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Effects of Impeller Blade Angle on the Efficiency of Water Type Centrifugal Pump and its CFD Analysis

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Abstract — *A pump is device which works on the principle of transferring the fluid at different heads as per requirement. The attention is focused on improvement of efficiencies, particularly the pressure, hydraulic efficiency and volumetric efficiency, of the water type centrifugal pump by modifying the impeller blade angles and its effects on the different performance parameters. The v6 water type centrifugal pump has been selected as a reference pump and its CFD & Analytical analysis is carried out then its impeller blade angle has been varied in a steps and the effects of the variation of the impeller blade angle is observed for various angles on the pressure, volumetric and hydraulic efficiencies of the pump and its validation has been shown by analytical and CFD analysis. The modification result has been checked by CFD analysis in ANSYS CFX Software.*

***Keywords**-Centrifugal Pump, Hydraulic Efficiency, Volumetric Efficiency, CFD Analysis, Impeller, Blade Angle, ANSYS*

I. INTRODUCTION

A pump is a system or device for raising, compressing or transporting of any liquid or a gas. Many kinds of pumps are available in market. Generally, a family of it can be classified as positive displacement pumps and kinetic pumps. Almost all large scale industries as well as domestic purpose centrifugal pump is mostly used.

❖ Working Principle Of Centrifugal Pump:-

With help of rotation of impeller increase pressure of fluid is main use of centrifugal pump work as roto-dynamic pump .The fluid will enter in to the centrifugal pump to its rotating axis and it will guide to rotate the impeller. In the impeller several guide blades are attached. The guide vanes are generally slopes in backward direction and it has some distance from direction of rotation. When fluid is enter in to impeller with help of suction system it will be rotate and pass through the impeller vanes. At starting it comes in to the impeller eye and then it will enter in to the impeller hub section. After passing through this system casing guide the fluid and transfer to the delivery side.

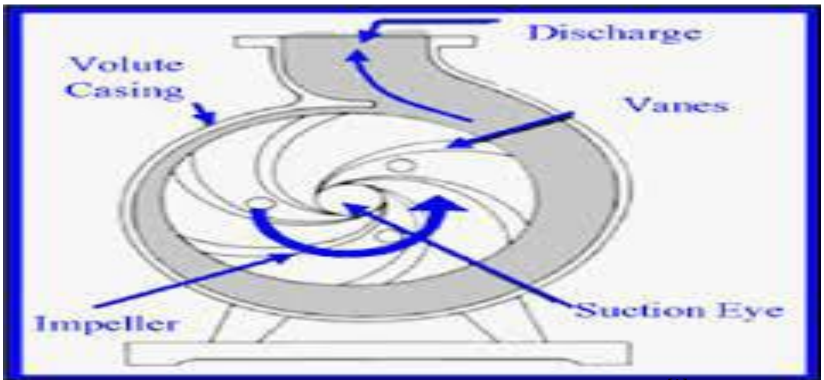

Figure-1.1:- Working principle of centrifugal pump [1]

II. MAIN SPECIFICATIONS OF CENTRIFUGAL PUMP:-

1. Pump type: - v6
2. Head height (h):- 10 to 120 m
3. Discharge (Q):- 0.005 m3/sec
4. Temperature of liquid (t):- 40 0C
5. Pump Speed (N):- 2400-2900 RPM

III. BASIC DATA OF EXISTING DESIGN OF IMPELLER:-

1. Nominal diameter at inlet (D):- 50.96mm
2. Torque (T):- 954.92 N. m
3. Shaft diameter (d_s):- 78mm
4. Impeller hub diameter (d_h) :- 116mm
5. Impeller eye diameter (d_e) :- 101.4mm
6. Velocity of fluid at impeller eye (C_0)=8.39m/s
7. Flow velocity at inlet (C_{m1})= 12.58m/s
8. Inlet blade angle (β_1) = 37^0
9. Outlet blade angle (β_2) = 53^0
10. Outlet diameter of impeller (D_0) = 248mm

IV. ANALYTICAL CALCULATIONS FOR THE BLADE INLET ANGLE OF 37° AND OUTLET ANGLE OF 57° FOR THE EFFICIENCIES OF THE EXISTING DESIGN OF IMPELLER:-

