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DESIGN AND OPTIMIZATION OF CENTRIFUGALIMPELLER OF VARIOUS DESIGNS USING CFD

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ABSTRACT

Centrifugal pumps are a sub-class of dynamic axisymmetric work-absorbingturbo machinery and used to transport fluid by conversion of rotational kinetic energy to hydrodynamic energy. This project investigates the study of complex internal flows in centrifugal pump impellers with the aid of computational fluiddynamics software thus facilitating the design of pumps. Here three different types of pump impellers had been taken. The pump specifications considered forinvestigation are discharge and speed. These specifications have been varied to perform a comparative study of these pump impellers. The impeller was modelled in CATIA and the blade to blade plane of the impellers was taken for the detailed study purpose because the flow occurs through this passage only. The blade to blade plane is modelled in CATIA software and the flow analysis is carried out using CFD software. Thus the valid results regarding the velocity distribution and pressure distributions were predicated and the performance of those pumps had been compared from the computational results.

Keywords: Centrifugal pump, Impeller analysis, CFD analysis.

1. INTRODUCTON

An impeller is a rotating component of a centrifugal pump which transfers energy from the motor that drives the pump to the fluid being pumped by acceleratingthe fluid outwards from the centre of rotation. The velocity achieved by the impeller transfers into pressure when the pump casing confines the outward movement of thefluid. Impellers are usually short cylinders with an open inlet (called an eye) to acceptincoming fluid, vanes to push the fluid radially, and a splined, keyed, or threaded boreto accept a drive-shaft.

Fig 1. Types of impeller blade

The impeller made out of cast material in many cases may be called rotor, also. It is cheaper to cast the radial impeller right in the support it is fitted on, which is put in motion by the gearbox from an electric motor, combustion engine or by steam driventurbine. The rotor usually names both the spindle and the impeller when they are mounted by bolts. In the case of where flow simply passes through a straight pipe to enter a centrifugal compressor; the flow is straight, uniform and has no vorticity. As illustrated below $\alpha 1 = 0°$. As the flow continues to pass into and through the centrifugal impeller, the impeller forces the flow to spin faster and faster.

2.LITERATURE REVIEW

Oh J.S, RO H.S and Goto. AOh and Ro (2022) used a compressible time marching method, a traditional Simple method, and a commercial program of CFX-TASC flow tosimulate flow pattern through a water pump and compared the difference between among these methods in predicting the pumps performance. Goto presented a comparison between the measured and computed exit-flow fields of a mixed flow impeller with various tip clearances, including the shrouded and un shrouded impellers,and confirmed the applicability of the incompressible version of the three-dimensional Navier-stokes code developed by Dawes for a mixed flow centrifugal pump.

ZhouWeidong, Ng and his colleagues (2022) also developed a three – dimensional time- marching, incompressible Navier-stokes solver using the pseudo compressibility technique to study the flow field through a mixed flow water-pump impeller. The applicability of the original code was validated by comparing it with many published experimental and computational results. Kaupert, potts, Tsukamoto Kaupert and his colleagues. Although these researchers predicted reverse flow in the impeller shroud region at small flow rates numerically, some contradictions still existed. Kaupert’s experimentsshowed the simultaneous appearance of shroud-side reverse flow at the impeller inlet and outlet but his CFD results failed to predict the numerical outlet – reverse flows. Sun and Tsukamoto validated the predicted results of the head-flow curves, diffuser inlet pressure distribution, and impeller radial forces by revealing the experimental data overthe entire flow range, and they predicted back flow at small rates, but they did not showan exact back- flow pattern along the impeller outlet.

E.C. Bacharoudis, A.E. Filios, M.D. Mentzos and D.P. Margaris (2021) in this study, the performance of impellers with the same outlet diameter having different outlet blade angles is thoroughly evaluated. The One-dimensional approach along withempirical equations is adopted for the design of each impeller. The predicted performance curves result through the calculation of the internal flow field. Head-discharge curve plays important role into different outlet angles. The influence of the outlet blade angle on the performance is verified with the CFD. The performance curvebecomes smoother and flatter with the increase with the increase outlet blade angle. Atnominal capacity, when the outlet blade angle was increased from 20° to 50°, the head was increased by more than 6% but the hydraulic efficiency was reduced by 4.5%. However, at high flow rates, the increase of the outlet blade angle caused a significant improvement of the hydraulic efficiency.

