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"DESIGN & OPTIMIZATION OF CENTRIFUGAL PUMP IMPELLER FOR CAVITATION ANALYSIS": A REVIEW

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Abstract: ***Centrifugal pumps are widely used for irrigation, 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 parameters and working conditions that yield optimal output 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. With the aid of the CFD approach, the complex internal flows in water pump impellers, can be well predicted, to speed up the pump design procedure. This paper exposes the various research work carried out in this direction especially in the content of parametric study and optimization of centrifugal pump impeller using CFD tool and DoE technique. Literature surveys indicate that very restricted work has been done in this area.***

Keywords:- Centrifugal pumps; CFD impeller, CFX, DOE.

I. INTRODUCTION

1. CENTRIFUGAL PUMP

A centrifugal pump consists of set of rotating vanes called as impellers which are enclosed in housing called as casing. Due to rotation of impeller the fluid from inner radius moves towards the outer radius during this, suction is created at the eye of the impeller. Therefore, continuous lifting of fluid from sump to the pump is carried out and kinetic energy is converted into pressure energy and head is developed from the fluid coming out from delivery pipe.

The increased popularity of centrifugal pumps is due to largely to the comparatively recent development of high speed electric motors, steam turbines and internal combustion engines. The centrifugal pump is a relatively high speed machine and the development of high speed drivers has made possible the development of compact, efficient pumps. Research and development has resulted in both improved performance and new materials of construction that have greatly expanded its field of applicability. It is not uncommon today to find efficiencies of 93%+ for large pumps and better than 50% for small fractional horsepower units.

The mechanical energy is provided with the help of electrically operated motor which is coupled with the pumps. The fluid or water is operated by motor and is forced by the pump to desired work which results into hydraulic energy [1].

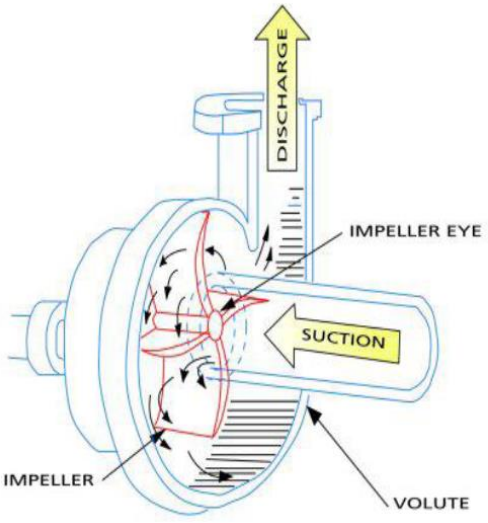

Fig.1. working principle of centrifugal pump

As we are aware of centrifugal pump that these are hydrodynamic machines in which rotating impeller continuously transmits mechanical work from driving machine to fluid. The kinetic energy is converted into potential pressure energy. So it is necessary that to be

concentrated on the design and development of impellers as well as volute casing used in pumps.

The centrifugal pump is a member of family known as rotary machine consists of two basic parts 1.The rotary element or impeller.2.The stationary element or casing (volute). A centrifugal pump delivers useful energy to the fluid on pumpage largely through velocity changes that occur as this fluid flows through the impeller and the associated fixed passage ways of the pump. It is converting of mechanical energy to hydraulic energy of the handling fluid to get it to a required place or height by the centrifugal force of the impeller blade. The input power of centrifugal pump is the mechanical energy and such as electrical motor of the drive shaft driven by the prime mover or small engine. The output energy is hydraulic energy of the fluid being raised or carried. In a centrifugal pump, the liquid is forced by atmospheric or other pressure into a set of rotating vanes. A centrifugal pump consists of a set of rotation vanes enclosed within a housing or casing that is used to impart energy to a fluid through centrifugal force. A pump transfer mechanical energy from some external source to the liquid flowing through it and losses occur in any energy conversion process. The energy transferred is predicted by the Euler Equation. The energy transfer quantities are losses between fluid power and mechanical power of the impeller or runner. Thus, centrifugal pump may be taken losses of energy.

1.2. COMPUTATIONAL FLUID DYNAMICS (CFD)

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.

CFD applies numerical methods (called discretization) to develop approximations of the governing equations of fluid mechanics in the fluid region of interest.

Computational Fluid Dynamics usually abbreviated as CFD, is a branch of fluid mechanics uses numerical methods and algorithms to solve and analyze problems that involve fluid flow. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. Computational techniques replace the governing partial differential equations with algebraic equations that are much easier to solve using computer.

1.3. Design of experiments (DOE)

Design of experiments (DOE) or experimental design is the design of any information-gathering exercises where variation is present, whether under the full control of the experimenter or not. However, in statistics, these terms are usually used for controlled experiments. Formal planned experimentation is often used in evaluating physical objects, chemical formulations, structures, components, and materials. Other types of study, and their design, are discussed in the articles on computer experiments, opinion polls and statistical surveys (which are types of observational study), natural experiments and quasi-experiments (for example, quasi-experimental design). See Experiment for the distinction between these types of experiments or studies. In the design of experiments, the experimenter is often interested in the effect of some process or intervention (the "treatment") on some objects (the "experimental units"), which may be people, parts of people, groups of people, plants, animals, etc. DOE is thus a discipline that has very broad application across all the natural and social sciences and engineering.

