# A Review of Advanced Methods and Measurements of Impeller Design

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*Abstract*— **The most common approach for measuring the mixed flow of a impeller is to determine the incident mixed flow the chamber .impeller considering revaluate component of a centrifugal pump with different position are applied. Usually material are composite materials, utilized aluminium alloy, iron ,steel ,bronze ,brass, which transfer energy from the motor the pump to the mixed flow of the fluid pumped by accelerating the fluid outwards from the centre of rotation. Therefore it is necessary to find out the design parameters and working conditions that yield optimal output and maximum efficiency with lowest power consumption are considered. In this review are indicates that Computational fluid dynamics (CFD) analysis is being increasingly applied in the different designs of centrifugal pumps used many applications like chemical industry, paramedical industry, biotechnology, polymers and food industry etc. With the aid of the measurement numerical approach, the mixed with internal flows in unique of application while considered of the impellers, can be well corrected less, strengthened, vibration less to speed up the pump design procedure. In review of the research paper carried out in this direction especially in the content of parametric study and optimization of centrifugal pump impeller using CFD tool and taguchi technique. Literature surveys indicate that very unique work has been done in this area.**

*Keyword:* **Impeller, Measurement, Advanced techniques.**

## I. INTRODUCTION

**IMPELLER**

A centrifugal pump is one of the simplest pieces of equipment in any process plant. Centrifugal pump comes under the category of rotating machinery. Its purpose is to convert energy of a prime mover first into velocity or kinetic energy and then into pressure energy of a fluid that is being pumped. The energy changes occur by virtue of two main parts of the pump, the impeller and the volute or diffuser. The impeller is the rotating part that converts driver energy into the kinetic energy. The volute or diffuser is the stationary part that converts the kinetic energy into pressure energy. Centrifugal pump impeller [3] Rotating machinery is commonly used in mechanical systems, including industrial turbo-machinery, machining tools, and aircraft gas turbine engines. Vibration caused by mass imbalance is a common problem in rotating machinery. Imbalance occurs if the principal axis of inertia of the rotor is not coincident with its geometric axis. Higher speeds cause much greater centrifugal

**Figure 1.1 Impeller model**

### 1.1 CFD

Computational fluid dynamic analysis imbalance forces and the current trend of rotating equipment toward higher power density clearly lead to higher operational speeds. Therefore, vibration control is essential in improving machining surface finish; achieving longer bearing, spindle, and tool life in high-speed machining; and reducing the number of unscheduled shutdowns. A great cost savings for high-speed pumps, turbines, compressors, and other turbo machinery used in industries can be realized by removing the unbalance. CFD is a branch of fluid mechanics uses numerical methods and algorithms to solve and analyse problems that involve fluid flow. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. Computational techniques replace the governing partial differential equations with algebraic equations that are much easier to solve using computer.

### 1.2DOE

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. However, in statistics, these terms are usually used for controlled experiments. Formal planned experimentation is often used in evaluating physical objects, chemical formulations, structures, components, and materials. Other types of study, and their design, are discussed in the articles on computer experiments, opinion polls and statistical surveys (which are types of observational study), natural experiments and quasi- experiments (for example, quasi-experimental design). See Experiment for the distinction between these types of experiments or studies. In the design of experiments, the experimenter is often interested in the effect of some process or intervention (the "treatment") on some objects (the "experimental )

**2. Literature Survey:**

Erik Dick et al1[2001] have used CFD-code Fluent 5.4for the flow analysis of two test pumps of end-suction volute type, one of low specific speed and one of medium specific speed. For both, head as function of flow rate for constant rotational speed is known from experiments. First, the impeller is generated. One impeller channel is meshed and is then rotationally copied the necessary number of times. For the first pump, the impeller is completely two-dimensional. The impeller mesh is made with hexahedra and wedge cells. For the second pump, the impeller channel is much more complex. The mesh is made in a completely unstructured way, mainly using tetrahedron, but other cell forms like pyramids, hexahedra and wedges also occur. The inlet channel is meshed for both pumps with prisms. The volute in both pumps is too complex for a structured grid. The total number of cell for pump 1 is about 300000. For pump 2, it is about 550 000.they found that Steady calculation methods like the Frozen Rotor method and the Mixing Plane method cannot be used with confidence to analyse the performance of volute centrifugal pumps.

K.W. Cheah et al2[2007] have investigated the complex internal flow in a centrifugal pump impeller with six twisted blades by simulation using a three-dimensional Navier-Stokes code with a standard k-e two-dimensional equation turbulence model. Different flow rates were specified at inlet boundary to predict the characteristics of the pump At design point, the internal flow or velocity vector is very smooth along the curvature along the blades. The single and double vertical flow structures are observed in the volute casing. When operating at off- design load, the flow pattern has changed significantly from the well-behaved flow pattern at design load condition. A strong flow recirculation at the centre of the passage of the impeller can be observed. The stall region developed due to the recirculation is blocking the flow passing through the passage.