LIU Houlin, WANG Yong, YUAN Shouqi (2021) TAN Minggao, and WANG Kai (2010) Blade number play the important role during designing the pump which affects the characteristics of the pump. The model pump has a design specific speed of 92.7 and an impeller with 5 blades. The blade number is varied to 4, 6, 7 with the casing andother geometric parameters keep constant. The inner flow fields and characteristics of the centrifugal pumps with different blade number are simulated and predicted in no cavitation and cavitation conditions by using commercial code FLUENT. Using rapid prototyping the impeller with different blade numbers is made. With the increase of blade number, the area of low pressure region at the suction of blade inlet grows continuously, and the uniformity of static pressure distribution at screw section becomeworse and worse while at diffusion section become better and better.

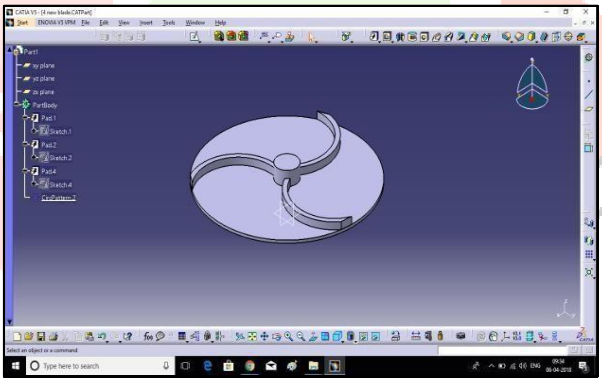
B. Mohan, B.E. Kumar (2021) the novel axial composite impeller has been developed using commercial tools pro-e. They have chosen the suitable materials for this study, namely Kevlar-49, Carbon and S-Glass with a standard epoxy resin for the composite matrix. Static and dynamic behaviors of the component were analyzed using finite element analysis commercial tool ANSYS 14.5. They have analyzed the stress distributions and displacements on the composite impeller in static analysis. The stress concentration regions were identified in this analysis. For transient analysis, we have applied dynamic force at various operating speeds of the impeller and analyzed the deflections and stress concentration regions.

3.DESIGN AND ANALYSIS

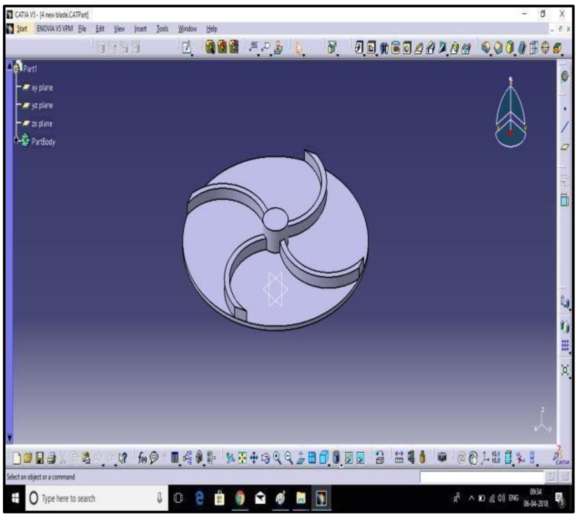
DESIGN

The design of the centrifugal impeller blade was designed in CATIA and the types of impeller blade we use to analyses are three blade impeller, four blade impeller, twisted four blade impeller. CATIA (an acronym of computer-aided three-dimensional interactive application) is amulti-platform software suite for computer-aided design (CAD), computer aided manufacturing (CAM), computer aided engineering (CAE), PLM and 3D, developed by the French company assault Systems. CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D sketches(blueprints). Systems engineering The CATIA Systems Engineeringsolution delivers a unique open and extensible systems engineering development platform that fully integrates the crossdisciplinemodeling, simulation, verification and business process support needed for developing complex 'cyber- physical' products. It enables organizations to evaluate requests for changes or develop new products or system variants utilizing a unified performance based systems engineering approach. The solution addresses the Model Based Systems Engineering (MBSE) needs of users developing today's smart products and systems and comprises the elements.

