International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
May 2018

Design and Simulation of Centrifugal Pump Using Composite Materials

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Abstract - *Centrifugal pumps are used to transport liquids/fluids by the conversion of the rotational kinetic energy to the hydro dynamics energy of the liquid flow. The rotational energy typically comes from an engine or electric motor or turbine. In the typical simple case, the fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits. The Contemporary impellers blades in Centrifugal pumps are used in industrial applications are made up of Aluminium or Steel. It is proposed to design a centrifugal pump using Computer Aided Design (CAD) software with various metal alloys and NonMetallic composite materials, analyze its strength and deformation using simulation software. In order to evaluate the effectiveness of Metal Alloys and NonMetallic composites. The present work aim is to change the material and performing the different analysis like Static, Dynamic, Analysis to find the best material to decrease the weight and increase its efficiency by using the software SOLID WORKS (2014 Premium Version). This also involves the method of manufacturing process to realize the Blower using Non-Metallic composite material.*

Key Words: Centrifugal pump, Computer Aided Design (CAD), Metal Alloys, Non-Metallic Composite Materials, SOLIDWORKS, Simulation Analysis.

1. INTRODUCTION

The application of fluid machinery has spread its wings in all aspects of human life. The usage of pumps extends to domestic services, commercial and agricultural services, municipal water/wastewater services, and industrial services such as food processing. Pumps are also used in chemical, petrochemical, pharmaceutical and mechanical industries. This chapter deals with the classification of the pumps, and the selection of the pumps based on their applications and their operating principles.

Classification

In general, pumps are classified into Positive Displacement Pumps and Centrifugal Pumps based on their working principles

Positive Displacement Pumps

A positive displacement pump operates by alternately filling a cavity and then displacing a given volume of liquid. The positive displacement pump delivers a constant volume of liquid against varying discharge pressure or head.

Single Rotor Pumps

Vane - The vane/vanes may be blades, buckets, rollers or slippers which cooperate with a dam to draw fluid into and out of the pump chamber.

Piston - Fluid is drawn in and out of the pump chamber by a piston/pistons reciprocating within a cylinder /cylinders and operating port valves.

Flexible Member - Pumping and sealing depend on the elasticity of a flexible member/members which may be a tube, vane or a liner.

Single Screw - Fluid is carried between rotor screw threads as they mesh with internal threads on the stator.

Progressing Cavity - Fluid is carried between a rotor and a flexible stator

Multiple Rotor Pumps

Gear - Fluid is carried between gear teeth and is expelled by the meshing of the gears which provide continuous sealing between the pump inlet and outlet.

Lobe - Fluid is carried between rotor lobes which provide continuous sealing between the pump inlet and outlet.

Circumferential Piston - Fluid is carried in spaces between piston surfaces not requiring contacts between rotor surfaces.

Multiple Screw - Fluid is carried between rotor screw threads as they mesh.

Centrifugal Pumps

Centrifugal pumps can be classified based on the manner in which fluid flows through the pump. The manner in which fluid flows through the pump is determined by the design of the pump casing and the impeller. The three types of flow through a centrifugal pump are radial flow, axial flow, and mixed flow

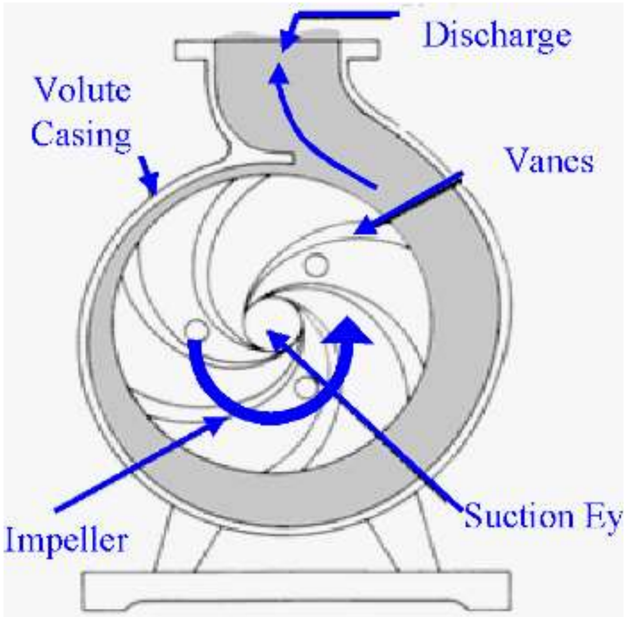

Fig 1: Centrifugal Pump

Radial Flow

In a radial flow pump, the liquid enters at the center of the impeller and it is directed out along the impeller blades in the direction at right angles to the shaft of the pump in which the pressure is developed wholly by centrifugal force. When the head requirement is more, radial flow pumps are preferred.

