Ansys-CFX analysis to design the diffuser of a multistage pump

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Abstract -*Multistage pumps, consisting of a series of impellers connected on a single shaft, play a significant role in global power usage. These pumps are commonly employed for transferring fluids with high head requirements and find applications in various industries, hydro storage energy plants, mine dewatering, and boiler feeding. To ensure economic viability and energy conservation, it is crucial to assess the performance and head loss of multistage pumps. One critical component of these pumps is the diffuser, which increases the fluid pressure as it exits the impeller at high velocity. This study focuses on evaluating the impact of the number of vanes in the diffuser on pump performance and head loss under different operating conditions. Computational fluid dynamics (CFD) is employed for the analysis, utilizing 3D models created using Creo Parametric software for different fluid domains of a two-stage pump. The components are individually meshed using ICEM-CFD, and simulation setup is performed using CFX-Pre software. The Ansys CFX solver is used to solve the flow equations, and CFD-Post is employed to acquire pump fluid flow details, calculate various heads, head losses, and other parameters.*

Key Words: CFX-Pre software, Computational fluid dynamic, Diffuser, Multistage pump, Impellers.

1.INTRODUCTION

In the current era of rapid industrialization and a fast-paced world, the efficient supply of fluid with high head requirements is essential for numerous applications. Multistage pumps have emerged as a popular choice for such tasks, given their ability to handle high-head fluid transfer. Conducting performance analysis and studying head losses in these pumps not only brings economic benefits but also contributes to energy conservation, considering the significant share (approximately 22 percent) [2] of global energy consumption attributed to multistage pumps. Therefore, this study aims to assess the behavior of head losses in different components of a multistage pump, particularly focusing on the impact of the number of vanes in the diffuser, across various operating conditions. The investigation involves a numerical simulation analysis of a two-stage centrifugal pump, followed by a comprehensive study of head losses and performance parameters.

A pump is a mechanical device used to transport fluids from one place to another. It works by creating a pressure difference that propels the fluid through a system. Pumps are widely used in various industries, including water supply, oil and gas, chemical processing, and wastewater treatment.

There are different types of pumps, such as centrifugal pumps, positive displacement pumps, and axial flow pumps. Centrifugal pumps are the most common and work by using an impeller to generate centrifugal force, pushing the fluid outward. Positive displacement pumps, on the other hand, use a mechanism to trap and transport fluid in discrete volumes. Axial flow pumps operate by propelling fluid parallel to the pump shaft.

Pumps play a critical role in many applications, including water distribution, irrigation, heating and cooling systems, fuel transportation, and industrial processes. They come in various sizes and capacities to meet specific requirements. Efficient pump design, maintenance, and operation are essential to ensure optimal performance and energy efficiency.

Pumps can be classified into different categories based on various factors such as their principle of operation, fluid handling capabilities, and design characteristics. Here are some common classifications of pumps:

1. Based on Principle of Operation:

Centrifugal Pumps: These pumps use centrifugal force generated by a rotating impeller to move fluid. They are widely used for low to medium viscosity fluids and high flow rates.

Positive Displacement Pumps: These pumps trap and transport fluid in discrete volumes, creating a pulsating flow. They are suitable for high viscosity fluids and applications requiring precise flow control.

Axial Flow Pumps: These pumps move fluid parallel to the pump shaft, using propeller-like blades. They are suitable for high flow rates and low to medium head applications.

Based on Fluid Handling:

Water Pumps: These pumps are specifically designed for handling water, including clean water pumps, wastewater pumps, submersible pumps, and booster pumps.

Chemical Pumps: These pumps are designed to handle corrosive or abrasive fluids, including acids, solvents, and chemicals. They are typically made of materials resistant to chemical attack.

Slurry Pumps: These pumps are used for pumping slurries, which are mixtures of solid particles and liquid. They are designed to handle high concentrations of solids.

2. Based on Design Characteristics:

Single-stage vs. Multistage Pumps: Single-stage pumps have only one impeller, while multistage pumps have multiple impellers arranged in series. Multistage pumps are capable of generating higher pressures.

Vertical vs. Horizontal Pumps: Vertical pumps have a vertically oriented shaft, while horizontal pumps have a horizontally oriented shaft. The choice depends on space availability and installation requirements.

Each type of pump has its own advantages and limitations, and the selection of the appropriate pump depends on the specific application requirements, fluid properties, flow rate, and pressure considerations.