E. C. Bacharoudis et al3[2008] have studied various parameters which affect the pump performance and energy consumption like the impeller outlet diameter, the blade angle and the blade number and evaluated the performance of impellers with the same outlet diameter having different outlet blade angles. The one-dimensional approach along with empirical equations is adopted for the design of each impeller. The influence of the outlet blade angle on the performance is verified with the CFD simulation. As the outlet blade angle increases the performance curve becomes smoother and flatter for the whole range of the flow rates. The numerical simulations seem to predict reasonably the total performance and the global characteristics of the laboratory pump. The influence of the outlet blade angle on the performance is verified with the CFD simulation. As the outlet blade angle increases the performance curve becomes smoother and flatter for the whole range of the flow rates.

Andrzej Wilk 4[2010] discusses the results of measurements of parameters of a high speed impeller pump with open-flow impeller having radial blades. They found that at high rotational speed pump has obtained a large delivery head, because the blade angle at outlet from the impeller is wide, liquid flowing out the impeller has large absolute velocity and dynamic delivery head of the impeller is large. The kinetic energy of the liquid was converted to pressure in spiral case and in the diffuser.

LIU Houlin et al5[2010] their investigation focuses mostly on the performance characteristics of axis flow pumps, the influence of blade number on inner flow filed and characteristics of centrifugal pump. the methods of numerical simulation and experimental verification are used to investigate the effects of blade number on flow field and characteristics of a centrifugal 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 and other 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. The comparison between prediction values and experimental results indicates that the prediction results are satisfied. The maximum discrepancy of prediction results for head, efficiency and required net positive suction head are 4.83%, 3.9% and 0.36 m, respectively.

S. Chakraborty et al6[2011] evaluated the performance of impellers with the same outlet diameter having different blade numbers for centrifugal pumps. The model pump has a design rotation speed of 4000 rpm and an impeller with 4,5,6,7,8,9,10,12 numbers of blades has been considered. The inner flow fields and characteristics of centrifugal pump with different blade number are simulated and predicted by using Ansys Fluent software. The simulation is steady and moving reference frame is applied to take into account the impeller-volute interaction. For each impeller, static pressure distribution, total pressure distribution and the changes in head as well as efficiencies of centrifugal pump are discussed. With the increase of blade number, the head and static pressure of the model increases, but the variable regulation of efficiency are complicated, but there are optimum values of blade number for each one.

K.M. Pandey et al7[2012] has studied the performance of impellers with the same outlet diameter having different blade numbers is thoroughly evaluated. The investigation focuses mostly on the performance characteristics of pump. The methods of numerical simulation and experimental verification are used to investigate the effects of blade number on flow field and performance of a centrifugal pump. They have performed two-dimensional steady numerical analysis for centrifugal pumps with impeller blades 7, 8 and 9 using Ansys Fluent 6.3 software for inlet diameter 80 mm and outlet diameter 168 mm at 2500 rpm rotational speed and also investigated the changes in head as well as efficiencies with the increase of blade number. They concluded that the head of centrifugal pump grows all the time with the increase of blade number but the change regulations of efficiency is little bit complex. The efficiency is maximum for 7 bladed impeller centrifugal pumps. So the optimum blade number of the model pump in this paper for efficiency is 7.

SHI Weidong et al8[2012] has evaluated the performances of the deep well centrifugal pump with four different impeller outlet widths and studied the numerical, theoretical and experimental methods . Two stages deep well centrifugal pump equipped with different impellers are simulated employing the commercial CFD software to solve the NavierStokes equations for three dimensional incompressible steady flow. The changing value of the impeller outlet width (b2) is 9 mm, 10 mm, 11 mm, and 12 mm The commonly used deep well centrifugal pump of 150QJ20 type was selected as the research object. Its main parameter at the design condition as follows: rated flow QN=20 m 3 /h, single stage head Hs=13 m, stage number N=5, speed n=2 850 r/min, specific speed ns=113. Result they found oversized impeller width leads to the impeller area ratio increasing, and causes the poor pump performance. A point worth emphasizing is that a relative small impeller outlet width conducive to get a better performance and lower power.

R Ragoth Singh et al9[2012] has discussed an application of the Taguchi method for optimizing the design parameters in blower operation. Optimization of design parameters using this technique is directly inclined towards economic solution for the turbo machinery industry. They have studied, the methodology to find near optimum combination of blower operating variables for performance enhancement were analysed using computational fluid dynamics(CFD). Taguchi orthogonal array (OA) based design of experiments (DoE) technique determines the required experimental trials. The experimental results are justified by Analysis of Variance (ANOVA) and confirmed by conformation experiments. The parameters chosen for design optimization are Impeller outlet diameter, Impeller wheel width, Thickness of blade and Impeller inlet diameter. The levels for the parametric specification are chosen from the ranges where the blower will get the best efficiency. CFD results were validated by the fine conformity between the CFD results and the experimental results.

R. R Singh et al10[2012] have evaluated the characteristics of low specific speed centrifugal water pump by studying the relationships among the impeller eye diameter, vane exit angle and width of the blade at exit. As these pumps are of Non-positive type, the discharge is greatly affected by any resistance to flow, outlet conditions and design parameters of impeller and casing. Different pump models are developed by varying critical design parameters to different levels. Response surface method is used for Optimization and Experimental Design (DoE). Computational Fluid Dynamics (CFD) analysis is carried out on the developed models to predict the performance virtually and to verify with the experimental result of the pump. Optimal pump design is formulated using Response surface method. The objective functions are defined as the total head and the total efficiency at the design flow-rate.

