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A Review on Static Analysis and Material Optimization Using FEA of Centrifugal Pump Impeller

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Abstract: Centrifugal pumps are the simplest equipment used in any process plant. Centrifugal pumps are commonly used in processing plants, water supply plants, steam power plants, oil refineries, etc. Its purpose is to convert the energy of an electric motor or turbine into the kinetic energy and then into pressure energy of a liquid that is being pumped. The energy changes take place with the help of two main components i.e. the impeller and the volute or diffuser. The impeller is the rotating component that converts input energy into the kinetic energy. In this paper, a literature survey is done on centrifugal pump impeller and its design and structural/static analysis using FEA Softwares for different materials.

Keywords: Centrifugal Pump Impeller, FEA, Static Analysis, Material Optimization.

I. INTRODUCTION

The centrifugal pump is mostly used pump type in the world used for residence, industrial and agricultural applications. Centrifugal pumps are used to transport fluids by converting mechanical energy to the hydrodynamic energy. The input power of centrifugal pump is electrical/ mechanical energy provided to impeller shaft and output power is hydraulic energy through which fluid gets transferred.

Centrifugal pump consists of two main components i.e. impeller and casing. The impeller consists of rotating vanes enclosed in a casing. As the impeller rotates the fluid from inner radius moves toward outward radius and the kinetic/ mechanical energy is converted into the pressure energy.

COMPONENTS OF A CENTRIFUGAL PUMP

The main components of centrifugal pumps which are described below:

1. Impeller: The pump impeller is a wheel type structure which transfers energy to the fluid by increasing the pressure and velocity. It is mounted on the shaft which is connected to the motor shaft. The design of the impeller depends upon the requirements for pressure, flow, and application.

   The impellers may be classified as.
   (a) Shrouded or closed impeller,
   (b) Semi-open impeller; and
   (c) Open impeller,

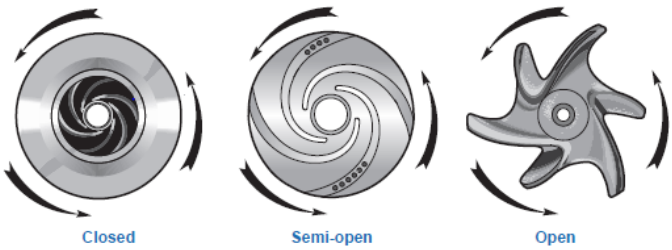

Fig. 1 Classification of pump impeller

In the closed or shrouded impeller blades are covered with the metal cover plates on both sides. These plates or shrouds are called as crown plate and base plate. The base plate of the closed impeller provides better guidance for the fluid and is more efficient. This type of impeller is mostly used to pump the pure liquid which is completely free from debris.

When the blades have only the base plate, then the impeller is called as 'semi-open type impeller'. This impeller is suitable for the fluids containing some debris.

An 'open impeller' is that whose blades have neither the crown plate nor the base plate. This type of impeller is used to pump fluids containing suspended solid matter for example paper pulp and water containing sand.

2. Casing: It is an airtight chamber which surrounds the impeller. It is similar to the casing of a reaction turbine. The different types of casings that are commonly adopted are described later.
3. Suction Pipe: It is the pipe of which one end or upper end is connected to the inlet of the pump or center of the pump called as the eye. The other end or lower of the pipe is dips into the tank containing a liquid from which liquid is to lift. A foot valve is connected at the end which is dipped into the liquid. Foot valve is non-return type of vale which opens in upward direction only to pass the liquid in the upward direct only
4. Delivery Pipe: It is a pipe which is connected at its lower end to the outlet of the pump and it delivers the liquid to the required height. Just near the outlet of the pump on the delivery pipe, a delivery valve is invariably provided. A delivery valve is a regulating valve which is of sluice type and is required to be provided in order to control the flow from the pump into delivery pipe.

As the kinetic energy is converted to pressure/ hydraulic energy, stress generates in the impeller, therefore, it is necessary to do an analysis of the impeller strength which depends on the material used for the impeller. Also, the strength of the pump reduces due to stress corrosion problems in impeller which can be minimized using an alternate material having the same strength.

II. LITERATURE SURVEY

1. V. Jose Ananth Vino, "Analysis of Impeller of Centrifugal Pump"

The study in this paper regards to linear structural analysis of centrifugal pump impeller. Here they have assembled 5 parts of an impeller of Centrifugal pump and primary goal is to apply preload of 100 N in the belt and to check that impeller is not getting deflected to a maximum of 0.0075 mm. They have applied the material to pump whose elastic limit is not exceeded then the elastic limit. The variation of von-misses stress, von-misses strain, and deformation factor for different materials can be taken into consideration. The CATIA is used for modeling the impeller and analysis is done in ANSYS. ANSYS is dedicated finite element package used for determining the variation of stresses, strains, and deformation across the profile of the impeller. An attempt has been made to investigate the effect of temperature, pressure and induced stresses on the impeller. By identifying the true design feature, the extended service life and long term stability are assured.A structural analysis has been carried out to investigate the stresses, strains, and displacements of the impeller for different materials.

2. A Syam Prasad, BVVV Lakshmipathi Rao, A Babji, Dr P Kumar Babu, "Static and Dynamic Analysis of a Centrifugal Pump Impeller".