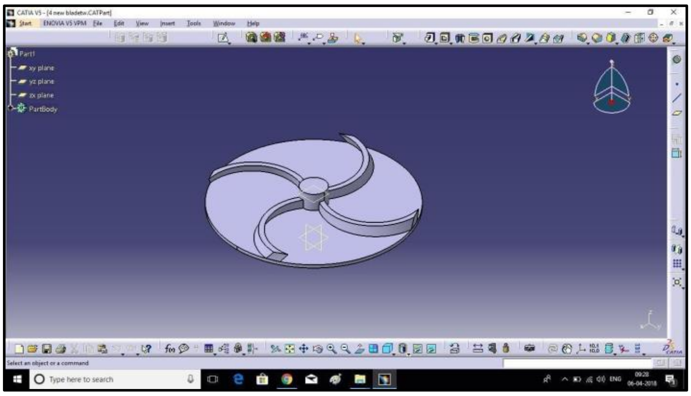
THREE BLADE IMPELLER



FOUR BLADE IMPELLER



TWISTED FOUR BLADE



4. RESULTS AND DISCUSSION

4.1 THREE BLADE IMPELLER

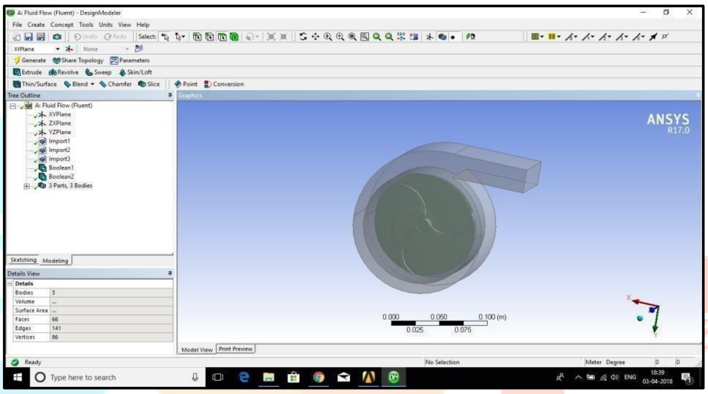


Fig: 2 Impeller Model

These were the model we designed in CATIA and imported in CFD to makean analyse its performance.

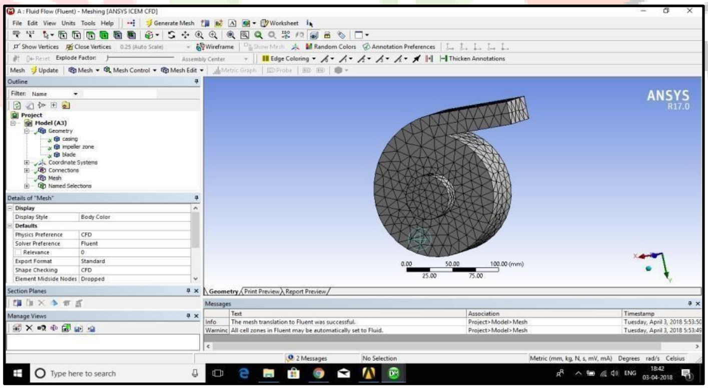


Fig: 3 Mesh Model of the Impeller

Next the second stage of the analyse in the process which is meshing stageand used to find results better.

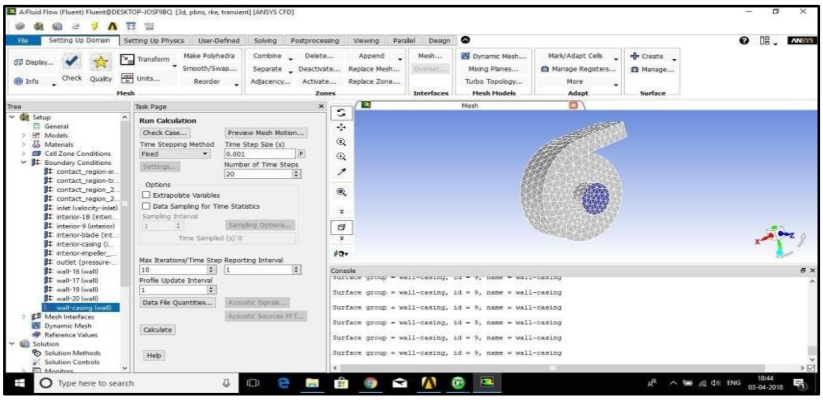


Fig: 4 Setup of Impeller

Then the is stage were we select the boundary conditions for the followingworkings

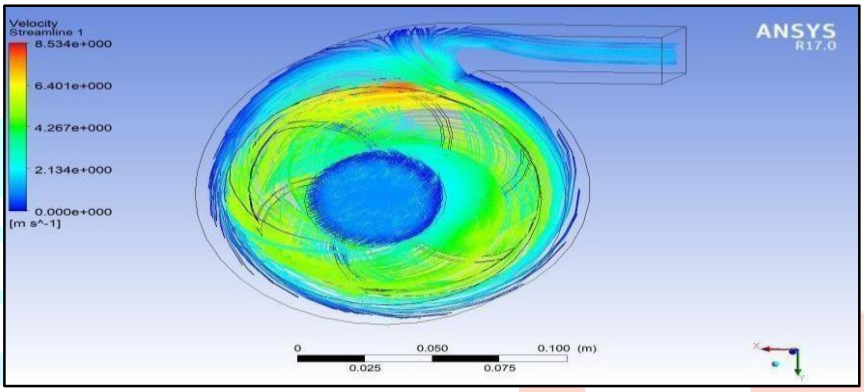


Fig: 5 Streamline of 3 Blade Impeller

In the streamline flow of the liquid in the impeller casing with accurate manner so it's easy to find its performance.

