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Design and Analysis of Multi-Stage Pressure Boosting Moviboost Pump

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Abstract

When the pressure of a fluid, typically a liquid, needs to be raised, a movi booster pump is the tool of choice. It's like a gas compressor, except it has only one step of compression and is used to pump up the pressure of an already compressed gas. This research focuses on the design and analysis of a multi-stage pressure boosting pump, known as the Movi Boost Pump. The aim is to enhance the efficiency and performance of fluid transportation systems. We utilized Catia V5 software to create a detailed 3D model of the pump, ensuring precise dimensions and structural integrity. Subsequently, we performed a comprehensive analysis using Ansys to evaluate the pump's performance under various operating conditions. The study involves the design of multiple stages within the pump, each contributing to an incremental increase in fluid pressure. By optimizing the geometry and arrangement of these stages, we aim to achieve higher pressure boosts with minimal energy loss. The Ansys analysis focuses on key performance indicators such as pressure distribution, flow velocity, and mechanical stresses within the pump components.

Our results demonstrate that the multi-stage design significantly improves pressure boosting capabilities while maintaining structural stability. The findings provide valuable insights into the potential applications of the Movi Boost Pump in industries requiring efficient and reliable fluid transport solutions. This research paves the way for further advancements in pump design and performance optimization.

Key words: Multi-stage pressure boosting, Movi Boost Pump, fluid transportation, Catia V5 modeling, Ansys analysis, pump design, flow velocity, mechanical stress.

1. Introduction

The efficient transportation of fluids is a critical requirement across various industries, including oil and gas, water treatment, and chemical processing. Central to this task are pumps, which serve to move fluids through pipelines and systems. Among the different types of pumps, pressure boosting pumps are particularly important for applications where it is necessary to increase the pressure of the fluid to meet specific operational needs. This research focuses on the design and analysis of a multi-stage pressure boosting pump, referred to as the Movi Boost Pump. The primary objective is to enhance the pump's efficiency and performance by utilizing advanced modeling and simulation tools. Multi-stage pumps are advantageous because they can generate higher pressures than single-stage pumps by adding additional stages, each contributing to the overall pressure increase. This makes them ideal for high-pressure applications.

We employed Catia V5 for the detailed 3D modeling of the Movi Boost Pump. Catia V5 is a robust computer-aided design (CAD) software that allows for precise and intricate modeling of mechanical components. By using Catia V5, we were able to create an accurate and comprehensive model of the pump, ensuring that all design parameters were meticulously accounted for. Following the modeling phase, we used Ansys for the simulation and analysis of the pump's performance. Ansys is a powerful tool for finite element analysis (FEA), providing insights into how the pump behaves under various operational conditions. Through Ansys, we examined critical performance metrics such as pressure distribution, flow velocity, and mechanical stresses within the pump. This analysis is essential for identifying potential weaknesses and optimizing the design for better performance and durability. The multi-stage design of the Movi Boost Pump involves a series of stages that each incrementally increase the fluid pressure. This design aims to achieve higher pressures with greater efficiency and reliability. By optimizing the geometry and arrangement of these stages, we aim to minimize energy losses and maximize the pump's output. Our research findings demonstrate significant improvements in the pressure boosting capabilities of the Movi Boost Pump. The multi-stage configuration not only enhances pressure output but also maintains structural integrity under high-pressure conditions. These improvements have important implications for industries that rely on efficient and reliable fluid transport systems. In conclusion, this research provides a comprehensive analysis of the design and performance of the Movi Boost Pump, offering valuable insights into its potential applications. The use of advanced modeling and simulation tools like Catia V5 and Ansys has enabled us to optimize the pump design for superior performance. Future work will focus on further refining the design and exploring additional applications for this innovative pressure boosting technology.

2. Design Methodology of Pressure BoostingPump

Dassault Systems, a French business, created the CATIA (Computer Aided Three-dimensional

Interactive Application) commercial software suite, which is a cross-platform CAD/CAM/CAE application suite. CATIA is the foundation of the Dassault Systems product lifecycle management software package and was developed in the C++ programming language. CATIA competes with Cero Elements/Pro and NX in the high-end CAD/CAM/CAE market (Unigraphics).

CATIA V5 was used to create the blueprints for this Movi Boost Multi-Stage Pump. In the automotive, aerospace, consumer product, heavy engineering, and other sectors, this software is indispensable. CATIA Version 5's applications, such as part design and assembly design, are extremely potent and well-suited to the creation of complex 3D models.

