An Investigation On Design And Performance Optimization Of Pump Impeller

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***Abstract* - An impeller is a main part of the pump. The pumps are widely used for power plant, steam power plants, sewage, oil refineries, chemical plants, hydraulic power service and agricultural sectors. Therefore, it is necessary to find out the working conditions and design parameters that yield optimal output and maximum efficiency with lowest power consumption. This paper investigates the design and performance optimization of the pump impeller. An overview of impeller blade performance, blade thickness, blade angle, manufacturing methods and required power consumption are analyzed. This study shows Computational fluid dynamics analysis (CFD) being applied in design optimization of pump impeller. With the assist of CFD tool, the tedious flows can be expected.**

***Keywords* - Investigates, Impeller Blade Performance, Blade Thickness, Blade Angle, CFD Tool.**

I. INTRODUCTION

A pump is a device, which converts mechanical energy to hydraulic energy. A wide variety of centrifugal pump types have been erected and used in various applications like power plants, industry and other technical sectors. However, their performance and design prediction process is still a difficult task, mostly due to the great number of free geometric parameters; the effect of these cannot be straightly evaluated. The major cost and time of the trial-and-error process by creating and testing physical models reduce the profit margins of the pump manufacturers. Such case, CFD analysis is being presently used in the design and construction fields of various pump types. The experimental method of pump test can yield the actual value of head developed, efficiency and power rating. But the internal flow condition cannot be estimated by the experimental results. From the CFD analysis, the difficult flow inside the impeller can be analyze. The complex flow uniqueness like inlet pre-swirl, flow separation and outlet recirculation cannot be seen by the experimental way of pump test. On considering the CFD analysis, the above flow characters can be visualized clearly.

II LITERATURE SURVEY

1. Optimization of impeller design

1.1 Based on the mixed flow pump

Guiding Li et al [1] this paper discussed the optimal design of this pump was conducted with only replaced with impeller and without replacing the fixed guide vane, flow passage and motor. A new pump impeller was optimally designed. The mixed-flow pump was numerically pretended by using Computational Fluid Dynamics software on the base of Spalart-Allmaras turbulence model to the unique design of the plant. The flow rate of this pump was increased by reducing the blade number, properly escalating the blade inlet structure angle, reducing the blade outlet structure angle and other methods.

Sambhrant Srivastava et al [2] have investigated the natural frequency and deformation of mixed flow pump impeller were evaluated based on two various blade positions in the meridional annulus. It was observed that the mixed flow pump impeller with inlet inclined blade position in the meridional annulus was more suitable than the trapezoidal one. The impeller with inlet inclined blade positioning is an optimum choice than the other one. Fig. 1 summarizes the two different positions ((a) forward, (b) trapezoidal) of the mixed flow pump impeller blades in the meridional annulus.

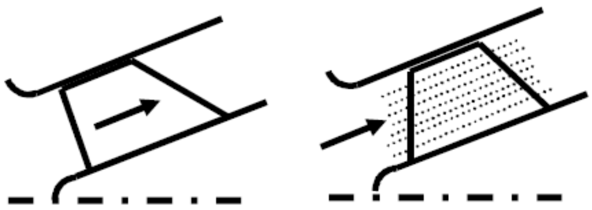

Fig. 1 The two different positions of the mixed flow pump impeller.

Sambhrant Srivastava et al [3] in this present work design and stress analysis had been performed on mixed flow pump impeller blades having dissimilar positions in the meridional annulus. This paper used basic methodology of turbo machinery and fluid mechanics. The stress investigation of the pump blades has been carried out using ANSYS 11 software. The inlet inclined blade position is a superior choice than the other one. Moreover, this observation was support by the maximum principal stresses occurred.

1.2 Based on centrifugal pump

R. Ragoth Singh et al [4] in this study, Computational Fluid Dynamics analysis was suggested to examine the flow in the centrifugal pump impeller using the Solid Works Flow Simulation (SWFS). The vane profile constructing to use two methods of circular arc method and point by point method is listed in

Table 1 The comparisons of efficiency

S.NO	METHOD	EFFICIENCY
1	Circular arc	58.53%
2	Point by point	57.31%

The Table 1 is discussed the efficiency of the circular arc method was 58.53% and point by point method was 57.31%. The circular arc method has provided a higher efficiency than a point by point method.

