Modeling and Analysis, Life Evaluation of Impeller of Submersible Pump to Improve Efficiency

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Abstract— A pump is a device that moves fluids (liquids or gases) or sometimes slurries, by mechanical action. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power. Present work on impeller of a submersible pump and design optimization by impeller of pump is carry out using analytical approach and FEM approach. Base model of a impeller is Modeling using Unigraphics and analysis (FEM ANYS) using work bench 14.5. The main Aim of work is structural analysis under static, dynamic load condition, vibration analysis, model analysis, high cycle fatigue analysis with life evaluation impeller of a submersible pump. FEM approach is evaluated by analytical method carry out in work. The expected outcome of project reduce cost cutting and weight to the strength ratio with custom made methodology for the structural integrating of impeller of submersible pump.
Key words: Submersible Pump, Impeller and Vanes

I. Introduction

A pump is a device that moves fluids (liquids or gases), or sometimes slurries, by mechanical action. Pump is device it may be mechanical energy into hydraulic energy is a pump. Pumps can be classified into three major groups according to the method they use to move the fluid: direct lift, displacement, and gravity pumps .Pumps operate by some mechanism (typically reciprocating or rotary), and consume energy to perform mechanical work by moving the water. Pumps operate via many energy sources, including manual operation, electricity, engines, or wind power. Other word pump may be hydraulic energy into mechanical energy or mechanical energy into hydraulic energy. It assists to increase the pressure energy or kinetic energy. or both of the fluid by converting the mechanical energy. The basic difference between a turbine and pump, from hydrodynamic point of view, is that in the former flow takes place from the high pressure side to the low pressure side, whereas in pump flow takes place from the low pressure towards the higher pressure. Thus in a turbine there is accelerated flow, while in a pump, the flow is decelerated. The Submersible Pump main application is agriculture, wind power, industries and water tank etc.

Impeller trimming is a common practice performed by pump manufacturers and users when it is necessary to adjust the centrifugal pump head and flow for the actual requirements. The impeller trimming is not strictly similar to the initial pump because only a few parameters are modified, while all the others remain unchanged. [1].

The flow pattern and power number in a vessel depend on the impeller blade angle, number of blades, blade width, blade twist, blade thickness, pumping direction and interaction of flow with the vessel wall. The effect of impeller design on the flow pattern and mixing time for a set of axial flow impellers have been studied by varying various parameters for impeller geometry. A very good agreement has been observed between experimental and the predicted mixing time over a wide range of impellers [2]

II. Objective

- Using analytical equations, geometric model is developed
- Static structural analysis of impeller of submersible pump
- Vibration analysis of impeller of submersible pump
- Life evaluation of impeller of submersible pump

III. Methodology

- Using analytical equation base line design model is developed
- Using Unigrapics and design submersible pumps modeled
- Static structural linear and bilinear analysis carryout for the certain boundary condition
- Vibration analysis is carryout the impeller submersible pump find model and natural frequency
- Life evaluation of impeller of submersible pump carry out is valuated with analytical method and FEA approach.

A. *The Submersible Impeller Pump*

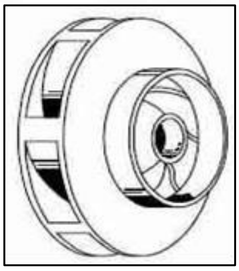

Fig. 1: Submersible impeller

Sl no	parameters	Dimensions
1	Inlet diameter (D1)	137.15 mm
2	Outlet diameter (D2)	297.67mm
3	Eye inlet diameter (d1)	80mm
4	Eye outlet diameter (d1)	100mm
5	Inlet angle (ϕ1)	23˚
6	Outlet angle (ϕ2)	20˚
7	No of vanes	8

Table 1: Impeller data

1) *Calculate Pump Specific Speed*

$$= \frac{RPM \times (GPM)^{.5}}{H^{.75}} \quad (1)$$

2) *Calculate Impeller Diameter*

Head constant =1.075

$$= \frac{1840 \times 1.075 \times (450)^{.5}}{3600} \qquad (2)$$

3) *Determine Eye Diameter*

$$\frac{D_1}{D_2} = 0.47 \qquad (3)$$

4) *Estimate Impeller Eye Area.*

Eye area=Area at impeller eye-shaft area =23.76-3.1=20.66 sq in.

5) *Estimate NPSHR*

$$C_{m1} = \frac{2100 \times .321}{20.66} = 32.63 \qquad (4)$$

6) *Volute area (A)*

$$A = \frac{0.04 \times GPM}{K_3 \times (H)^{.5}}$$

B. Geometric Model

Fig. 2: 3D model of impeller

C. Mesh of Impeller Model

Fig. 3: Meshed of impeller pump

The above figure shows meshing on impeller of submersible pump. Meshing is used in hexagonal mesh metric statistic nodes is 57644 and elements 18015. Using Ansys software work bench (14.5 work benches).

