A Review Paper on Improvement of Impeller Design a Centrifugal Pump using FEM and CFD

Anirudha S. Bhosale
PG Student
Department of Mechanical Engineering
D.K.T.E's Textile and Engineering Institute, Ichalkaranji (M.S.), India

P. N. Gore
Professor
Department of Mechanical Engineering
D.K.T.E's Textile and Engineering Institute, Ichalkaranji (M.S.), India

Abstract

Centrifugal pumps are widely used for water supply plants, steam power plants, sewage, oil refineries, chemical plants, hydraulic power service, food processing factories and mines, because of their suitability in practically any service. Therefore it is necessary to find out the design parameter, working conditions and maximum efficiency with lowest power consumption. Study indicates that Computational fluid dynamics (CFD) analysis is being increasingly applied in the design of centrifugal pumps. Various parameters affect the pump performance and energy consumption. The impeller material, blade angle and the blade number are the most critical. Therefore it is necessary for development in the impeller so we can improve the performance of pump.
Keywords: Static Analysis, Pump Impeller, FEM, CFD, MS, Glass Fiber etc.

I. INTRODUCTION

An impeller is a rotating component of a centrifugal pump, usually made of iron, steel, bronze, brass, aluminum or non-metal, which transfers energy from the motor that drives the pump to the fluid being pumped by accelerating the fluid outwards from the center of rotation. The velocity achieved by the impeller transfers into pressure when the outward movement of the fluid is confined by the pump casing. Impellers are usually short cylinders with an open inlet (called an eye) to accept incoming fluid, vanes to push the fluid radially and a splined, keyed or threaded bore to accept a drive-shaft.

A. FEA and CFD

Finite element analysis is one of such numerical procedure for analyzing and solving wide range of complex engineering problems (may be structural, heat conduction, flow field) which are complicated to be solved satisfactorily by any of the available classical analytical methods.

Computational Fluid Dynamics is very useful for predicting pump performance at various rotational speeds. With the help of numerical simulation mechanical behavior can be analyzed. The prediction of behavior in a given physical situation consists of the values of the relevant variables governing the processes. CFD provides a cost- effective and accurate alternative to scale model testing with variations on the simulation being performed quickly offering obvious advantages.

II. LITERATURE REVIEW

E.C. Bacharoudis, A.E. Filios, M.D. Mentzos and D.P. Margaris (2008) 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 with empirical 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 play important role into different outlet angles. The influence of the outlet blade angle on the performance is verified with the CFD. The performance curve becomes smoother and flatter with the increase with the increase outlet blade angle. At nominal 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, 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 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 non-cavitation and caviation 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 become worse and worse while at diffusion section become better and better. The head of model pump is increase with the increase with pump but there is variation with efficiency and cavitation is complicated. These results are important to design of the centrifugal pump.

B.Mohan, B.E.Kumar (2011) 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.

S.Rajendran, Dr.K.Purushothaman (2012) described the simulation of the flow in the impeller of a centrifugal pump. The analysis of centrifugal pump impeller design is carried out using ANSYS-CFX. The complex internal flows in Centrifugal pump impellers can be well predicted through ANSYS-CFX. The numerical solution of the discredited three-dimensional, incompressible Navier-Stokes equations over an unstructured grid is accomplished with an ANSYS-CFX.

A Syam Prasad, BVVV Lakshmipathi Rao, A Babji, Dr P Kumar Babu (2013) It described the static and dynamic analysis of a centrifugal pump impeller which is made of three different alloy materials (viz., Inconel alloy 740, Incoloy alloy 803, Warpaloy) to estimate its performance. The investigation has been done by using CATIA and ANSYS13.0 softwares. A structural analysis has been carried out to investigate the stresses, strains and displacements of the impeller and modal analysis has been carried out to investigate the frequency and deflection of the impeller. An attempt is also made to suggest the best alloy for an impeller of a centrifugal pump by comparing the results obtained for three different alloys.

Sambhrant Srivastavaa, Apurba Kumar Roy and Kaushik Kumar (2014) discussed natural frequency and deformation of mixed flow pump impeller were evaluated considering two different blade positions in the meridional annulus. ANSYS was used for the investigation of natural frequency and deformation. 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.