C_{m2} = 0.687 * C_{m1}
= 0.687* 12.58
= 8.64 m/s

Where $u_2 = \frac{C_{m2}}{\tan \beta_2} + \sqrt{\frac{C_{m2}}{2\tan \beta_2} + gH}$

$u_2 = \frac{8.64}{\tan 53.03} + \sqrt{\frac{8.64}{2\tan 53} + 9.8 * 55}$

= 23.47 m /sec

$\tan\beta_2 = \frac{v_{f2}}{u_2 - v_{w2}}$

$\tan 53 = \frac{8.39}{23.47 - vw2}$

V_{w2} = 23.47 m/sec

Volumetric Efficiency:- $\frac{g\,H}{Vw2 * u2}$

$= \frac{9.81 * 55}{23.47 * 29.80}$

= 77.20 %

Hydraulic efficiency = $\frac{actual\ head\ of\ centrifugal\ pump}{total\ head\ of\ centrifugal\ pump}$

$= \frac{55}{120}$

= 45.83%

u_2 = outlet velocity of fluid m/s

V_{w2} = velocity of whirl of fluid m/s

V_{f2} = flow velocity of fluid m/s

C_{m2} = mean velocity of fluid at impeller hub outlet

C_{m1}= mean velocity of fluid at impeller hub inlet

C_{m0}= mean velocity of fluid at impeller eye inlet

V. DEIGN MODIFICATION OF EXISTING IMPELLER:-

In existing design the impeller blade outlet angle is 53^0 and inlet angle is 37^0. So modification in design has been done that inlet angle is fixed and outlet angle will be changed in the step of 2 (two) degrees of incremental. So it can be analyzed that at which point efficiency will be maximum. However the blade outlet blade angle is also decreased it check for its effects on the efficiency of the pump.

With help of CFD analysis and applying all boundary conditions which already given in existing design parameter is added in CFX module. In CFD analysis it is generally working on the Finite Element Method in which mainly three processes will be done:

1. Pre-processing:- In pre-processing the design of part is made with help of computer aided design and it is import in to the ANSYS work bench.
2. Processing: - In Processing the file is converted in .iges form and it is send to mesh section. In meshing whole part is discretize and convert in to small elements. After it is convert in small element given boundary conditions as per analysis should be done.
3. Post Processing: - In post processing final result will be getting and as per required data is filled then it gives the proper result of the analysis. In this software calculator is given in post processor so that it is give the result of pressure, velocity, density, efficiency, etc.

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ANSYS is most important for doing CFD analysis in which concludes the result of water head, pressure, efficiency, pressure ratio etc. can be calculated. Generally CFD analysis takes much more time for post processing because of the flow of fluid and meshing depends upon the result tab.

VI. CFD ANALYSIS RESULTS FOR THE VARIATION OF IMPELLER OUTLET BLADE ANGLESS:-

The following are the steps in which the analysis has been carried out:

a. Generation of basic Geometrical model
b. Mashing of the model
c. Applying the boundary conditions
d. Result of the CFD analysis (Pressure Region)

The impeller inlet blade angle is kept constant and outlet angles have been varied in the fixed degrees and its CFD models have been analyzed for its impact on the pressure, hydraulic effieicncy and volumetric effeiciencies.