Axial Flow

In an axial flow pump, the impeller pushes the liquid in the direction parallel to the pump shaft in which the pressure is developed by the propelling or lifting action of the vanes of the impeller on the liquid. Axial flow pumps are sometimes called propeller pumps because they operate essentially as the propeller of a boat does. When more flow rate is required, axial flow type pumps are preferred.

2. LITERATURE REVIEW

Lazarkiewicz Stepen (1965) has explained the procedure to calculate the dimensions of the impeller and has also discussed various methods for determining the shape of the impeller blades, which are referred to by the designers. The effects of the individual parameters that influence the performance of the impeller were studied by the authors Lobanoff (1985) and Stepanoff (1948)

Van Esch (1997) in his thesis has shown that the flow in hydraulic pumps of the radial and mixed flow type, operating at conditions not too far from design point, can be considered as an incompressible potential flow, where the influence of viscosity is restricted to thin boundary layers, wakes and mixing areas. He also concluded that the design of hydraulic turbo machines has reached the stage where improvements can be achieved only through a detailed understanding of the internal flow. The internal flow structure in a centrifugal pump impeller is complex, involving streamline curvature, system rotation, separation and turbulence effects.

Pedersen et al (2003) has done an exhaustive study to visualize the flow in the centrifugal pump impeller and his research outcome provides a detailed instantaneous data of the impeller flow field in the rotating passage of a centrifugal pump impeller.

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Frost and Nilsen proposed a simple model for estimating the contribution of the volute to the shut-off head of a centrifugal pump or fan. The model is based on an assumed linear distribution of tangential velocity in the plane of the cutwater, which satisfies approximately the continuity condition of zero net flow into the outlet duct. The contribution of the impeller is assumed to be that given by a solid body rotation at the angular velocity of the pump from the bore of the inlet duct to the impeller tip. The simple radial equilibrium equation is then used to calculate the static head rise in both the impeller and volute. The resultant prediction of shut-off head has been compared to test data on various pump series made available by courtesy of two European manufacturers. In all of the series, the impeller diameter has been varied between 100 and 90 to 80 percent of its design value and has been tested in the designed volute. Since a review of the available literature did not show any previous work of a fully consistent nature on this topic, the proposed model as described in detail is offered as a fairly accurate prediction technique for design purposes.

OBJECTIVES OF THE PROPOSED WORK

The aim of this thesis is to propose a computational tool for hydrodynamic design of centrifugal pump impeller.

The objective of this work is to

- Optimize the impeller design,
- Static and dynamic analysis on centrifugal pump impeller balde is carried out to evaluate performance at different load conditions
- Validate the design by experiment, with different types composite materials

Simulate the design to validate and get the insight of the approach.

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3. METHODOLOGY

Modelling

MATHEMATICAL CALCULATION FOR THE CASE STUDY

1. Calculate pump specific speed

$$N_s = \frac{1450 * \sqrt{1000/3600}}{40^{3/4}} = 48.07460 RPM$$

2. Calculate the input and output power

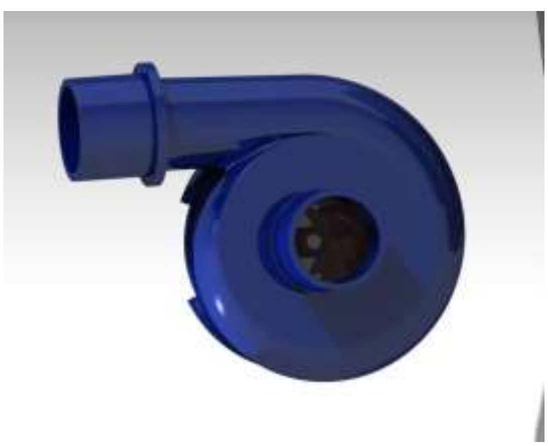
$P_o = 1000 * 9.806 * 40 * 0.2778 = 109 kW$

$P_s = 109/0.86 = 126.7 kW$ say 127kW

3- Calculate input torque to pump

T=127000*60/2*3.14*1450 =837 N.m

2d drawing of centrifugal pimp



Centrifugal pump Solidworks CAD Model

MATERIALS

Aluminium alloy 6061

Density	2.7 g/cm³
Tensile strength	124–290 MPa
Melting Temperature	585 °C
Thermal conductivity	151–202 W/(m·K)

E-Glass / Epoxy

Density	1.90 g/cm³
Tensile strength	490 MPa
Melting Temperature	177 °C
Thermal conductivity	0.15-0.25 W/(m·K)

Testing the performance of a pump using conventional and experimental method is time consuming and costly. It takes a long time to approve a design, if we make multiple proto type and then test each of them. Instead, simulation is used to find the performance of an impeller and casing using Computational Fluid Dynamics software. Once the flow pattern and performance are satisfactory, then we can go for one or two types to validate the simulation results.