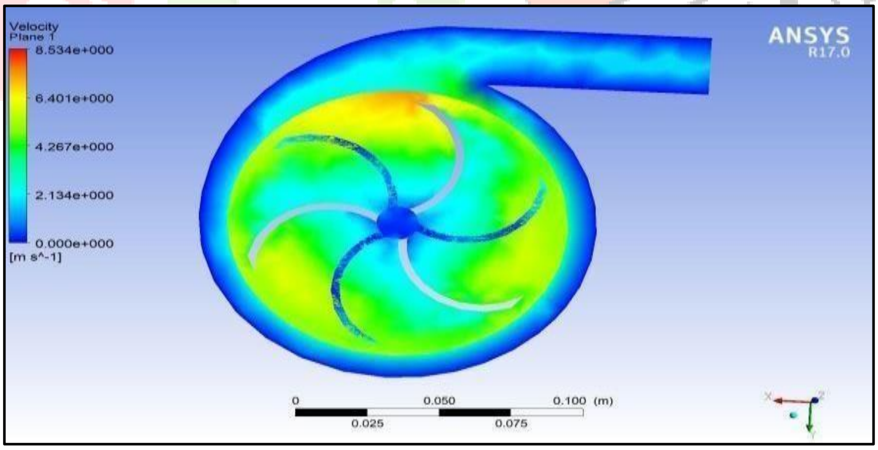


Fig: 6 Velocity of 3 Blade Impeller

In the velocity of the impeller blade so its performance can bechanged before fabricating them.

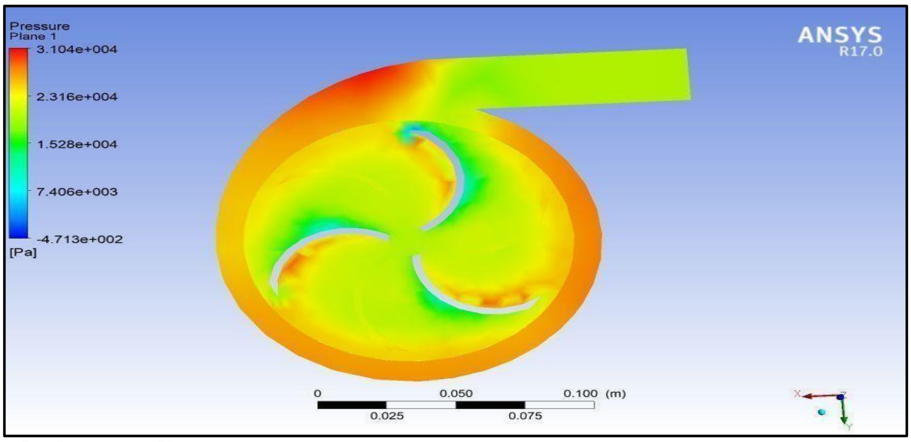


Fig:7 Pressure of 3 Blade Impeller

In the pressure flow in the impeller casing to be tested and used to findthe pressure ranges in whole body.

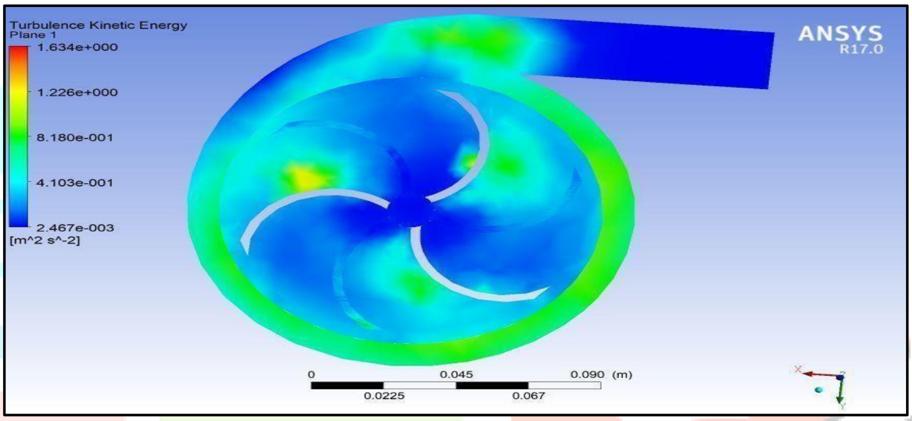


Fig: 8 Turbulent Kinetic Energy of 3 Blade Impeller

In it is used to associated with eddies in turbulent flow and produced by fluidshear, friction or eddy scales.