Yu-Tai Lee et al [5] have investigated effort utilized a mathematical optimization with experimental steering techniques to redesign inlet duct, the fan blades and shroud of the impeller. The final flow path modifications not only met the pressure condition, but also decrease the fan power by 8.8% over the baseline. A double-inlet, double-width impeller was customized to fit into a baseline double-discharge volute for a centrifugal fan. The goal was to reduce power consumption while retaining a particular output pressure at the lift-side volute exit.

Shalini rai et al [6] this paper effort utilized a numerical optimization with an experimental steering procedure to redesign the fan blades, inlet duct, and covering of the impeller. The final flow path variation not only met the pressure condition, but also minimized the fan power by 8.8% over the baseline. This reduction in power agrees with the 8.7% reduction obtained from the CFD predictions.

Vijaypratap R Singh et al [7] this paper exposes the numerous research work carried out in this direction especially in the matter of parametric investigation and optimization of centrifugal pump impeller using CFD tool and DOE technique. The above investigation in flow pattern inside the pump and altering the important parameters efficiency of the pump can be improved.

2. Optimization of impeller performance

M.G.Patel et al [8] have investigated the three pumps of different specific speeds are taken for used to the effect of exit angle. Head and efficiency have been found with the use of a hydraulic loss model. The blade exit angle has a significant and equal effect on the head and the efficiency. With the increase in blade exit angle the performance of the centrifugal pump is increased.

P.Usha Sri et al [9] have investigated the simulation of the flow in a centrifugal pump impeller at five dissimilar flow coefficients viz.0.0146, 0.0346, 0.0546 (designed flow coefficient), 0.0746 and 0.0946. The computational fluid dynamics analysis is carried out with ANSYS-CFX. The increase of the designed flow rate result a decrease in the total head of the pump.

P.Gurupranesh et al [10] this study is devoted to improve the performance of the centrifugal pump through design changes of the impeller. The impeller is modeled in Solid works 2012 software and computational fluid dynamics analysis was carried out using fluid flow simulation package. CFD analysis had been established to predict the performance of the pump and a relative analysis is made for the full control volume by varying meshing Overall efficiency of the pump is 61%, the CFD results predict total head of 50 m.

3. Optimization of blade number used in the impeller

Suresh Pittala et al [11] have proposed 20 blade impeller, in order to reduce cost and noise. Also Comparison between these impellers is made in respect of other aspects like material, outlet velocity, fluid discharge and efficiency. By using computational fluid dynamics (CFD).this paper Compared to 6 blades and 20 blade impeller.

Table 2. Comparisons between 6 blade and 20 blade impeller

S.No	Parameter	6 blade impeller	20 blade impeller	Benefits of new model
1	Inlet angle	73.5^0	38^0	Flow increment
2	Outlet angle	56.5^0	62^0	Flow increment
3	Number of blades	6	20	Flow increment
4	Material	Steel	ABS (C_8H_8)	Cost reduction
5	Outlet velocity	23.22 m/s	32.46 m/s	Outlet velocity increment
6	Discharge	4.00 LPs	5.2 LPs	Discharge increased
7	Head	12m	18 m	Head increased

Table 2 discusses the 20 blades impeller gives more discharge at the outlet of the impeller and also velocity obtained from the CFD predictions is 35.46 m/s.

LIU Houlin et al [12] have investigation focuses mostly on the performance characteristics of axial flow pumps. The methods of numerical simulation and experimental confirmation are used to investigate the effect of number of blades on flow field and uniqueness of a centrifugal pump. The increase of blade number is helpful to minimize the mixture loss of wake and get in a centrifugal pump.