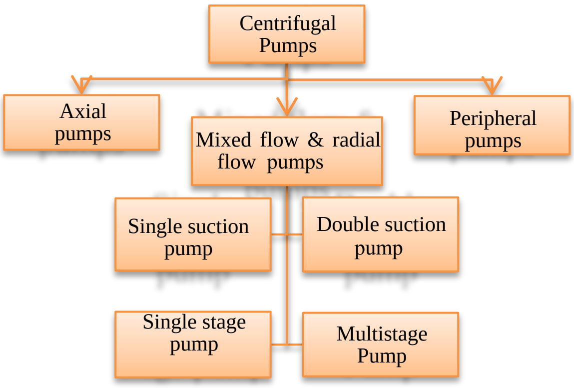


Figure 1.4: Classification of centrifugal.

2. Objective of the Current Work:

- Evaluate and optimize the design of a multistage pump.
- Perform numerical simulations of a two-stage multistage pump with varying numbers of diffuser vanes at different discharge conditions.
- Analyze the impact of the number of diffuser vanes on the pump's performance and head loss.

3. Analysis

The primary focus of this work is to assess the design and performance of the multistage pump by investigating the effects of varying diffuser vanes and discharges. Through numerical simulations and analysis, valuable insights will be gained regarding the head loss characteristics and overall performance of the pump.

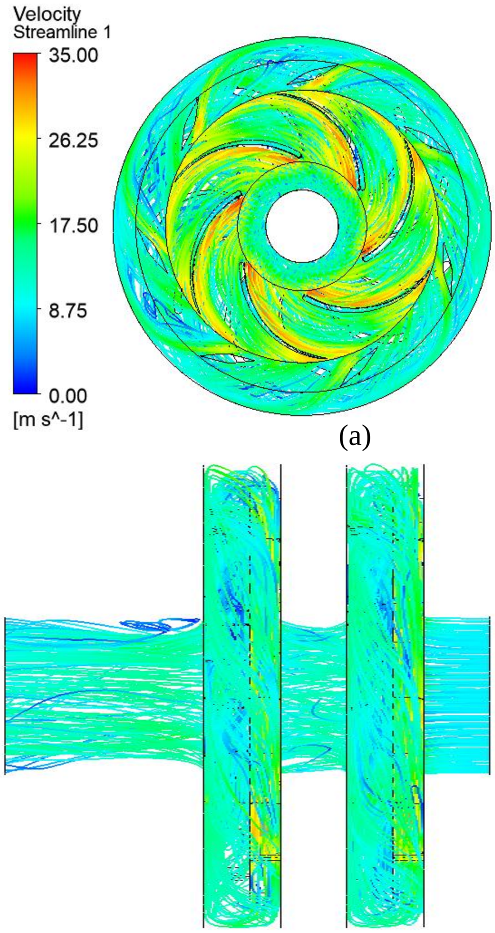
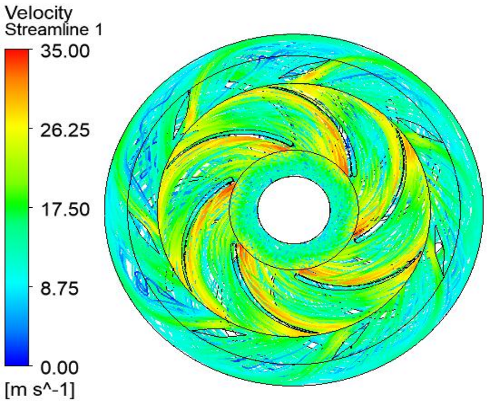


Figure 3.1: Stream lines for 7 diffuser vanes (a) Radial, (b) Axial.

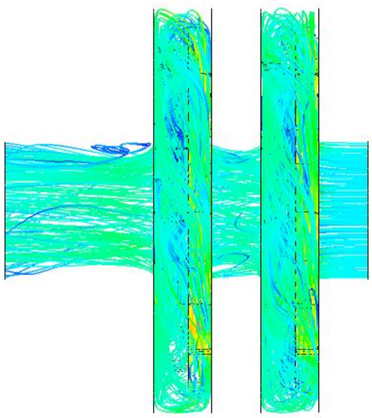
Streamline Patterns Analysis for a 2-Stage Pump:

The streamline patterns were examined at the optimal efficiency point for each configuration of diffuser vanes. These patterns provide insights into the flow behavior within the pump. It is observed that the pump's inlet generates suction, resulting in fluid being drawn in at a high velocity. Consequently, the fluid particles exhibit higher velocities at the pump's intake compared to the outlet. Additionally, the influence of impeller rotation on expelling fluid from the domain leads to increased velocity at the impeller exit.

3.2 Streamline Patterns for 7 Diffuser Vanes: Figure 3.2 (a) and (b) depict the velocity streamlines in the radial and axial planes, respectively, for the configuration with seven diffuser vanes. The kinetic energy from the rotating impeller contributes to higher fluid velocities within the impeller. In the diffuser section, the velocity decreases by 4.42 m/s, resulting in a smooth flow in the pump flow channels.



