

# OPTIMIZATION OF CENTRIFUGAL PUMP IMPELLER OUTLET VANE ANGLE BY USING MODAL ANALYSIS

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## ABSTRACT

*A centrifugal pump is one of the simplest pieces of equipment in any process plant. Liquid is forced into an impeller either by atmospheric pressure, or in case of a jet pump by artificial pressure. The vanes of impeller pass kinetic energy to the liquid, thereby causing the liquid to rotate. The liquid leaves the impeller at high velocity. The impeller is surrounded by a volute casing or in case of a turbine pump a stationary diffuser ring. The volute or stationary diffuser ring converts the kinetic energy into pressure energy. An impeller is a circular metallic disc with a built-in passage for the flow of fluid. As the performance of the pump depends on the type of impeller, it is important to select a suitable design and to maintain the impeller in good condition. It is important to recognize that the design of any machine involving aerodynamics, thermodynamics, fluid dynamics, stress analysis, vibration analysis, the selection of materials, and the requirements for manufacturing. Though impellers have been developed as highly efficient, design is still based on various empirical and semi empirical rules proposed by designers. Further the scope of work was extended towards performance evaluation of impeller by changing vane angle of impeller vanes. To optimize impeller vane angle, design and modeling of impeller for various vane angle. The modeling of the impeller will do by using solid modeling software, CATIA V5 R17. It is proposed to design a impeller for various vane angles, analyze its strength and deformation using FEM software like ANSYS V12. Modal analysis is performed on impeller to find out first 5 natural frequencies*

**Keywords :** Centrifugal Pump, Impeller, Pump Vane, Static And Modal Response, Vibration

## I INTRODUCTION

Centrifugal pumps are very common equipment used in residence, agriculture and industrial applications. It is essential for a pump manufactured at low cost and consuming less power with high efficiency. The overall performance is based on the impeller parameters and it is essential to identify the optimized design parameter of the impeller. R. Ragoth Singh, and M. Nataraj<sup>[1]</sup> study the performance of centrifugal pump impeller by developing the vane profile by circular arc method and point by point method and perform CFD analysis of the impeller vane profile for forward and backward curved vane. Adgale Tushar Balkrishna, G.R.Gogate and R.V. Bajaj<sup>[2]</sup> work on pump reducing vibration levels below permissible levels in Centrifugal blower. Karthik Matta, Kode Srividya and Inturi Prakash<sup>[3]</sup> are change the material of centrifugal pump impeller and study the effect on the performance of pump by static and modal analysis of same. Energy Efficiency Guide for Industry in Asia<sup>[4]</sup> study the performance of pump and suggest the energy saving parameter for pump design and design overall pump. C. Kundera and V.A. Martsinkovsky<sup>[5]</sup> are done static analysis

and deriving relationships between the impeller geometry and the basic performance parameters of the pump. A numerical example was used to show the calculation procedure of static characteristics for the predetermined parameters of an impeller for a single-stage pump. Shardul Sunil Kulkarni<sup>[6]</sup> CFD analysis is currently being used in the design and construction stage of various pump types, the use of which reduces significantly the new pump development time and costs. The scope of present work is to investigate the performance of impeller by developing the vane profile by changing vane outlet angle from standard range  $16^\circ$  to  $35^\circ$  and inlet angle calculate as per design of given data of pump. After designing the pump, pump design check by reverse Designing method for pump mathematically validation method then after check same by using software result and then manufacturing model of same design data and check the same data by experimental method.