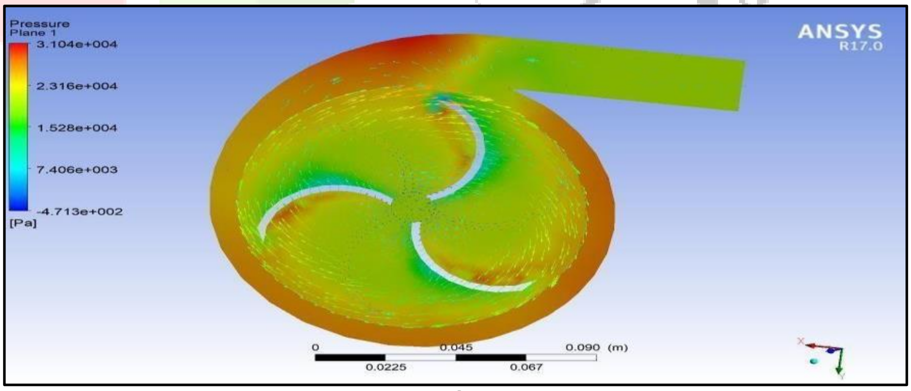


Fig: 9 Vector plot of 3 Blade Impeller

4.2 FOUR BLADE IMPELLER

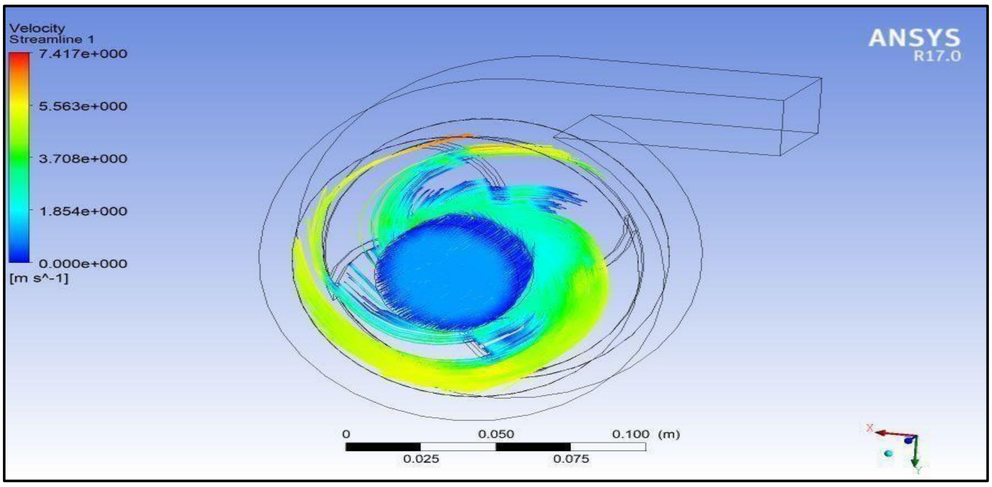


Fig: 10 Streamline of 4 Blade Impeller

In the streamline flow of the liquid in the impeller casing with accurate manner so it's easy to find its performance.

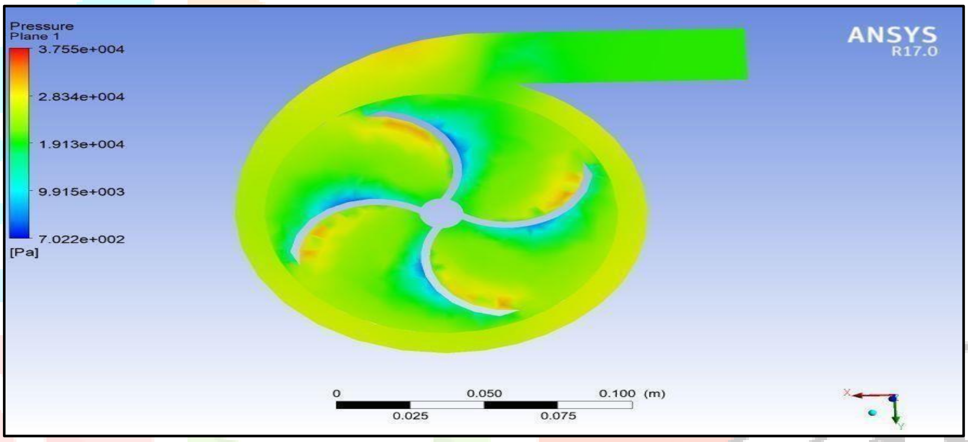


Fig: 11 Velocity of 4 Blade Impeller

In the velocity of the impeller blade so its performance can be changedbefore fabricating them.

