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Design and Optimization of 7 Blades Centrifugal Pump Impeller using CFD Analysis

[1]Shivang Kumar Pandey, [2]Prof. Pushparaj Singh

[1]Research Scholar, Department of Mechanical Engineering, Rewa Institute of Technology, Rewa, India

[2]Assistant Professor & HOD, Department of Mechanical Engineering, Rewa Institute of Technology, Rewa, India

ABSTRACT: This research focuses on the design and optimization of a 7-blade centrifugal pump impeller using Computational Fluid Dynamics (CFD) analysis. The impeller, a key component in centrifugal pumps, plays a crucial role in fluid conveyance. The study employs advanced CFD techniques to model and analyze fluid flow within the impeller, aiming to enhance performance, efficiency, and cavitation resistance. By iteratively refining blade geometry and assessing various operating conditions, this research seeks to contribute insights into the design principles for achieving an optimized 7-blade impeller, addressing challenges associated with fluid dynamics and pump efficiency.

KEYWORDS: Blade, CFD, Centrifugal Pump, Impeller, Ansys.

I. INTRODUCTION

Centrifugal pumps are integral to numerous industries, serving as workhorses in fluid transportation systems. At the core of these pumps lies the impeller, a rotating component responsible for imparting kinetic energy to the fluid, driving its movement through the pump. The design and optimization of the impeller are pivotal in achieving optimal pump performance.

This research specifically delves into the design and optimization of a 7-blade centrifugal pump impeller, recognizing the importance of blade count in influencing pump efficiency and hydraulic characteristics. The choice of seven blades is based on a balance between maximizing energy transfer and minimizing potential issues such as cavitation. By employing Computational Fluid Dynamics (CFD) analysis, a sophisticated approach is taken to model the fluid flow within the impeller and evaluate its performance under varying conditions.

The initial phase of the study involves the geometric design of the 7-blade impeller, considering factors such as blade curvature, angles, and spacing. These parameters are carefully selected to achieve a balanced and efficient flow while mitigating the risk of cavitation. Subsequently, the impeller undergoes multiple iterations, guided by insights from CFD simulations, to optimize its design.

CFD analysis provides a virtual environment for assessing the impeller's performance, enabling the visualization of fluid flow patterns, pressure distributions, and velocity profiles. This detailed analysis helps identify areas of potential improvement in the impeller design, allowing for informed modifications and refinements.

The optimization process involves a comprehensive exploration of the design space, considering variations in rotational speed, fluid viscosity, and inlet conditions. Sensitivity analyses are conducted to understand the impact of different parameters on pump efficiency, enabling the identification of key design variables.

Challenges such as cavitation, which can compromise pump performance and longevity, are addressed through the optimization process. By refining the impeller geometry and its interaction with the fluid, the research aims to minimize the risk of cavitation while maximizing pump efficiency.

The outcomes of this study are expected to contribute valuable insights into the design and optimization of 7-blade centrifugal pump impellers. By leveraging CFD analysis, the research aims to provide a deeper understanding of fluid dynamics within the impeller and guide the development of more efficient and reliable pump systems. Ultimately, this

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work seeks to advance the state-of-the-art in centrifugal pump technology, offering practical design principles for achieving optimal performance in fluid handling applications.

II. METHODOLOGY

The methodology is as per following steps-

1. **Geometry Definition:**
   - Establish the initial geometric parameters of the 7-blade impeller, including blade curvature, angles, and spacing. Utilize design guidelines and considerations from the literature review.
2. **CFD Model Setup:**
   - Build a three-dimensional (3D) computational model of the impeller geometry using CFD software. Define fluid properties, boundary conditions, and mesh parameters for the simulation.
3. **Mesh Generation:**
   - Generate a structured or unstructured mesh for the impeller geometry, ensuring adequate resolution to capture flow details while maintaining computational efficiency.
4. **Solver Settings:**
   - Configure CFD solver settings, including turbulence models, numerical schemes, and convergence criteria. Validate the chosen settings through preliminary simulations or benchmark cases.
5. **Baseline Simulation:**
   - Perform a baseline CFD simulation to analyze the initial impeller design under typical operating conditions. Evaluate performance metrics and identify areas for improvement.
6. **Design Iterations:**
   - Implement design modifications based on insights from the baseline simulation. Iteratively refine the impeller geometry, adjusting parameters such as blade angles or curvature.
7. **Sensitivity Analysis:**
   - Conduct sensitivity analyses to assess the impact of varying parameters (e.g., rotational speed, fluid properties) on impeller performance. Identify key design variables influencing pump efficiency.
8. **Optimization:**
   - Use optimization algorithms or parametric studies to systematically explore the design space and identify the optimal impeller configuration. Consider trade-offs between different performances metrics.

