ABSTRACT
To improve the efficiency of mixed flow pump, computational fluid dynamics (CFD) analysis is one of the advanced tools used in the pump industry. From the CFD analysis, the velocity and pressure in the outlet of the impeller is predicted. These outlet flow conditions are used to calculate the efficiency of the impeller. The optimum inlet and outlet vane angles are calculate for the existing impeller by using the empirical relations. The maximum head is obtained from the CFD analysis, it is reduce outlet recirculation or it is increase outlet recirculation flow cause to improve efficiency. Thought that the calculation results by numerically simulation software Fluent can truly reflect the flow in the impeller of a mixed flow pump on the premise that the turbulent model and boundary conditions are similar to the actual situations.[1] By change the outlet angle the head of the impeller is improve. Finally, from CFD analysis the calculated efficiency of the impeller with optimum vane angle can be improved by changing the inlet and outlet angle. The Head created by this analysis would be higher.

KEY WORDS: Mixed flow pump, computational Fluid Dynamics (CFD) analysis, of impeller. With using software

1.1 INTRODUCTION
A pump is a device used to move fluids 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 few types of pump in Radial flow pump, mixed flow pump, axial flow pump. A wide variety of pump types have been constructed and used in many different applications in industry. From the CFD analysis software and advanced post processing tools the complex flow inside the impeller can be analyzed.

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.

1.2 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 as shown in fig 1. 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.

1.3 Types of Blades
1.3.1 Backward curved blades, β2<90°
When β2<90°, Cotβ2 is positive and hence with increase in mass flow rate, the head decreases. The head capacity characteristic has a negative slope.

1.3.2 Radial Blades β2=0
For radial vanes β2=0 and cotβ2 =0, so head does not vary with flow rate.

1.3.3 Forward-Curved Blades, β2<90°
For forward curved blades β2<90° and cotβ2 is negative. Hence, with increase in mass flow rate head also increases, the head capacity characteristic has a positive slope.

As shown from Figure 2 for forward blades impeller, the fluids leaves the impeller with relatively high speed which means that the major part of the energy gained is kinetic energy, this type of impeller requires a very good diffuser to convert this kinetic energy to pressure energy. In practice, it is difficult to construct this kind of diffuser; also it is usually more efficient to convert pressure energy to kinetic energy rather than converting kinetic energy to pressure energy.

Fig.2 Types of Impeller blade base on curvature of blades

1.4 General Information on Multi stage Mixed Flow Pumps
“The pumps are divided into two basic groups, depending on the way in which the liquid is transferred from suction side to the delivery side of the casing as positive displacement pumps and impeller or rotodynamic pumps”. The rotodynamic pump and impeller pump terms are firstly introduced by H. Addison, Based on the direction of the flow, the rotodynamic pumps are in the category of cased pumps. The moving element in rotodynamic pumps is the impeller which is the rotor mounted on the rotating shaft and increases the moment of momentum of the flowing liquid in the impeller. The turbine pumps are first used as lifting water from the small diameter water supplies and irrigation wells. However they are used in wide range of applications other then lifting water from irrigation wells such as used in circulation systems in the steel industry for cooling, water extraction from boreholes and rivers, sea water services, deep sea mining, extraction water from geothermal wells, city water district systems and etc. Moreover, the main advantage of using the
vertical turbine pumps is the ability to assemble the stages in series connection thus increasing the pressure rise across the pump easily.

The pumps are classified by their specific speed. Non-dimensional specific speed or type number, \( N \), of the pump is defined as:

\[
N = \frac{\sqrt[3]{Q \cdot H}}{D^2 \cdot g}
\]

Where, \( \omega \) is in rad/s, \( Q \) is in \( m^3/s \), \( g \) is in m/s\(^2\) and \( H \) is m.