1. **Impeller Inlet Blade Angle 37^0 And Outlet Blade Angle 49^0:**

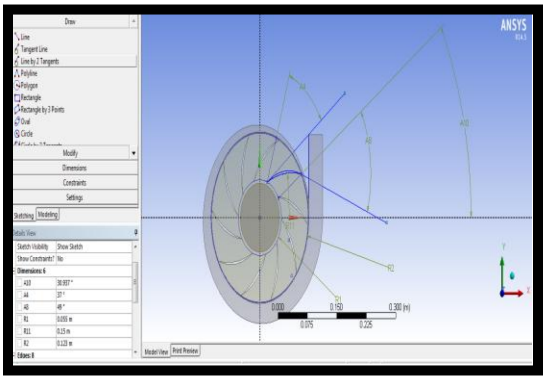

Fig. 6.1: Basic geometry

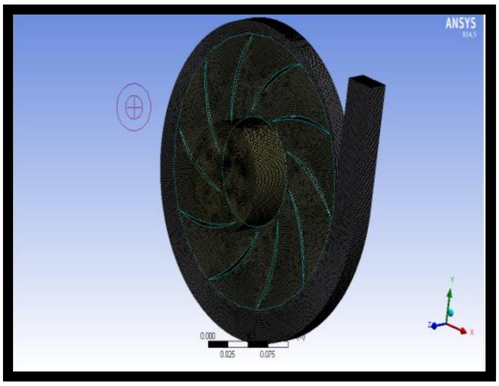

Fig.: 6.2 Mashing of the model

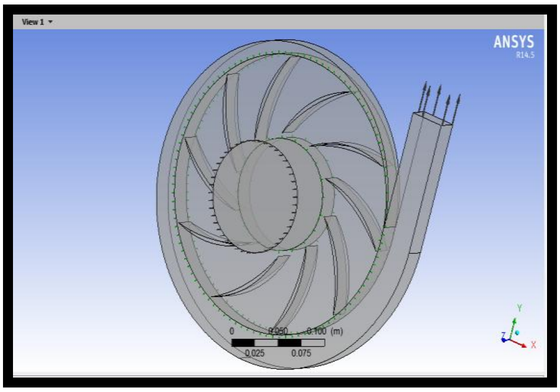

Fig. 6.3: Boundry conditions

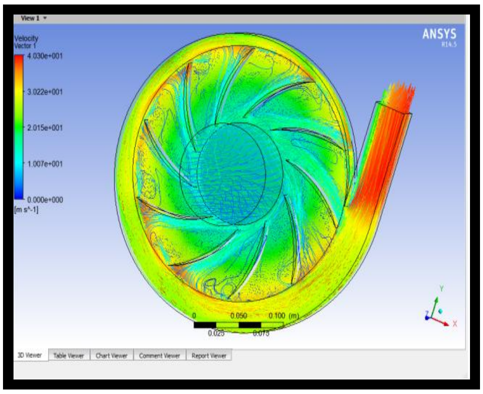

Fig. 6.4: CFD result (Delivery pipe Pressure)

2. **Impeller Inlet Blade Angle 37^0 and Outlet Blade Angle 51^0:-**

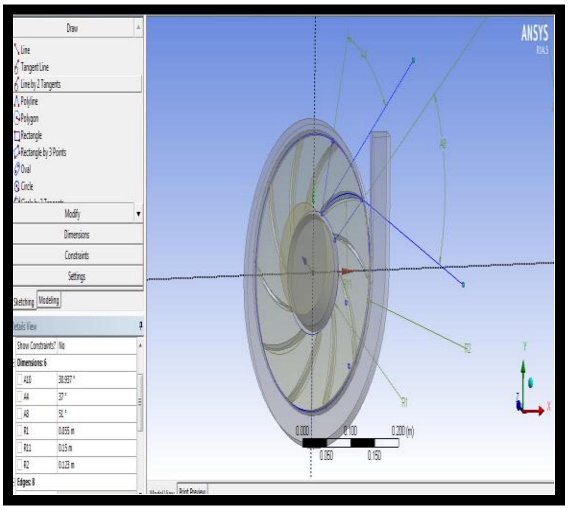

Fig. 6.5: Basic geometry

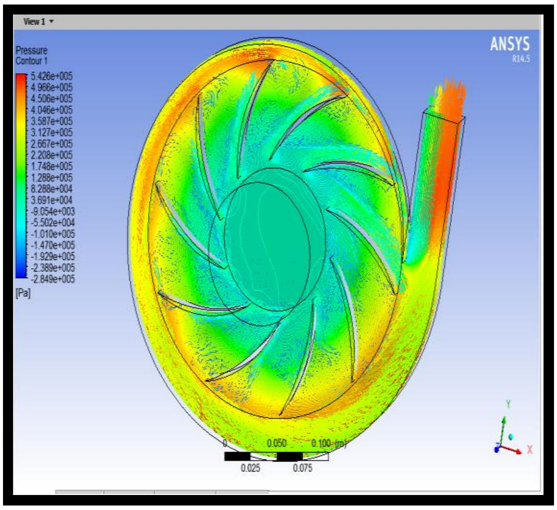

Fig.: 6.6 CFD result (Delivery pipe pressure)