II. LITERATURE

Mitesh Daxini et. al. [2017] [1] the application of superconducting magnets at liquid helium temperature needs circulation of supercritical helium (SHe) to remove heat loads of magnet system and maintain the magnet at low temperature. Design of this pump involves, vacuum, low temperature and high density SHe. All these involvements make the design of pump different than that for conventional pumps used at room temperature.

Anirudha S. Bhosale et. al. [2017] [2] 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.

S. Mayakannan et. al. [2016] [3] The objective of this paper is to be design the impeller for a centrifugal caustic slurry pump to increase its power and efficiency, and showing the advantage of designing parameters (six blade turbine ,design changes from impeller) comparing with the old material of a TURBINE. An investigation in to usage of new materials is required. In the present work impeller was designed with two different materials. The investigation can be done by using SOLIDWORKS and ANSYS WORK BENCH software. The SOLIDWORKS is used for modeling the impeller and analysis is done.

Shantanu Roy et. al. [2016] [4] Some of researchers studies on the effect of blade trailing edge angle on the performance of a centrifugal pump having long been investigated with experimentally and theoretically. Then the study can be applied to establish the correlation between the pump characteristics and efficiency numerically.

Nilesh Nemgonda Patil [2015] [5] Nowadays, the centrifugal pumps became very popular because of recent development of high speed electric motors, steam turbines etc. Centrifugal pumps can be single-stage or may be multistage pumps. It depends upon the number of impellers used in the pump. Single stage pump consists of only one impeller while in multistage pumps the impellers are mounted in the series in pumps. These Centrifugal pumps can be analyzed by software code like Computational Fluid Dynamics (CFD).This CFD tool or code helps to optimize the pump performance.

Chetan Kallappa Tambake et. al. [2015] [6] This paper deals with design of monoblock centrifugal pump. The different parameters of pump impeller are impeller inlet and outlet diameter, blade angles and blade numbers but one of the most critical parameter is Impeller blade angles.

Ajith M S et. al. [2015] [7] In this study, Computational Fluid Dynamics (CFD) approach was suggested to investigate the flow in the centrifugal pump impeller using the Ansys Fluent. Impeller is designed for the head (H) 70 m; discharge (Q) 80 L/sec; and speed (N) 1400 rpm. Impeller vane profile was generated by circular arc method and point by point method and CFD analysis was performed for the impeller vane profile.

MOHAMED SALEM et. al. [2015] [8] Various parameters affect the pump performance. The impeller outlet diameter, the blade angle, the blade number and casing are the most critical. In this study, experimental and numerical investigations are carried out for two impellers different in diameter with the same casing.

Sung Kim et. al. [2015] [9] describe a numerical study about the performance improvement of a mixed-flow pump by optimizing the design of the impeller and diffuser using a commercial computational fluid dynamics (CFD) code and design-of-experiments (DOE). In comparing the results of the numerical analysis and the experiment with the optimally designed mixed flow pump, the Ht and ηt designed pump was proved using a pump performance test.

Huang Ren Fang et. al. [2015] [10] A modified NSGA-II algorithm coupled with a dynamic crowding distance (DCD) method is proposed for the multi-objective optimization of a mixed flow pump impeller. After optimization, velocity gradients on the suction surface are smoother and flow separations are eliminated at the blade inlet part.

Vijaypratap R Singh et. al. [2014] [11] Centrifugal pumps are widely used for irrigation, 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 parameters and working conditions that yield optimal output and maximum efficiency with lowest power consumption.

III. RESEARCH MOTIVATION

The maximum working efficiency of all the pumps is less, and a lot of energy is wasted as a result of this. Large quantum of energy can be saved by way of increasing the efficiency of these pumps. With the

advances in computer technology and more in-depth understanding of unsteady flow phenomenon, it is now feasible to carry out numerical calculations to investigate the flow phenomenon within pumps in an economic way and a reasonable time.

Conventionally, many aspects of the design of impeller are based on empirical formulae derived from experience and thumb rules. Therefore, studying the parameters scientifically will serve the dual purpose of increasing the efficiency and also establishing a scientific method of designing the impeller.

IV. SCOPE OF THE WORK

Flow through the pump have adverse pressure gradient hence pump efficiency will be lower than the turbine. so by studying the flow pattern inside the pump and varying the critical parameters efficiency of the pump can be improved.

V. CONCLUSION

The Hydraulic design of the impeller can be optimized by means of trial and error methods or by means changing the input design of impeller. From the CFD results mechanical behavior of impeller parts with various parameters like velocity contours can be predicted and the optimum design will be manufactured and is to be used.

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