Initially it deals with the modelling approach of the pump. The simulation is carried out for

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different speeds with varying operating conditions. Then the simulation results are compared with the experimental results for the same operating conditions to confirm the suitability of this approach.

4. RESULTS AND DISCUSSION

Simulation Results

The results of the flow analysis can be viewed using plots or through surface integrals as shown in Figures 4.1 to 4.6. Surface integrals provides the required value at the given boundary condition. Plots give a graphical view of the results and they are of two types, namely, contour and vector plots. Contour plots show the constant magnitude for a selected variable (isotherms, isobars etc.). Vector plot is used to give the direction in which the flow occurs.

From Figures, it is inferred that there is a uniform distribution of pressure and velocity around the impeller in the volute casing for the maximum efficiency condition over the full open condition. The difference in the flow pattern is the cause of the radial and axial imbalances.rom, it is inferred that a highly non-uniform distribution of pressure is observed around the impeller in the volute casing, but it is less when compared to that of 2300 rpm. As a result, the impeller is subjected to some static radial thrust.

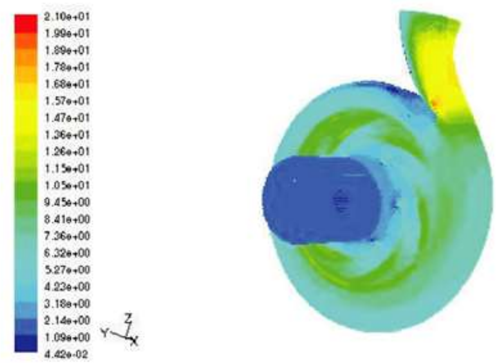

Figure 3: Static pressure and velocity distribution for 2300 rpm for Aluminium alloy 6061

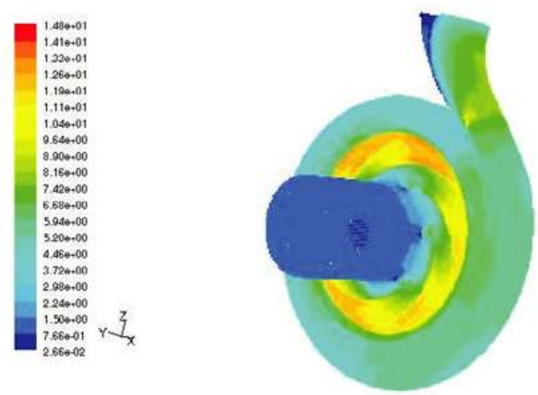

Figure 4: Static pressure and velocity distribution for 2300 rpm for E-Glass / Epoxy

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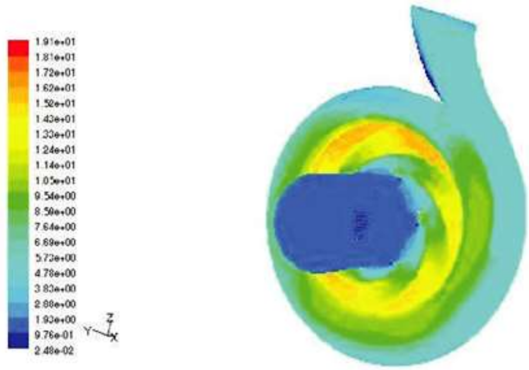

Figure 5: Static pressure and velocity distribution for 2880 rpm for E-Glass / Epoxy

5. CONCLUSION

- Modelling and simulation of centrifugal pump impeller has done using Solid Works software.
- After observing the CFD analysis values we can conclude that e-epoxy has the better performance is given compared to the Aluminium alloy E-glass/Epoxy material is non metallic component so, the chattering noise will be low compared to other materials during the functioning process.
- For manufacturing the centrifugal pump impeller we can proceed with Epoxy/E-glass material because it has high performance and ot will give good efficient capa and reasonable manufacturing cost.

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