Statistics	
Nodes	57644
Elements	18015
Mesh Metric	None

Table 2: Meshed of impeller

IV. Finite Element Approach

Finite element Method based upon discritization of component into Finite number of blocks (elements),Finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It uses subdivision of a whole problem domain into simpler parts, called finite elements, and variational methods from the calculus of variations to solve the problem by minimizing an associated error function.

Analogous to the idea that connecting many tiny straight lines can approximate a larger circle, FEM encompasses methods for connecting many simple element equations over many small subdomains, named finite elements, to approximate a more complex equation over a larger domain.

A. Linear Static Analysis

It is the simplest and most commonly used type of analysis

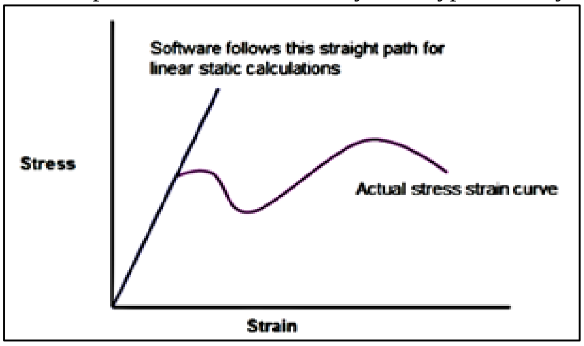

Fig. 4: Linear Static Approach

Linear means straight line. σ = €E is the equation of straight line (y = mx+c) passing through origin. ‘E’, Young’s modulus is the slope of curve and is a constant. In real life, after passing yield point material follows nonlinear curve but software follows same straight line. Component break into two separate pieces after crossing ultimate stress but software based analysis never show failure in this fashion.

It shows single unbroken part only with red color zone at the location of failure. Analyst has to conclude whether the component is safe or fail by comparing maximum stress value with the yield or ultimate stress.

B. Bilinear Kinematic Hardening

The yield criterion for many materials depends on the history of loading and evolution of plastic strain. The change in the yield criterion due to loading is called hardening and is defined by the hardening rule. Hardening behaviour results in an increase in yield stress upon further loading from a state on the yield surface so that for a plastically deforming material, an increase in stress is accompanied by an increase in plastic strain.

The linear analysis is x and y direction perpendicular (straight) to line .also bilinear analysis as x and y is average of the stress is bilinear analysis.

C. Boundary Condition

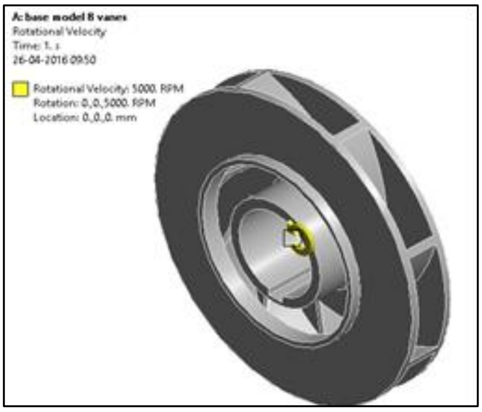

Fig. 4: Rotational speed 5000 rpm

The rotational velocity of submersible impeller pump is 5000 rpm. It is x in zero (constraint) rotation in z and y direction.

D. *Gun Metal Physical Properties*

Properties	Values	
Density	8.72*10^3	kg/m^3
Young's modulus	103^3	mpa
Tensile strength	310	mpa
Yield strength	152	mpa
Fatigue strength	90	mpa