Neelambika, Veerbhadrappa (2014) a detailed CFD analysis was done to predict the flow pattern inside the impeller which is an active pump component. The optimum inlet and outlet vane angles are calculated for the existing impeller by using the empirical relations. In the first case, outlet angle is increased by 5°. From the outlet flow conditions, obtained from the CFD analysis, it is evident that the reduced outlet recirculation and flow separation cause the improved efficiency. By changing the outlet angle the efficiency of the impeller is improved to 59%. In the second case inlet angle is decreased by 10%. The efficiency of the impeller in this case is 61%. From this analysis it is understood that the changes in the inlet vane angle did not change the efficiency of the impeller as much as the changes in outlet angle. The existing impeller, the head and efficiency are found out to be 19.24 m and 55% respectively. The impeller 1, the percentage increase in the head and efficiency are 3.22% and 7.27% respectively. The impeller 2, the percentage increase in the head and efficiency are 10.29% and 10.91% respectively. The impeller 3, the percentage increase in the head and efficiency are 13.66% and 18.18% respectively. Based on the above, it is concluded that impeller 3 gives better performance.

Santosh Shuklaa, Apurba Kumar, Royband Kaushik Kumar (2015) highlight to minimize the stress developed and deformation. The 3D model of mixed flow pump impeller blade was developed using CATIA and with four different materials (Copper alloy, Bronze, Stainless steel and Titanium alloy) analysis was done in ANSYS 11.0 with similar loading and support conditions. The results obtained were compared. It was observed that Titanium alloy can be considered as the constructional material for the blades as it gave minimum deformation (at Tip) and Stress (at base).

Basavraj, H.Hasu (2016): In this paper, the analyze the centrifugal pump with the change in the vane angle. The model pump changes the vane angle with 16,8,20 deg. Static analysis and Modal analyses are performed on the impeller to determine stresses, deformations and frequencies by applying the rotational velocity for different materials. By observing the structural analysis results, the deformation and stress values are slightly varying by varying the blade angles. By observing model analysis results, CFRP has more frequency value. The vibrations are more when CFRP is used and the frequency and deformation values are less when Stainless Steel is used. So CFRP is better material. CFD analysis is done by applying the velocity of fluid to determine pressures developed mass flow rates.

III. REMARK FROM LITERATURE SURVEY

The literatures above provide brief information about use of different materials for impeller design including metals and non-metals. Research papers are showing static and dynamic analysis of impeller in centrifugal pump. The Hydraulic design of the impeller can be optimized by means changing the input design of impeller. With the use of the FEM we can predict that impeller material suitable for the pump. In design of impeller as part in a centrifugal pump, weight reduction done by use of composite material where as there are challenges in static and dynamic stresses developed.

REFERENCES

[1] E.C. Bacharoudis, A.E. Filios, M.D. Mentzos and D.P. Margaris (2008),"Parametric study of centrifugal pump by varying the outlet blade angle", The open mechanical engineering journal, 2008, 75-83.
[2] LIU Houlin, WANG Yong, YUAN Shouqi, TAN Minggao, and WANG Kai (2010),"Effects of blade number of characteristic of centrifugal pump ",Chinese journal of mechanical engineering,2010.
[3] B.Mohan, B.E. Kumar, (2014), "Structural Analysis on Impeller of an Axial Flow Compressor using Fem", International Journal of Engineering Research & Technology ISSN: 2278-0181 Vol. 3 Issue 10.

[4] S.Rajendran and Dr.K.Purushothaman, (2012), "Analysis of a centrifugal pump impeller using ANSYS-CFX", International Journal of Engineering Research & Technology, Vol 1 Issue 3.
[5] A Syam Prasad, BVVV Lakshmipathi Rao, A Babji, Dr.P Kumar Babu, (2013), "Static and Dynamic Analysis of a Centrifugal Pump Impeller", International Journal of Scientific & Engineering Research, Volume 4, Issue 10.
[6] Neelambika, Veerbhadrappa (2014) "CFD analysis of mixed flow impeller", International journal of research engineering and technology.
[7] Sambhrant Srivastavaa, Apurba Kumar Roy and Kaushik Kumar, (2014) "Design of a mixed flow pump impeller and its validation using FEM analysis", Science Direct, Procedia Technology 14, PN 181 – 187.
[8] Santosh Shukla, Apurba Kumar Roy and Kaushik Kumar, (2015) "Material Selection for blades of Mixed Flow Pump Impeller Using ANSYS", Science Direct, Materials Today: Proceedings 2, 2022 – 2029.
[9] Basawaraj, H.Hasu (2016), "A study analysis on centrifugal pump impeller guide vane with fem approach by using different material", IJES 2016 Volume 2016 Issue 8.