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III. SIMULATION RESULTS

The simulation is performed using the ANSYS software with CFD analysis.

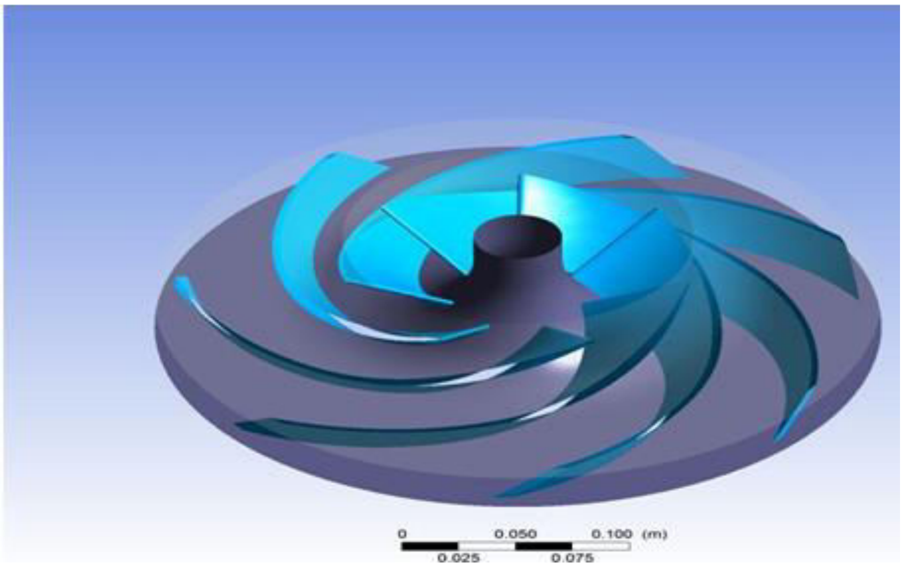

Figure 1: Isometric View of the Blade, Hub and Shroud

Figure 1 is showing the isometric perspective on the sharp edge, center point and cover where Isometric projection is a technique for outwardly addressing three-layered articles in two aspects in specialized and designing drawings.