## II PREVIOUS STUDY

In Static and Dynamic Analysis of Centrifugal Blower Impeller using FEA shows by Adgale Tushar Balkrishna, G.R.Gogate and R.V.Bajaj and find out Total deformation of existing and modified impeller. The Centrifugal blower impeller considered for case study has OD660mm, ID200mm, Width of blade at leading edge 45mm, Width of blade at trailing edge 30mm, thickness of back plate 4 mm, thickness of blades 4 mm and shroud 3 mm. Number of blades is 12. Speed of impeller is 2900 rpm. The modified impeller considered for case study has same dimensional considerations except, thickness of back plate 6 mm, thickness of blades 5 mm and shroud 4 mm. In existing impeller its first modal frequency i.e. 99 Hz is closer to cretical frequency of fan i.e. 96Hz. After modifying the impeller the first modal frequency was shifted to 122 Hz. Frequency Response of Displacement Amplitude (mm) versus Frequency (Hz) was carried out in x, y and z direction. Directional deformation obtained for existing impeller in the form of amplitude in x, y, z is 0.0311 mm, 0.0651 mm and 0.0641 mm respectively. Directional deformation obtained in the form amplitude in x, y, z is 0.0113 mm, 0.005 mm and 0.00506 mm respectively for modified impeller.

In Static and Dynamic Response of an Impeller at Varying Effects shows by Karthik Matta, Kode Srividya, Inturi Prakash An impeller is a rotating component of a centrifugal pump, usually made of iron, steel, bronze, brass, aluminum or plastic, 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. It is proposed to design a blower with composite material, analyze its strength and deformation using FEM software. In order to evaluate the effectiveness of composites and metal blower and impeller using FEA packaged (ANSYS). Modal analysis is performed on both Aluminum and composite centrifugal blower impeller to find out first 5 natural frequencies

In Static and Dynamic Analysis of A Pump Impeller with a Balancing Device Part I: Static Analysis shows by C. Kundera and V.A. Martsinkovsky design and static analysis of an impeller for a single-stage pump. The impeller is directly connected with a balancing device. The impeller needs to have a properly designed system of longitudinal and lateral clearances on both sides. With the simplifying assumptions concerning the flow and distribution of pressure in the longitudinal and lateral clearances, the static analysis involved deriving relationships between the impeller geometry

and the basic performance parameters of the pump. A numerical example was used to show the calculation procedure of static characteristics for the predetermined parameters.

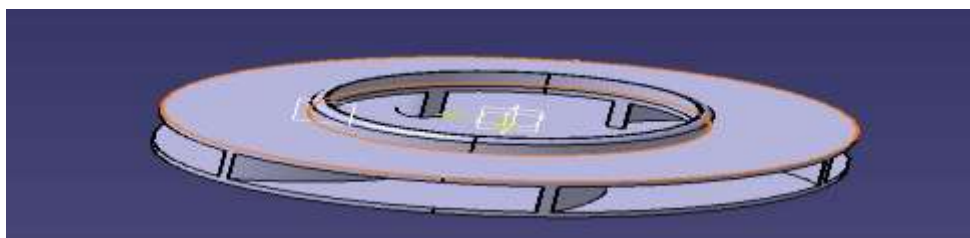
In Static stress and modal analysis on the impeller of screw centrifugal pump shows by S Q Yuan, T Li, J P Yuan and J J Zhou are modeling of the screw centrifugal pump was set up with Pro/E, the meshing of the fluid domain and the impeller were completed with Workbench. The 3-D steady turbulence flow in the pump was simulated by using ANSYS under the design condition to get the pressure distribution on the surface of the blades. The static pressure and modal analysis were set using sequential coupling technique based on the simulation result. The results show that the maximum equivalent stress which is far less than the permissible stress occurs at the blade connected with the hub; the maximum deformation of the impeller occurs at the edge of the blade inlet; the deformation domain increase with the frequency ascended. The impeller static stress characteristics is analyses at the same time on the in a modal analysis and we get the Eigen frequency and vibration type. The calculation provide important basis for the safe operation of the pump.