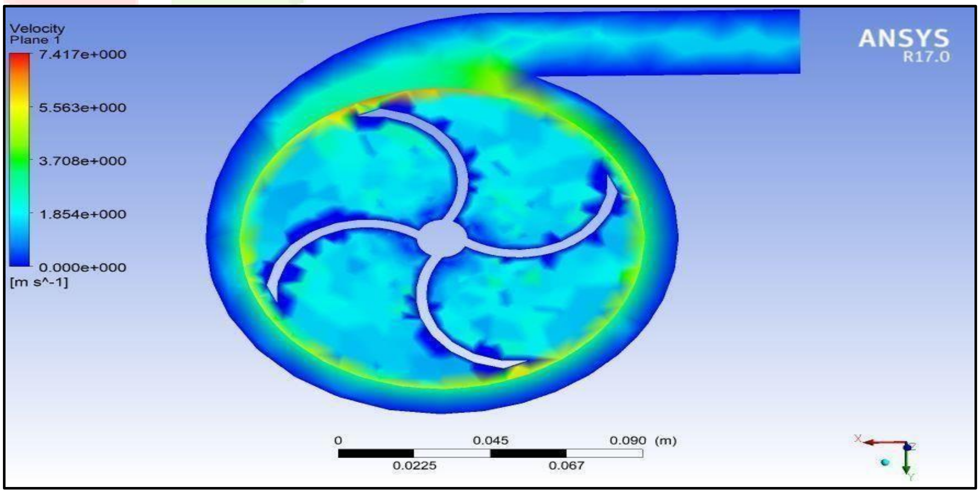


Fig: 12 Pressure of 4 Blade Impeller

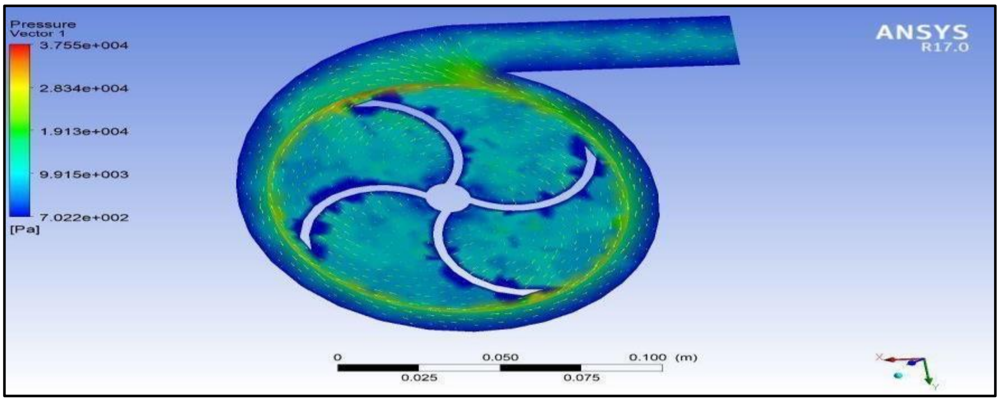


Fig: 13 Turbulent Kinetic Energy of 4 Blade Impeller

In the pressure flow in the impeller casing to be tested and used tofind the pressure ranges in whole body.

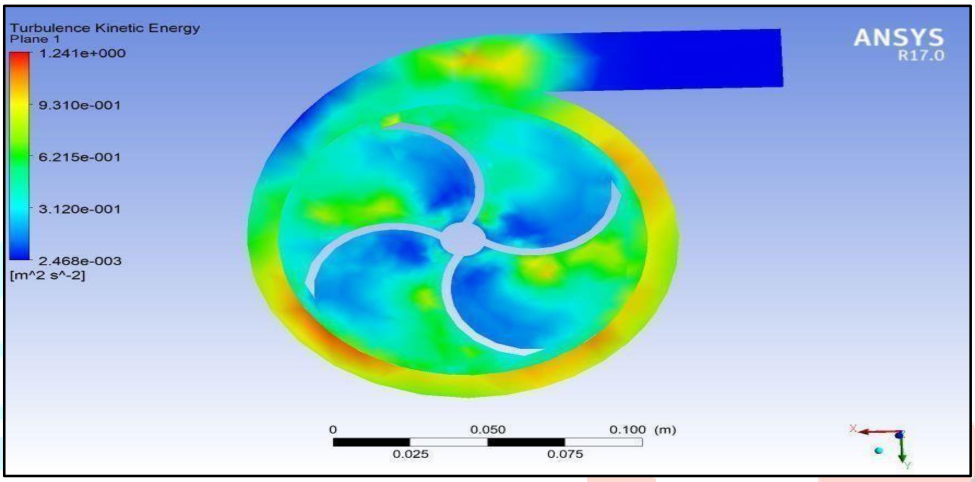


Fig: 14 Vector plot of 4 Blade Impeller

In it is used to associated with eddies in turbulent flow and produced by fluidshear, friction or eddy scales.