3. **Impeller Inlet Blade Angle 37^0 and Outlet Blade Angle 53^0:-**

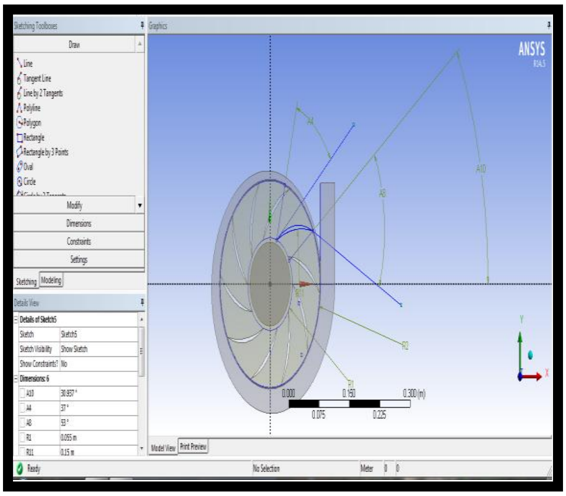

Fig. 6.7: Basic geometry

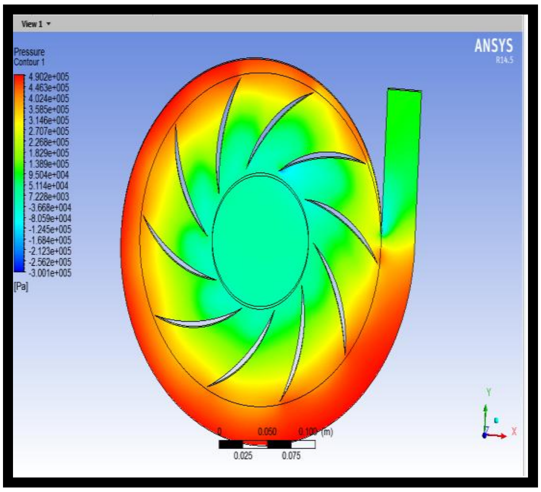

Fig.: 6.8 CFD result (Casing Pressure)

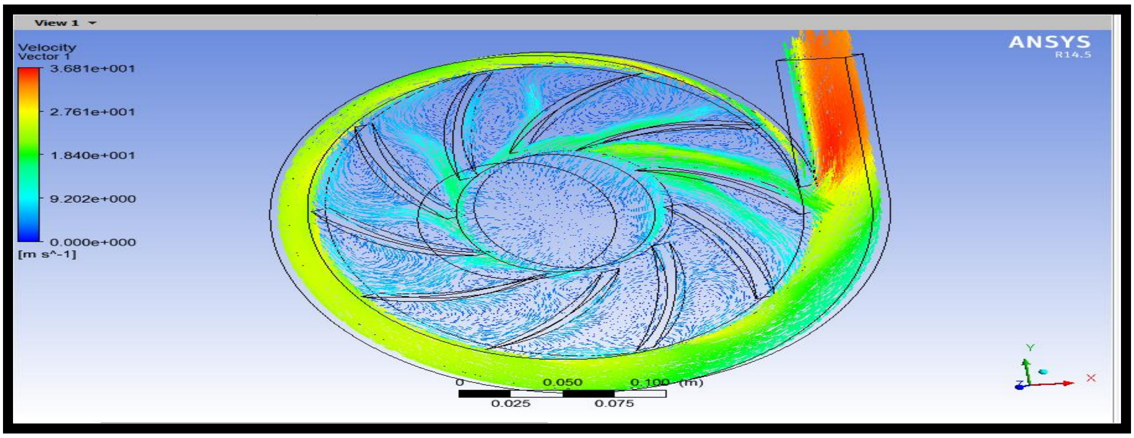

Fig.: 6.9 CFD result (Delivery pipe pressure)