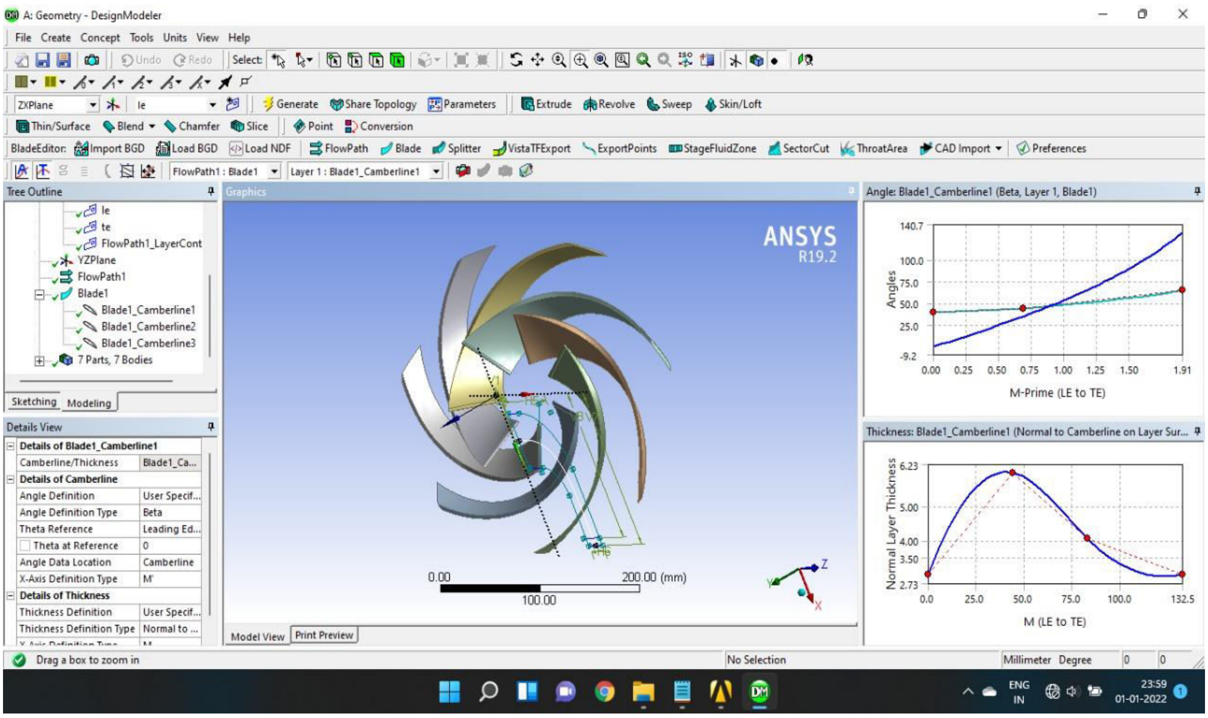

Figure 2: 7 Blade view at angles

Figure 2 is showing the various angle view of the 7 blade impller. The Geometry windows is open in this state.

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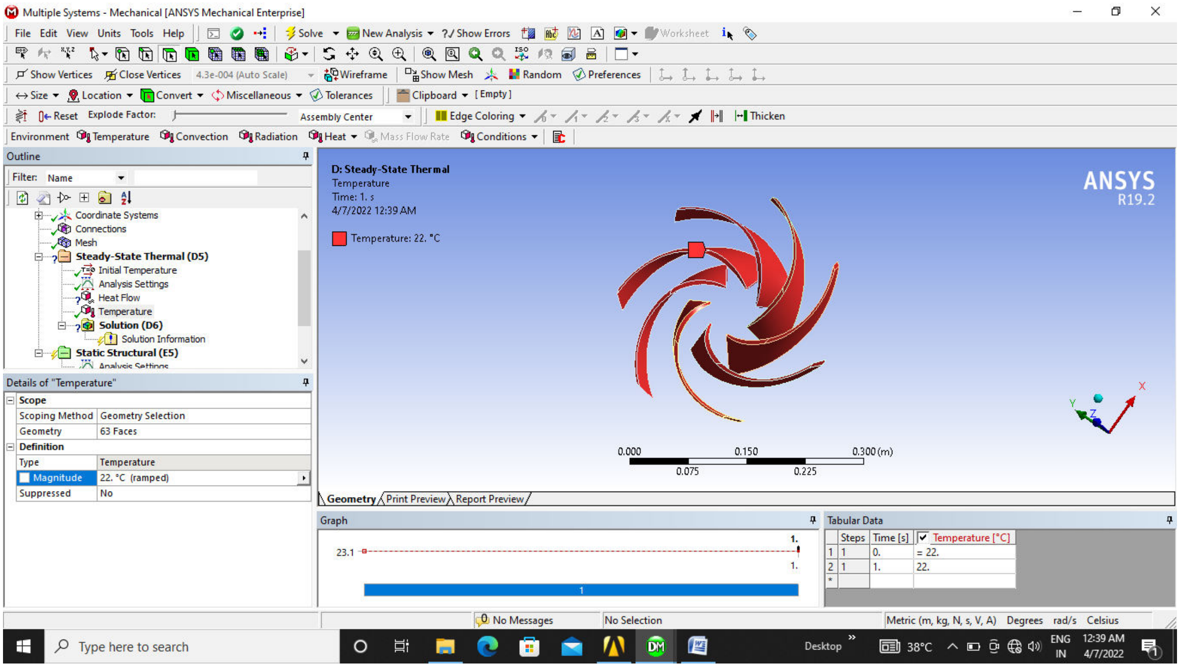

Figure 3: Blades temperature distribution

Now apply the blades temperature distribution in the geometry, the initial temperature is 22'C. The initial time and steps counts the temperature in this steady state thermal analysis.

Table 1: Result Comparison

Sr No.	Parameters	Previous Work	Proposed Work
1	Pressure	740 kPa	425 kPa
2	Number of blade	8	7
3	Total Nodes	75223	25956
4	Total Efficiency	69.39%	96.2650 %

IV. CONCLUSION

The proposed work reflects a comprehensive and successful effort in optimizing the centrifugal pump impeller. The decision to reduce the number of blades from 8 in the previous work to 7 in the proposed work indicates a deliberate effort to optimize the impeller geometry. This change might be aimed at achieving a better balance between kinetic energy transfer and minimizing potential issues such as cavitation. The combination of reduced pressure, a refined blade configuration, improved computational efficiency, and a significant increase in total efficiency collectively suggests advancements that align with the goals of achieving a more efficient and reliable pump system. These improvements have the potential to positively impact various industrial applications, offering enhanced performance and energy efficiency.

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