4.3 TWISTED FOUR BLADE IMPELLER

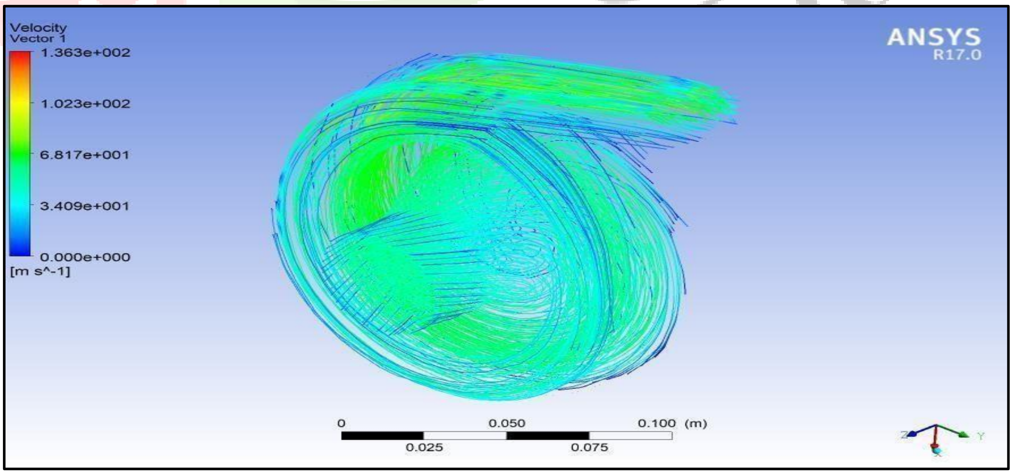


Fig: 15 Streamline of Twisted 4 Blade Impeller

In the streamline flow of the liquid in the impeller casing with accuratemanner so it's easy to find its performance.

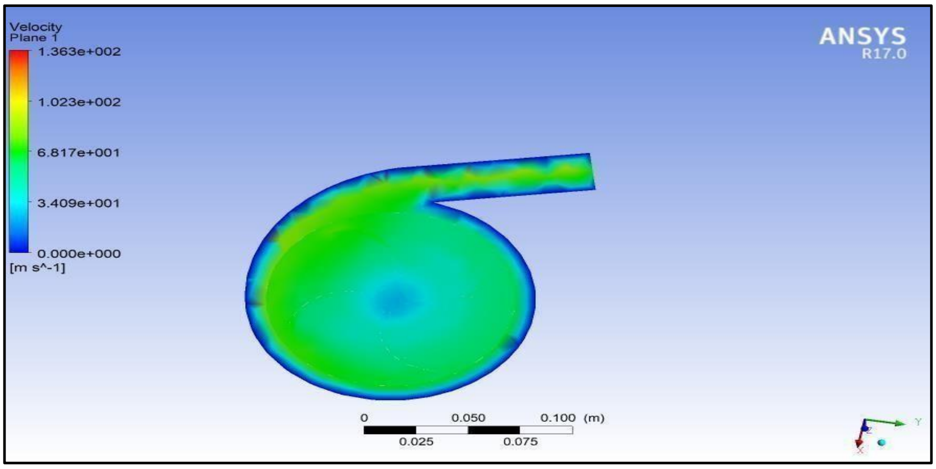


Fig: :16 Velocity of Twisted 4 Blade Impeller

In the velocity of the impeller blade so its performance can be changedbefore fabricating them.

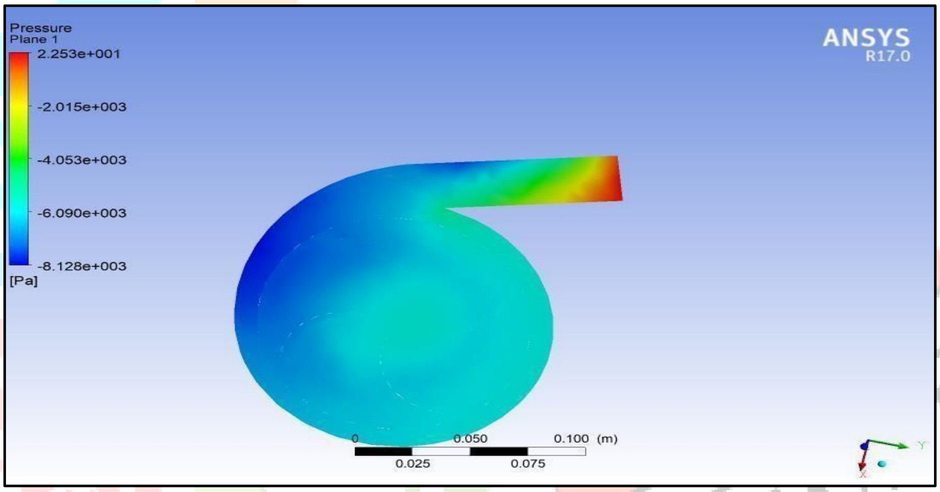


Fig: 17 Pressure of Twisted 4 Blade Impeller

In the pressure flow in the impeller casing to be tested and used tofind the pressure ranges in whole body.