Table 3: Gun Metal Physical Properties

V. RESULT AND OBSERVATION

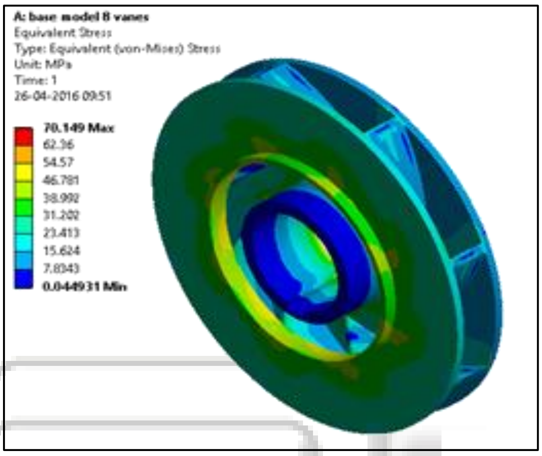

Fig. 5: Von-mises stress of impeller

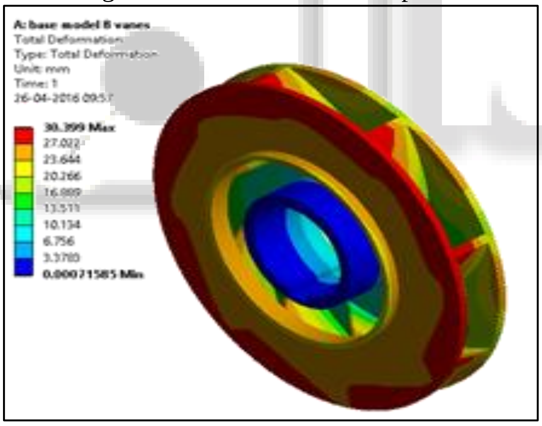

Fig. 6: Total deformation of impeller pump

VI. RESULT AND VALIDATION

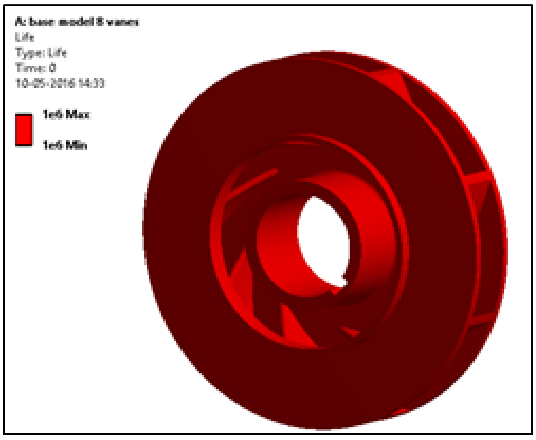

Fig. 6: Life evaluation of impeller

A. *Goodman Diagram*

Mean Stress can be calculated from,

$$\sigma_{mean} = \frac{\sigma_{von}}{2}$$

Where

σvon = Equivalent von-Misses Stress

$$\sigma_{mean} = \frac{\sigma_1 + \sigma_2}{2}$$

$$\sigma_{mean} = 49.76 \text{ MPa}$$

$$\sigma_a = \frac{\sigma_1 - \sigma_2}{2}.$$

$$= 29.96 \text{ MPa}$$

Where

σ_1= Maximum Principal Stress

σ_2= Minimum Principal Stress

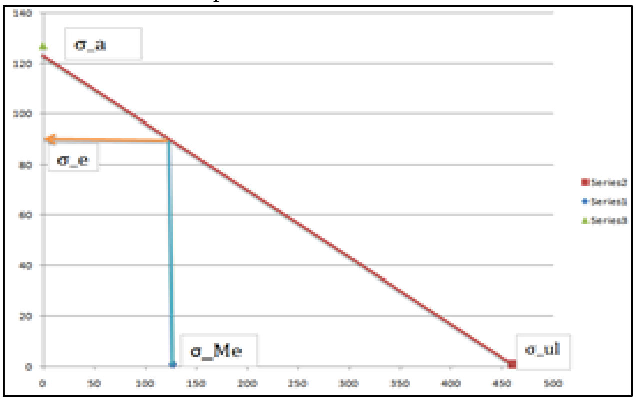

Fig. 7: Goodman Diagram

Number of cycles:

$$N_f = \left\{ \frac{[\sigma_{ult} - \sigma_{ult}(\frac{1}{fos} - \frac{\sigma_a}{\sigma_e})]}{\sigma_a} \right\}^{\frac{1}{0.08}}$$

Where,

Nf=Fatigue life

σutl=Ultimate stress

Fos=Factor of Safety

σe=Endurance limit

b = Fatigue strength exponent

σa=Alternating stress

$$N_f = 1.554 \times 10^6$$

The resulting life of failure obtained by analytical method is greater than Cycles hence it is high cycle fatigue.

VII. CONCLUSION

The modeling of the impeller is one critical parameter that should be the prime concern when considering the efficiency of the pump. Submersible pumps are used in clear water, sewage water and also in seas. Considering all these factors we need to model an impeller in a more practical way to suit to all these conditions. The impeller model is developed Unighaphoc software using analytical equation. The impeller is tested in ANSYS (work bench 14.5). The linear analysis is carryout equivalent and maximum is below than allowable stress it is concludes submersible impeller design is safe. Vibration analysis carryout natural frequency and model shape, to identify 6 model shape. The impeller design is comparison Gun metal and CFRP laminated material the composite material efficiency is improved. Also life validation of impeller is comparison FEM and analytical is 1.56*10^6.

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