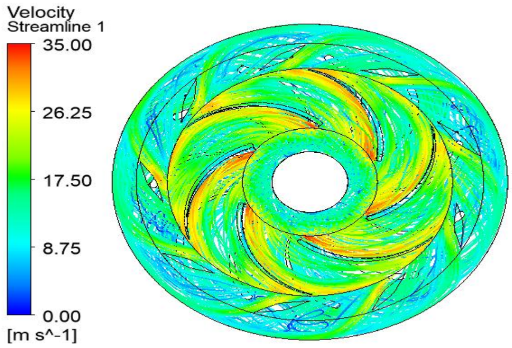
(a)



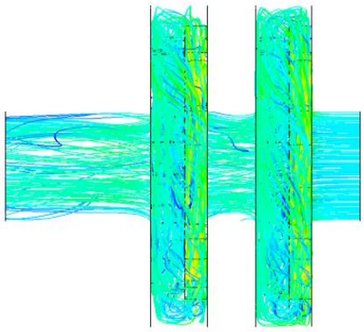
(b)

3.2 Streamline Patterns for 8 Diffuser Vanes: Figure 3.2 (a) and (b) illustrate the velocity streamlines for the configuration with eight diffuser vanes in the radial and axial planes, respectively. Similar to the previous configuration, the impeller's kinetic energy elevates the fluid velocity within the impeller. The velocity reduction in the diffuser is measured at 4.39 m/s, achieving a smooth flow in the pump flow channels.

5.7.3 Streamline Patterns for 9 Diffuser Vanes: Figure 5.23 (a) and (b) display the velocity streamlines in the radial and axial planes, respectively, for the configuration with nine diffuser vanes. The impeller's kinetic energy contributes to higher fluid velocities within the impeller, while the diffuser reduces the velocity by 4.52 m/s, resulting in a smooth flow in the pump flow channels.



(a)



(b)

5.7.4 Streamline Patterns for 10 Diffuser Vanes: Figure 5.24 (a) and (b) showcase the velocity streamlines in the radial and axial planes, respectively, for the configuration with ten diffuser vanes. The impeller's kinetic energy promotes higher fluid velocities within the impeller, while the diffuser reduces the velocity by 4.51 m/s, ensuring a smooth flow in the pump flow channels.

5.7.5 Streamline Patterns for 11 Diffuser Vanes: Figure 5.25 (a) and (b) demonstrate the velocity streamlines in the radial and axial planes, respectively, for the configuration with eleven diffuser vanes. Similar to the previous configurations, the impeller's kinetic energy leads to increased fluid velocity within the impeller. The diffuser section reduces the velocity by 4.60 m/s, achieving a smooth flow in the pump flow channels.

These streamline pattern analyses provide valuable insights into the flow characteristics and efficiency of the 2-stage pump for different configurations of diffuser vanes.

4. Conclusion:

Based on the comprehensive simulation process and analysis of the above-discussed parameters, the following conclusions can be drawn:

I. At 1900 rpm and for 6 different discharges, the evaluation of 5 different numbers of diffuser vanes revealed that the best efficiency was achieved with 7 diffuser vanes at a flow rate of 630 m3/h, while the lowest efficiency was also observed with 7 diffuser vanes.

II. The diffuser's performance seems to be influenced by the odd number of vanes, which performs better compared to an even number of vanes in the impeller. This could be attributed to the relative angular positions of the diffuser and impeller vanes.

III. The head values for discharges of 580, 630, and 700 m3/h are almost similar across all vanes. Hence, it can be concluded that the impact of the diffuser's number of vanes on the head is minimal at higher flow rates.

IV. The size reduction of the diffuser channel significantly affects the performance of the multistage pump.

V. Considering all the aforementioned criteria, the multistage pump with nine vanes in the diffuser demonstrates a slight advantage over pumps with fewer vanes.

VI. The relative positioning of the impeller and diffuser vanes has a significant influence on the results obtained from the numerical modeling of the multistage pump.

These conclusions provide valuable insights into the design and optimization of multistage pumps, specifically regarding the number of diffuser vanes and their impact on the pump's performance and efficiency.

Scope of the Work:

- Gather necessary design information such as pump sizing and boundary conditions.
- Develop a 3D model of the multistage pump using Creo parametric software and generate meshes for all its components using ICEM-CFD.
- Conduct preliminary processing and simulation of the two-stage pump with different combinations of diffuser vanes and discharge rates.
- Evaluate and analyze the results of head loss and performance metrics of the multistage pump.

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