and compared with predicated value. The value of validation analysis for mixed flow pump head is 20.58m, power consumed is 2546.62w and efficiency is 88.34%.
- These analysis values of mixed flow pump head, power consumed and efficiency are very closer to the predicated by Minitab software 16 values.
- Also prove that Taguchi parameter concept is more powerful and efficient tool for maximize head and efficiency and minimize power consumed.
- By the Taguchi method in the mixed flow 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.

## CHAPTER -9 REFERENCE

### PAPERS:-

1. Kiran patel and N. Ramakrishnan, “computational fluid dynamics Analysis of mixed flow pump”
2. A. Manivannan, “computational fluid dynamics Analysis of mixed flow pump impeller” International Journal of Engineering, Science and Technology, Vol2, No.6,2010,pp.200-206
3. Mandar tabib, Graeme lane, William yang and m Philip schwarz “cfd simulation of a solvent extraction pump mixer unit: evaluating large eddy simulation and rans based models”, Seventh International Conference on CFD in the Minerals and Process Industries,CSIRO, Melbourne, Australia9-11 December 2009
4. Vasilios a. grapsas, john s. anagnostopoulos and dimitrios e. papantonis, “experimental and numerical study of a radial flow pump impeller with 2d-curved blades” proceedings of

- the 5th iasme / wseas international conference on fluid mechanics and aerodynamics, athens, greece, august 25-27, 2007
5. Maitellic. w. s. de p.1; bbezerra, v. m. de f.; cda mata,w. "simulation of flow in a centrifugal pump of esp systems using computational fluid dynamics" brazilian journal of petroleum and gas | v. 4 n. 1 | p. 001-009 | 2010 | issn 1982-0593
  6. Michal varcholaa, peter hlbocanb, b\*, "geometry design of a mixed flow pump using experimental results of on internal impeller flow" international scientific and engineering conference "hervicon-2011 procedia engineering 39 ( 2012 ) 168 – 174
  7. Pramesh kumar<sup>1</sup>, h.l.tiwari<sup>2</sup>, dr. v. prashad<sup>3</sup>, dr. v.k.gahlot<sup>4</sup>, "design of francis type mixed flow pump impeller using C++" journal of engineering research and studies e-issn 0976-7916
  8. j. manikandan, "performance evaluation of mixed flow pump using computational fluid dynamics" european journal of scientific research issn 1450-216x vol.80 no.4 (2012), pp.479-486
  9. Milan sedlar, "numerical investigation of flow in mixed-flow pump with volute" jana sigmunda 79, 78350 lutin, czech republic

**BOOKS:-**

[1] V. K. Jain

Vertical turbine, mixed flow and propeller pumps

[2] By G. K. Sahu

Principles of axial and mixed flow pumps

<http://ebooks.cambridge.org/chapter.jsf?bid=CBO9780511529573&cid=CBO9780511529573A031>

**NOMENCLATURE:-**

- $D_i$  - Inlet diameter of impeller (mm)  
 $D_o$  - Outlet diameter of impeller (mm)  
 $\beta$  - Inlet blade angle (Degree)  
 $\alpha$  - Outlet blade angle (Degree)  
 $t$  - Blade thickness (mm)  
 $N$  - Impeller rotation speed (r.p.m)  
 $N_{ib}$  - Number of impeller blade  
 $L$  - Length of the impeller (mm)  
 $P_i$  - Inlet pressure of the impeller (Pa)  
 $P_o$  - Outlet pressure of the impeller (Pa)  
 $u_i$  - Inlet velocity of the impeller (m/sec)  
 $u_o$  - Outlet velocity of the impeller (m/sec)  
 $U$  - Circumferential velocity (m/sec)  
 $\omega$  - Angular velocity of impeller (deg/sec)  
 $T_i$  - Inlet water temperature of impeller (K)  
 $T_o$  - Outlet water temperature of impeller (K)  
 $\rho$  - Water Density  
 $Q$  - Mass flow rate ( $m^3/sec$ )  
 $P$  - Power consumed  
 $H$  - Head (m)  
 $\eta_{mp}$  - Mixed flow pump efficiency (%)