4. Impeller Inlet Blade Angle 37^0 and Outlet Blade Angle 55^0:-

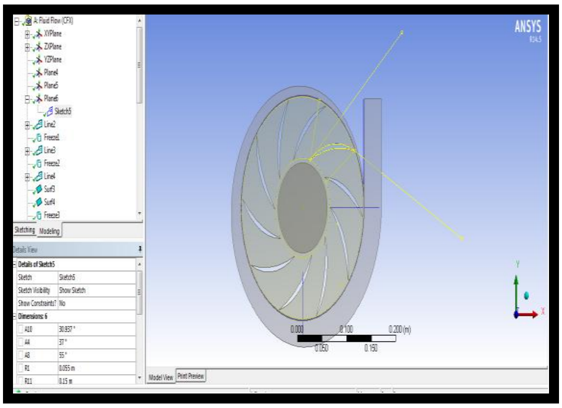

Fig. 6.10: Basic geometry

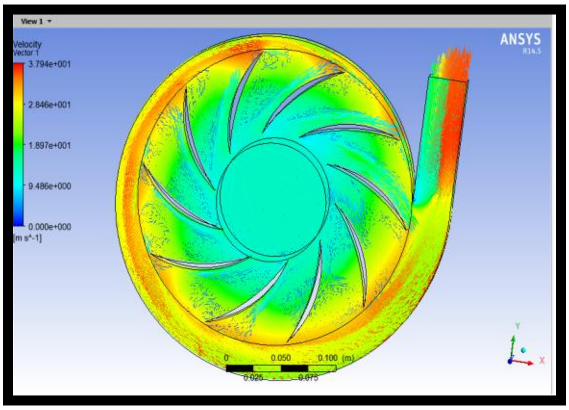

Fig.: 6.11 CFD result (Delivery pipe pressure)

5. Impeller Inlet Blade Angle 37^0 and Outlet Blade Angle 57^0:-

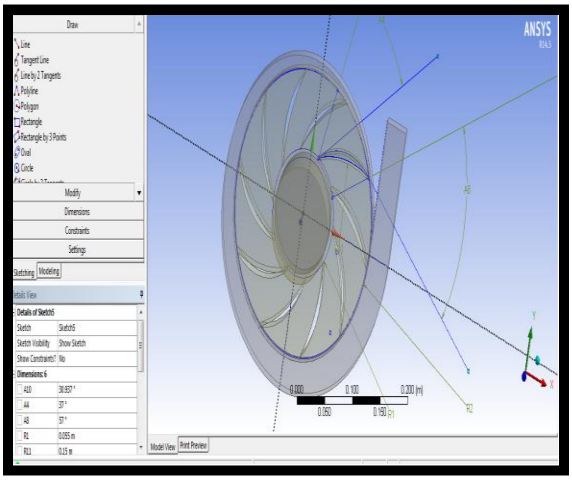

Fig. 6.12: Basic geometry

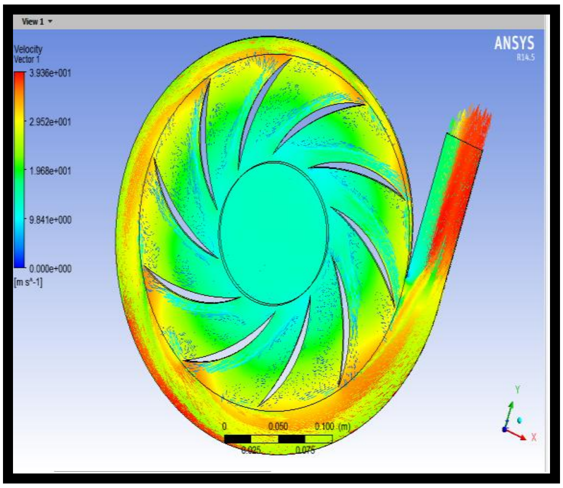

Fig.: 6.13 CFD result (Delivery pipe pressure)