### III OBJECTIVE OF STUDY

“Optimization of outlet vane angle of centrifugal pump impeller” in this case given data are getting from pump impeller and casing manufacturing company for designing of pump impeller. After getting data, design the impeller of pump. In this design modeling of impeller done by using CATIA by varying the vane outlet angle by  $20^\circ, 24^\circ, 30^\circ$  and  $35^\circ$  in the range of  $16^\circ$  to  $35^\circ$ . After modeling the impeller this data will import in ANSYSE. In Analysis consist of Static analysis and modal analysis, From Static Analysis of all types of impeller obtain the Total deformation and equivalent Stress and from Modal analysis we obtain natural frequency of vibration of all type of impeller. Our main aim is to kept natural frequency greater than critical frequency of impeller to avoid vibrational destruction of pump impeller because vibrational effect is most important factor to design the pump so that in dynamic analysis we done only modal analysis and static analysis of given model

#### 3.1 Modeling By Using CATIA V5 R17

Modeling of Impeller is done using 3D software CATIA V5 R17. The material used for impeller manufacturing is Structural Steel. Steel has Density  $7850 \text{ kg/m}^3$ , Yield Strength  $250 \text{ MPa}$ , Ultimate Tensile Strength  $460 \text{ MPa}$ , Poisson's Ratio  $0.3$  and reference temperature taken is  $22^\circ\text{C}$ . The fluid medium is water.



**Fig 1:- CATIA part of Impeller**

### 3.2 Loading Condition

There are three types of loading that actually act on the centrifugal impeller. The first one is the centrifugal force because of impeller rotation that resulted in centrifugal acceleration of the impeller body. The second is moment that resulted from force from fix centre of impeller. The last one is the Hydrostatic pressure from pressure conversion between the vane and the water. In this case the Hub side of impeller kept as fix constrain and apply all above force on impeller in static analysis of pump. After completing static analysis we obtain minimum natural frequency of all impeller by using modal analysis of pump and compare it with mathematical values of all above.

### 3.3 Analysis of Impeller

Equivalent stress distribution on the impeller is find out .The stress in the inlet and the outlet of the blade is larger, this is due to the particularity of the impeller structure and the hydraulic pressure on the impeller outlet is larger.

#### 3.3.1 Analysis of Centrifugal Pump Impeller Using ANSYS12

The analysis of centrifugal blower has been carried out by using ANSYS 12 general purpose FEM software. Meshing of the same is been done in ANSYS itself.

#### 3.3.2 Modal and Vibration Mode of Impeller

Modal is the natural vibration characteristics of the mechanical structure. Each modal has specific natural frequency, damping ratio and mode shape. There are two kinds of modal analysis methods, experimental modal analysis and calculating modal analysis. In the former method modal parameters are acquired from the acquisition system input and output signals in the experiment. The latter method is obtained by the finite element calculation. ANSYS Workbench is used to analysis the 1—6 order mode of the impeller. For the frequency of high order mode is higher than the impeller working frequency, the 1st--6th order mode are analyzed.

### 3.4 Causes of Vibration

The causes of vibration can be divided into 3 broad categories:

1. Misapplication, design, or manufacture- caused
2. Internally-caused
3. Externally-caused

Critical speed issues is practically non-existent in horizontal pumps running at full speeds: Manufacturers design their products so that the first critical speed is above the highest rotative speed. ("Critical Speed" is the theoretical angular velocity which excites the natural frequency of the rotating equipment. As the speed of rotation approaches the natural frequency, vibration and resonance occur.) In vertical pumps such as vertical turbines with a variety of lengths and heads, critical speeds should be considered prior to manufacture. In horizontal pumps, critical speed will typically result

from over-speeding, lack of piping support, or on multi-pump packages where it was not considered. (In the lack of piping support, the piping becomes “part of the pump” in essence, and the critical speed of the system is different than the critical speed of the pump. This is akin to the external issues discussed as follows. There are two ways to correct critical speed issues and reducing the vibration to acceptable levels, Change the natural frequency of the pump. This should be done in consultation with or assistance from, the pump manufacturer.

#### IV RESULTS DISCUSSION

Static and Dynamic analysis will carry out using ANSYS12. There will find out Equivalent (Von-Misses) stress for all cases and total deformation of all vane angle impeller. In all impeller its first modal frequency of vibration and compare all its result with critical frequency of same model. Find out maximum efficient model for Regular design

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