Table 3 Experimental values

Blade number Z	Head H/m	Efficiency %	NPSHR H_{RNPS}/m
4	27.51	74.07	4.04
5	30.38	75.63	3.68
6	30.54	74.20	4.66
7	32.91	77.45	4.95

The Table 3 is discussed to impeller blade number is increased and efficiency also increased.

4. Optimization of CFD analysis

Mehul P et al [13] in this study, Cfd analysis of mixed flow pump impeller. The optimum inlet and outlet vane angles can be calculated for the present impeller by enhancing the empirical relations. In first stage outlet angle is increasing, and second stage inlet angle is decrease obtain from the CFD analysis. Finally, from CFD analysis the designed efficiency of the impeller with optimum vane angle can be developed by changing the inlet and outlet angle.

Jekim J et al [14] To analyze the centrifugal pump using the CFD techniques and predict the performance of a mixed flow-type impeller of centrifugal Pump, in this paper, Experimental investigation were conducted on centrifugal water pump with a 111 mm outlet impeller diameter, backward curved blades, a nominal discharge of 4.00 laps and 12 m of head to assess the effect of various operating conditions like Head, Power, Discharge and Speed on the performance of the pump. The best operating condition is flow rate 6.25 LPs, head 12.49 m, efficiency 3.67% of the selected pump.

5. Optimization of the impeller blade angle

Li Wei et al [15] have investigated this paper to increase the impeller outlet angle and analysis the numerical simulation. When the impeller outlet angle was increased, local medium energy lost severely. While the angle decreasing, the blade was suitable for the flow of the solid particles, which has enhanced the impeller wearing and increased efficiency. The impeller blade exit angle in the design of sewage pumps is meaner than the one of fresh water pumps. This can decrease the strike of solidity to the blade, minimize wear and increase efficiency.

E.C. Bacharoudis et al [16] have investigated the performance of impellers with the identical outlet diameter having different outlet blade angles is thoroughly evaluated. The CFD tool is used to the analysis of flow rate. This paper concluded the increase of the outlet blade angle causes a considerable improvement of the hydraulic efficiency

6. Optimization of impeller manufacturing

Francis Quail et al [17] this paper presents a technique of rapid manufacture used in the growth of a regenerative pump impeller. Rapid manufacturing technology was used to create tedious impeller blade profiles for testing as part of a regenerative pump optimization process. This practice offers the opportunity to produce components of increased complexity whilst ensuring strength, performance, quality and speed of manufacture.

7. Another aspect

M.Mohammed Mohaideen et al [18] this paper discussed with optimizing the design of radial fan impeller utilizing finite element analysis [FEA]. The analysis was performed using the standard thickness of the impeller of the radial fan. An attempt has been made to increase the Fan efficiency by optimizing the thickness of the different components in the fan impeller, and investing the stress variations. Optimizing the thickness of the impeller part tends to decrease in weight of the Fan Impeller, and in turn the power needed for driving the fan decreases.

Roman Celin et al [19] this paper investigated to determine a possible cause for the impeller-blade failure.The most feasible reason for the impeller-blade failure was the fatigue stress. The investigation standard nondestructive and destructive methods were used. The most possible cause for the impeller-blade breakdown was the fatigue caused by the flow-induced vibrations due to a turbulent flow over the blades and the internal stresses caused by the welding repair of the casting defects.

Abdellah Ait Moussa et al [20] this paper investigated to design and optimization of turbo machine impellers in pumps and turbines is a highly intricate task due to the complex three-dimensional shape of the impeller blades and surrounding devices. The technique could also be unmitigated to comprise additional terms in the increase of the blade angle. It can also be developed if parameterization of the meridional projection can also integrated.

III Summary

A centrifugal pump is more widely used because of its advantages like initial cost is low, efficiency is high, discharge is uniform and continuous flow .From the literature survey, it is concluded that

- Increase in exit angle achieves high flow rate
- Thickness of the blade is reduced to enhance the power consumption in considerable rate
- Model made by rapid prototyping techniques saves both time and cost, while compared with conventional methods
- The inclined position of the inlet blade results better choice than the trapezoidal position With the assist of CFD tool, prediction model can be developed and the tedious flows can be expected.

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