The mixed flow pumps by means of specific speed range are located between the radial pumps and axial flow pumps. The overlapping region between the radial and mixed flow pumps are named as Francis type. The specific speed range of the mixed flow pumps are given differently in the literature because of the overlapping regions of the mixed flow range with axial flow pumps and radial pumps. The range for the mixed flow pumps by means of specific speed is given in References. The mixed flow pumps discharges relatively low heads however the usage of mixed flow pumps as vertical turbine type assembly allows series connection. Thus the head of the pump assembly may be increased by series connection of the stages for the desired flow rate. The pump efficiency concerns are playing a major role in the usage of mixed flow type vertical turbine pumps. The Francis type and mixed flow type pumps have better efficiency characteristics among the other types.

The development of the mixed flow type turbine type pumps are highly related to the demands of the market. The different application types developed during the years. However the concerns about energy consumption are the most important factor in the development of all type of pumps. The improvements in manufacturing techniques such as casting, surface finish on the impellers, rapid prototyping and precise measuring devices lead the industry to produce pumps with better efficiencies.

### 1.4.1 Vertical type Mixed flow Pump and Working Principle

The vertical turbine type mixed flow pumps are mainly composed of four subassemblies. These subassemblies are the driver, discharge head, column assembly and the pump assembly. The pump assembly is also composed of several parts which are shown in Figure 3. The power is transmitted from the electric motor or any other type of driver such as diesel engine to the pump.

### 1.4.2 Velocity diagram

Assumptions for Velocity Diagram of Pump Impeller:
- Liquid enters the impeller eye in radial direction.
- No Energy losses in impeller due to friction & eddy formation.
- Liquid enters without shock.
- Uniform velocity distribution in the passage between two adjacent vanes.

![Velocity Diagram](image)

Now,

Mass Flow Rate,

From Inlet Velocity Triangle,

Inlet Blade Angle,

And

From Outlet Velocity Triangle,

And,

Outlet Blade Angle,

Head Generated by Impeller,

Overall Efficiency of Impeller,

### 1.4.3 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. Special
attention to the type of ESP is required when using certain types of liquids. ESPs commonly used on board naval vessels cannot be used to dewater contaminated flooded spaces. These use a 440 volt A/C motor that operates a small centrifugal pump. It can also be used out of the water, taking suction with a 2-1/2 inch non-collapsible hose. The pumped liquid is circulated around the motor for cooling purposes. There is a possibility that the gasoline will leak into the pump causing a fire or destroying the pump, so hot water and flammable liquids should be avoided.

So, the main applications of the submersible pump are,

- Domestic & Community water supply
- Industries
- High rise buildings
- Agriculture
- Dairies
- Fire fighting systems
- Cooling water circulating systems

Fig: - 5 Types of pump

MA Xi-jin and ZHANG Hua-chuan in predicated the hydraulic performance of a three-level Circulating mixed flow pump of a nuclear power station by CFD software. Meanwhile, they conducted performance test on clear water rig. The numerically simulation results were in good coincidence with the Experimental results. [2]The Mixed flow of the liquid occurs when the flow is 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. There are three types of blade used in mixed flow pump; forward curved blade, Backward curved blade, axial curved blade. Mixed flow pumps are widely used for water transportation or as cooling water pumps in power stations.

To increase the flow rate of the pump without changing the head, the blades of the newly designed Axial pump impeller. Excellent impeller blade with similar specific speed, the blade was designed into “C" type curved section to reduce the Occurrence of vortexes at the head of the blade. Properly reduce the blade outlet structure Angle β2K to eliminate or weaken the effect of vortex, and increase the flow rate in. [3] Mixed flow pump can we used in following application like Domestic & Community water supply, Industries, High rise buildings, Agriculture, Dairies, Firefighting systems, cooling water circulating systems. Not many CFD studies or measurements concerning the complex flow in all types of centrifugal pumps have been reported [4, 5].

2. LITERATURE SURVEY

Kiran Patel et al, studied the 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: - 6] Head versus Capacity Curve

Power predicted by CFD analysis is 5 to 10% higher at rated point. To compare with the test result, disc-friction power loss calculated using NEL method [6] the volumetric efficiency is determined. Pump efficiency considering disc friction loss and leakage-loss is predicted and it was found within +5% ranges, at duty point. Efficiency predicted by CFD analysis is higher than the test result. Leakage-loss is predicted using. Efficiency is improved by 1% after matching stator angle and changing hub curve profile. Stator blade loading at hub and shroud has improved.