6. IMPELLER INLET BLADE ANGLE 37^0 AND OUTLET BLADE ANGLE 59^0:-

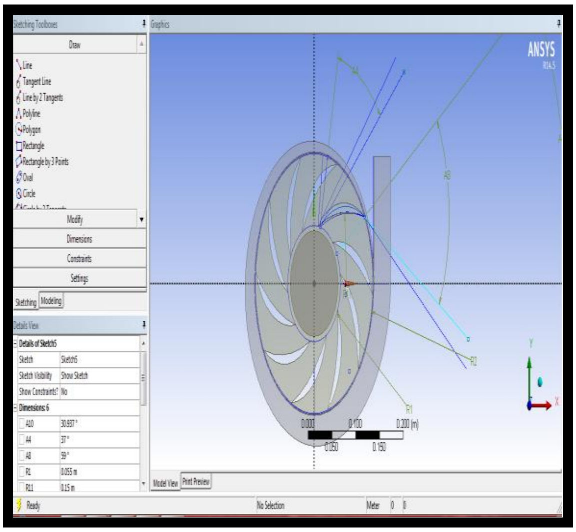

Fig. 6.14: Basic geometry

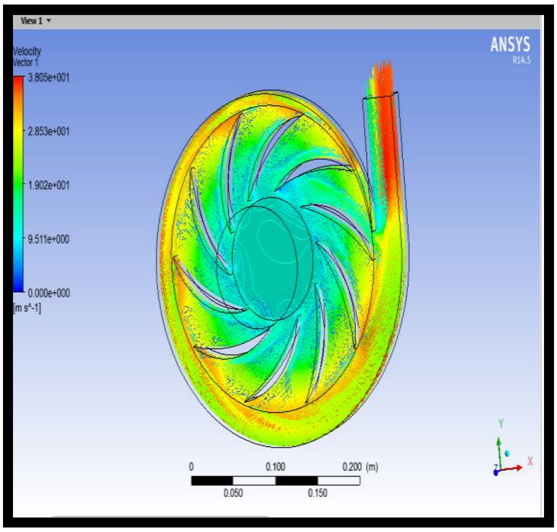

Fig.: 6.15 CFD result (Delivery pipe pressure)

7. IMPELLER INLET BLADE ANGLE 37^0 AND OUTLET BLADE ANGLE 65^0:-

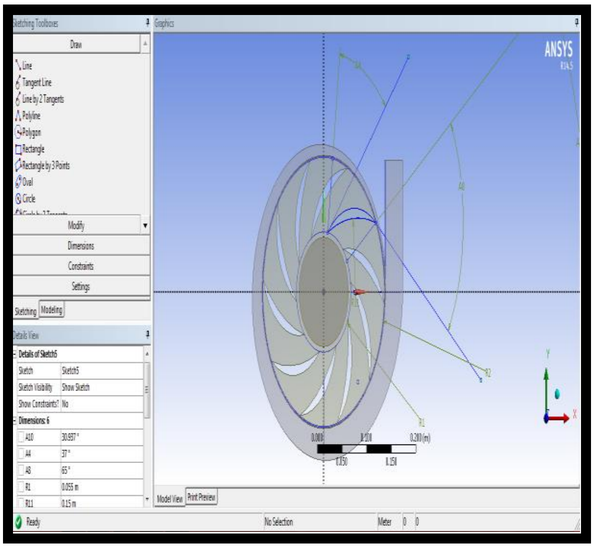

Fig. 6.16: Basic geometry

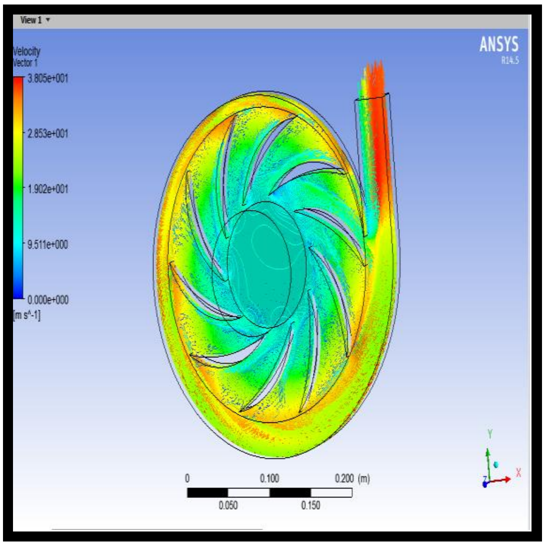

Fig.: 6.17 CFD result (Delivery pipe pressure)

VII. CFD ANALYSIS RESULT TABLE:-

Sr no.	Inlet Angle (^{0})	Outlet Angle (^{0})	Hydraulic Efficiency (%) η_h	Volumetric Efficiency (%) η_v	Pressure ratio (output/ input) (p_2/p_1)
1	37^0	49^0	39.21%	68.45%	4.23
2	37^0	51^0	41.14%	71.21%	4.49

3	37^0	53^0	42.28%	75.28%	5.43
4	37^0	55^0	48.56%	77.54%	6.18
5	37^0	57^0	53.71%	79.26%	7.23
6	37^0	59^0	57.59%	81.61%	7.49
7	37^0	65^0	52.42%	77.27%	6.99

After doing this analysis it can be identified that at impeller outlet blade angle 59^0 the volumetric efficiency and hydraulic efficiency is maximum and as per efficiency pressure ratio has also increased and so higher water head. The results of the CFD analysis have been validated with analytical calculations which show that the result of the CFD analysis is very accurate with the analytical calculations and hence reliable for the usage.