Ashok Thummar et al11 [2012] A performance analysis of centrifugal pump is carried out and analysed to get the best performance point. The various performance parameters of centrifugal pump such as overall efficiency, cavitations, slip factor, losses etc. have been calculated. For that four different types of open well centrifugal pump namely impeller 165mm, 210 mm, 170 mm, and123 mm were selected for the performance analysis. During the investigation period it is found that the overall efficiency of the pump is increases as the flow rate and head decreases where as the power input is increased.

Ling Zhou et al12[2013]have used an orthogonal experiment to optimize the impeller design parameters. The prototype experimental test results of the original pump were acquired and compared with the data predicted from the numerical simulation, which presents a good agreement under all operating conditions. Five main impeller geometric parameters namely impeller outlet width 2, impeller inlet diameter1, impeller blade wrapping angle , impeller blade outlet angle 2, and impeller blade inlet angle 1. were chosen as the research factors. 16 impellers were designed and modelled according to orthogonal array table. Then, the 16 impellers equipped with the same volute were simulated by the same numerical methods. Through the variance analysis method, the best parameter combination for higher efficiency was captured finally. Compared with the original pump, the pump efficiency and head of optimal pump have a significant improvement. optimal impeller design was adopted as , #2 =11 mm, #1 = 66 mm, @ = 130°, #2= 15°, and #1 = 12° based on the results .orthogonal experiment. Then, the final optimized impeller was designed and assembled with the same volute and simulated by the same numerical methods. At the design flow rate, the optimal pump has 67.55% efficiency and 30.93m head. Compared with the original pump with 64.11% efficiency and 29.21 m, the increase is 5.4% and 5.9% in percent separately Shalin P Marathe et al13[2013] has studied the performance of the centrifugal pump having the backward, radial and forward bladed type of impeller. The impeller is modeled using Creo Parametric 1.0 having 70 and 80 degree outlet blade angle for the backward type and outlet blade angle 90 for radial and 100 degree for forward type impeller respectively. Numerical simulation is carried out using ANSYS CFX and standard k- turbulence model is adopted for the analysis purpose. The results obtained from the analysis shows that the characteristic curve for different outlet blade angles are completely matched with the numerical results and it can be concluded from the results that for low head operating conditions, the impeller with backward bladed works efficiently and the problem of the cavitations, which reduces the performance of the pump is less. Alok ku Nanda et al14 [2013] Used to assess the performance of pelton wheel turbine with different range of rotational speeds and varying loads using surface response methodology (RSM). The result value reveals that the predicted value and the observed value for turbine shaft rotation in rpm are indicating a very good fit for the response function equation.

## 3. CRITICAL PARAMETERS OF CENTRIFUGAL PUMP IMPELLER

From the literature review critical parameter of the centrifugal pump impeller is found out which highly affect the performance characteristic of centrifugal pump are,

1. Impeller outlet width (#2) Pump head decreases with increased blade width. This is due to augmenting the liquid pressure drop with increasing blade width. Also, the required pump brake horsepower decreases when the blade width rises.

2. Impeller outlet diameter(#2) pump head increases with increasing impeller diameter, which can be explained by the fact that the liquid static pressure drop in impeller decreases with increasing impeller diameter. In other words, for a given volume flow-rate, the pressure difference between the volute outlet and the impeller inlet is higher for an impeller with a greater diameter. In addition the brake horsepower increases relative to the increasing impeller diameter, due to the requested augmented impeller shaft torque relative to the size of the impeller diameter.

3. Impeller Outlet Blade Height pump head as a function of the volume flow rate with the outlet blade height pump head increases with increasing outlet blade height. This can be explained by the fact that, when the volume flow rate is kept constant, the increased outlet blade height leads to the decreasing meridional velocity, which increases the pump head since the outlet tangential velocity and the outlet blade angle remain constant. In other words, the liquid pressure drop in the impeller decreases as a function of the increase in outlet blade height as a parameter.

4. Number of blade on the impeller(Z) Experiments shows that pump head increases with a greater blade number. This is explained by the decrease in the liquid pressure drop in the flow passage with an augmented impeller blade number, keeping the same total volume flow rate the pump brake horsepower increases relatively with the augmented blade number. This is due to the increase in the request pump shaft torque, as the pump blade number also increases.

## 4. CONCLUSION

Centrifugal pump is more widely used because of following advantages.

- Its initial cost is low Efficiency is high
- Discharge is uniform and continuous flow
- Installation and maintenance is easy.

As the centrifugal pump is used in very wide verity of applications So, it is quite necessary to measure the various pump performance parameters for the efficient operation of centrifugal pump, but Experimental studies to determine different performance parameters in different type of pumps are complex, time consuming and costly. So by using CFD and DOE prediction model it is easy to predict the performance of different pump and speed up the production.

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