Fig: - 7 Efficiency versus Capacity Curve

A Manivannan et al. studied the CFD analysis of mixed flow pump derived that the mixed flow pump the best efficiency point of the pump is found to be 11 lps. The existing impeller, the head, power rating and efficiency are found out to be 19.24 m, 9.46 kW and 55% respectively.

Fig: - 8 Head developed by the existing and modified impellers

The impeller 1, the percentage increase in the head, power rating and efficiency are 3.22%, 3.9% and 7.27% respectively.

Fig: - 9 Efficiency of the existing and modified impellers

The impeller 2, the percentage increase in the head, power rating and efficiency are 10.29%, 7.61% and 10.91% respectively. Viscous flow analysis of mixed flow pump impeller.[7] The impeller 3, the percentage increase in the head, power rating and efficiency are 13.66%, 12.16% and 18.18% respectively.

Mandar TABIB et al., studied the 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 %. In the CFD analysis high values were obtained for the head, comparing to the manufacturer experimental head. 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.

Fig: - 10 Results obtained in the simulations and manufacturer head curve.

Jidong et al., studied the Optimum design on impeller blade of mixed-flow pump based on CFD analysis. Under filing of impeller blades at the trailing edge improved the performance of the pump that is designed in this study, as stated in References. Best efficiency point of the pump that is designed in this study moves from 53 l/s to 56 l/s and system efficiency increases 2% for the best efficiency point. The disturbance on the trailing edge of the blade caused by offsetting the designed surface in order to give thickness the blade is reduced, when under filing is performed in the impeller blades, While making the comparison of the CFD results; the convergence of the analyses should be obtained. If the instable analyses are faced by means of convergence, the number of elements should be increased and the analyses should be rerun for the stability. The integration of the CFD software to the design process is a continuous procedure. The code should be verified in each case study by comparing the CFD results with actual test results. The specific methods were to increase the blade inlet structure angle $\beta 1K$ at the blade the affect of vortex, and increase the flow rate in. [11] the test results are compared with the CFD results and hydraulic design of the pump. Selecting the suitable blade and vane thicknesses, blade swirl and vane swept angles are important from the manufacturing point of view.

Michal Varcholaa et al., studied the Geometry Design of a Mixed Flow Pump Using Experimental Results of on Internal Impeller Flow research of the velocity and pressure flow field in the impeller of the mixed flow pump.[12]

A subject of this paper is a numerical solution of a mixed - flow pump geometry with respect to a distribution of a static ressure in the channel of the pump. The distributions of pressure and velocity fields were obtained through experiments. The blade's design was obtained according to the pressure distribution in the impellers’ channel. The hydraulic projection of an impeller is very sensitive in terms of the overall efficiency as well as the position of the best efficiency point. Or said in a different way, the
match of optimal flow-rate and the specific energy measured and calculated. The pump designed through the described procedure, achieved its peak efficiency at the calculation point, which justifies the validity of the procedure. It can be said that the method used for projection of a blade cut based on the characteristic pressure distribution in the channel of the impeller, seems to be perspective for the prime projection of geometry of the diagonal pump.

3.1 MY COMMENTS:
From the above review it is conclude that the following scope of work.

- CFD analysis of mixed flow impeller
- impeller & blade material to be changed
- number of blade increases
- number of blade decreases
- blade inlet angle to be changed
- blade outlet angle to be changed
- fluid inlet temperature of impeller center
- fluid outlet temperature of diffuser
- CFD software results compare with the actual tested results and get maximum head

Nomenclature
C1 - axial velocity (m/s)
D1 - inlet diameter (m)
Q - Discharge (m³/s)
U1 - circumferential velocity (m/s)
β1 - inlet blade angle (Deg)
ω - Angular velocity (deg/s)

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