VIII. ANALYTICAL CALCULATION OF THE VOLUMETRIC AND HYDRAULIC EFFICIENCY FOR THE INLET BLADE ANGLE OF 37° AND OUTLET BLADE ANGLE 59° :-

$$u_2 = \frac{c_{m2}}{\tan\beta_2} + \sqrt{\frac{c_{m2}}{2\tan\beta_2} + gH}$$

$$u_2 = \frac{8.64}{\tan 59} + \sqrt{\frac{8.64}{2\tan 59} + 9.8 * 70}$$

$$= 31.45 \text{ m/sec}$$

$$\tan\beta_2 = \frac{v_{f2}}{u_2 - v_{w2}}$$

$$\tan 53 = \frac{8.39}{23.47 - vw2}$$

V_{w2} = 26.25 m/sec

- Volumetric Efficiency:- $\frac{g\,H}{V_{w2} * u_2}$

$$= \frac{9.81 * 55}{26.25 * 31.45}$$

$$= 83.17\,\%$$

- Hydraulic efficiency = $\frac{actual\ head\ of\ centrifugal\ pump}{total\ head\ of\ centrifugal\ pump}$

$$= \frac{70}{120}$$

$$= 58.33\%$$

❖ **COMPARISON TABLE FOR THE ANALYTICAL AND CFD RESULTS :-**

	Analytical Calculation	**CFD analysis**
Blade Outlet Angle	59^0	59^0
Hydraulic efficiency	58.33%	57.59%
Volumetric efficiency	83.17%	81.61%
Error in hydraulic efficiency	1.01%	
Error in volumetric efficiency	1.01%	

IX. CONCLUSION:-

It is clear from the results of the analysis that with the increase of the outlet blade angle from 49° to 59° the volumetric efficiency, hydraulic efficiency and pressure ratio in the delivery pipe increases with the increase of the outlet angle. By varying the outlet angle of the blade from 59° to 90° the volumetric efficiency, hydraulic efficiency and pressure ratio decrease with the increase of the outlet blade angle. The optimum outlet blade angle is found at 59° which gives the best possible volumetric efficiency, hydraulic efficiency and pressure ratio for the delivery pipe in the given range of variation the outlet angle of the blade of impeller from 49° to 90° in the selected v6 type of water type hydraulic centrifugal pump.

REFERENCES

[1] Dr. Wangming Lu, Mark L. Redding,Avinash V. Sarlashkar, "BladePro-CF: An ANSYS-based Impeller Analysis System"

[2] B. Sanda, C.V. Daniela "The influence of the inlet angle over the radial impeller geometry design approach with ansys" J Eng. Stu. Res. vol. 18 pp. 32-39, 2012.

[3] M. Ashri, S. Karuppanan, S. Patil1 and I. Ibrahim," Modal Analysis of a Centrifugal Pump Impeller Using Finite Element Method" MATEC Web of Conferences, vol. 13 pp. 04030(1-5) 2014.

[4] K. Matta, K. Srividya, I. Prakash,"Static and Dynamic Response of an Impeller at Varying Effects" IOSR-JMCEvol. 11, pp. 101-106, Jan. 2014.

[5] E.C. Bacharoudis, A.E. Filios, M.D. Mentzos and D.P. Margaris, "Parametric Study of a Centrifugal Pump Impeller by Varying the Outlet Blade Angle" The Open Mechanical Engineering Journal, 2008, 2,pp. 75-83

[6] A S. Prasad, B. L. Rao, A Babji, Dr P. K. Babu," Static and Dynamic Analysis of a Centrifugal Pump Impeller", Int. J Eng. Res. App., vol. 4, pp. 966-971, Oct. 2013.

[7] Sambhrant Srivastava, Apurba Kumar Roy, and Kaushik Kumar," Design of a mixed flow pump impeller and its validation using FEM analysis,Procedia Technology 14 (2014) 181 – 187

[8] Rotodynamics Pump (Centrifugal and Axial) By K.M.Shrinivasan

[9] www.rumfordgroup.com

[10] www.mcnallyinstitute.com