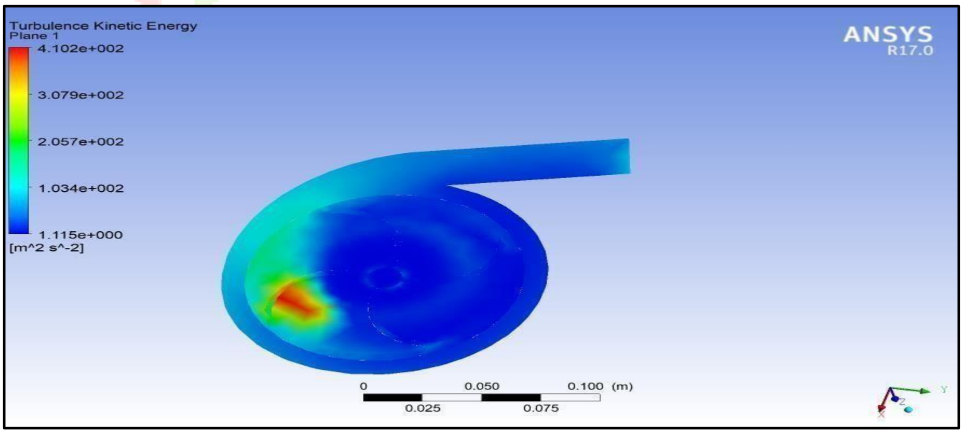


Fig: 18 Turbulent Kinetic Energy of Twisted 4 Blade Impeller

In is used to associated with eddies in turbulent flow and produced by fluidshear, friction or eddy scales.

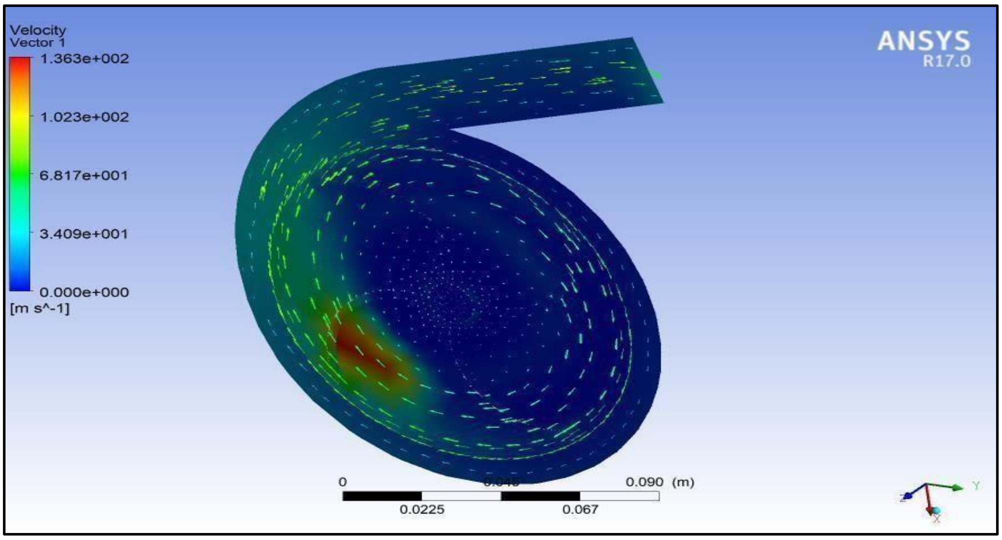


Fig: 19 Vector plot of Twisted 4 Blade Impeller

In the vector plot it used for streamline plot are post processing toolsfor visualizing fluid flow.

COMPARISON BETWEEN ALL THREE TYPES OF IMPELLER

CONTENTS	VELOCITY (m s-1	PRESSURE (Pa)
THREE BLADE	8.534e0	3.104e004
FOUR BLADE	7.417e0	3.775e004
TWISTED FOUR BLADE	1.363e002	2.253e001

Fig :20 Comparison of various type of Impeller.

5. CONCLUSION

The impeller blade was designed and analyse its performance. The various blade geometry of the impeller had been taken for analysis. The analysis was carried out in Fluent (Computational fluid dynamics). The velocity and pressure distributionin the various blade was studied. Design of an impeller was carried out by considering the Head, Discharge and the speed of the pump. Here the performance of three blades geometry had been studied by changing their specifications and design. Twisted four blades had better velocity when compared with other designs.

6.REFERENCES

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