This paper deals with 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 CAT-IA and ANSYS13.0 software. The CATIA is used for modeling the impeller and analysis has been done by using ANSYS. ANSYS is dedicated finite element package used for determining the variation of stresses, strains, and deformation across the profile of the impeller. HYPER MESH 9.0 is also used to generate good and optimum meshing of the impeller to obtain accurate results. A structural analysis has been carried out to investigate the stresses, strains, and displacements of the impeller and modal analysis have 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 (viz., Inconel alloy 740, Incoloy alloy 803, Warpaloy).

The best material for the design of impeller is Inconel 740. Specific modulus of Inconel 740 obtained in static analysis is 10 % higher than other material. The natural frequency in the modal analysis is 6% higher than other material. The deformation of Inconel 740 in static analysis is reducing by 12%.

3. Kotakar Sandeep Gulabrao1, Prof. D.S. Khedekar2 "OPTIMIZATION OF CENTRIFUGAL PUMP IMPELLEROUTLET VANE ANGLE BY USING MODAL ANALYSIS"

This paper deals with the performance evaluation of impeller by changing vane angle of impeller vanes. To optimize impeller vane angle, design and modeling of the impeller for various vane angles, the modelling of the impeller has done by using solid modeling software, CATIA V5 R17. It is proposed to design an impeller for various vane angles, analyze its strength and deformation using FEM software like ANSYSE V12. Modal analysis is performed on the impeller to find out first 5 natural frequencies.

4. Kesare Sunil Vikas, Prof. Swami M. C. "Analysis and optimization of Centrifugal Blower by using FEA"

This paper deals with the many problems regarding centrifugal blower such as corrosion. in the centrifugal blower made up of MS corrosion is a major problem. This paper gives a solution to this problem by optimization of centrifugal blower impeller by static and modal analysis using FEA for the material MS, SS.SS304L.The MS impeller is replaced by SS304L food grade material

which reduces corrosion problem. The maximum deformation occurred in blower impeller is 0.0406mm which is in safe limits and also induced stress is 6.68MPa which is much less than the allowable stress.

5. J. Acosta, R. D. Bowerman, "An Experimental Study of Centrifugal Pump Impellers",

Experimental investigations were made on four two-dimensional impellers and on a well-designed commercial three-dimensional Franc is impeller. The overall performance of each of these impellers was measured and internal energy loss and pressure distribution data were also obtained for several impellers. The exit angle of the two-dimensional impellers was fixed and the inlet angle was systematically varied. However, the hydraulic characteristics of these impellers were all found to differ, the source of the variation being in the various loss distributions and hence internal flow patterns in the impellers. The two-dimensional and three-dimensional impeller loss distributions were also different. The Francis impeller performance agreed better with potential theory than that of the two-dimensional impellers, and it is concluded that the different loss distribution of the two type's arc response.

6. Santosh Shuklaa, Apurba Kumar Royband Kaushik Kumar, "Material Selection for blades of Mixed Flow Pump Impeller Using ANSYS",

The material used in designing any object greatly affects the various design parameters like thickness, profile, machinability, strength etc. In this work, four different readily available materials were chosen. The basic emphasis has been put 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 the base).

7. Static Analysis of Centrifugal Blower Using Composite Material Mr M. Sampath Kumar, Mr Dsvsra Varaprasad, Mr Vijaykumar

This paper deals with the static and model analysis of centrifugal blowers using composite materials. Centrifugal blowers are used in marine applications which have high noise levels. The noise generated by a rotary part is mostly due to random loading force on the blades and periodic iteration of incoming air with the blades of the rotor. The Contemporary blades in marine applications are made up of Aluminium or Steel and generate noise that causes disturbance to the people working near the blower. This paper work aims at observing the choice of E-Glass as an alternative to metal for better vibration control. E-Glass, known for their superior damping characteristics are more promising in vibration reduction compared to metals. The stresses of E-Glass/Epoxy blower obtained in the static analysis are within the allowable stress limit. The natural frequency of E-glass blower is reducing by 16.6% to 27.7% because of high stiffness. The weight of the E-Glass blower is 15 kg which is less than the Aluminium blower with a weight of 19 kg. From the results of the harmonic analysis, the damping effect is more in E-Glass blower which controls the vibration levels. From the above results, we can conclude that E-Glass blower is preferable than Aluminium blower and based up on frequency values can be reduced.

8. Ronald S. Miller "CORROSION IN PUMPS" Central Materials Service Laboratory.

This paper deals with the corrosion problems occurred in the pumps and material selection. Many corrosion related problems encountered in pumps during their useful life. The different types of corrosion are general, corrosion-erosion, crevice corrosion, stress corrosion cracking, intergranular corrosion and cavitations.

SCOPE OF THE WORK

The proposed work is to carry out static analysis using different materials, its fabrication, testing, and comparison of results which will results in weight and material optimization using FEA

CONCLUSION

The pump impeller which is made up of existing material has more weight than a composite material. Also, the strength of the existing material of centrifugal pump impeller is less than the composite materials. In order to reduce the weight of the impeller and to improve the strength of the pump impeller, static analysis can be done and use different material such as composite materials. From the FEA results, best material will be selected and pump impeller will be fabricated and tested for the selected material

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