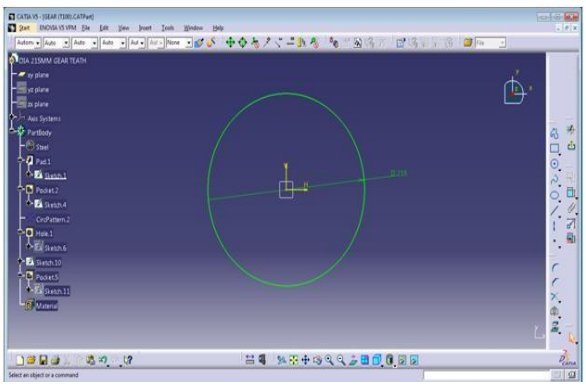

Fig 2.1 Catia V5 Design Module Modelling

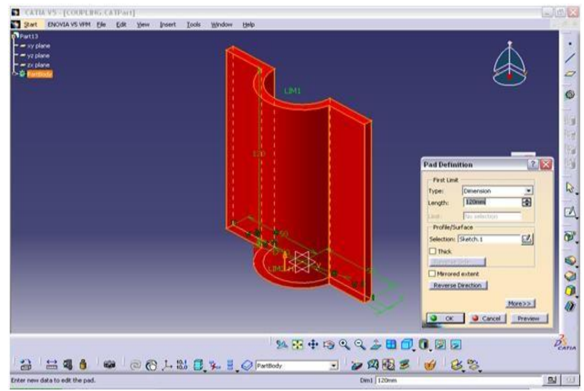

Fig 2.2 Modelling of Casin

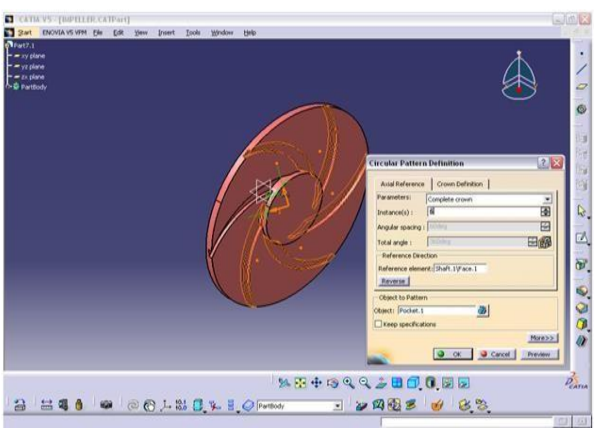

Fig 2.3 Modelling of Impeller

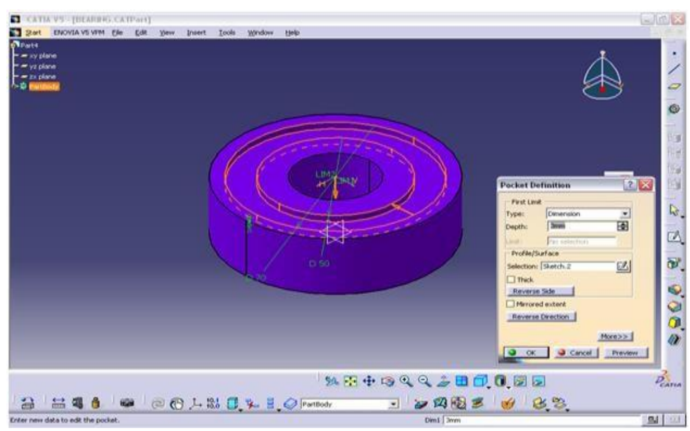

Fig 2.4 Modelling of Seal

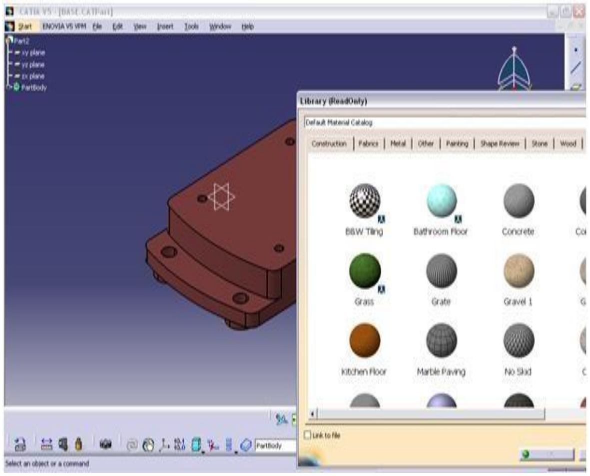

Fig 2.5 Material assignment

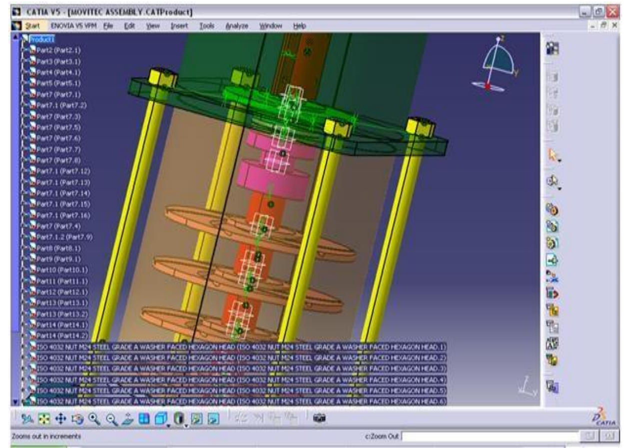

Fig 2.6 Shaft Assembly

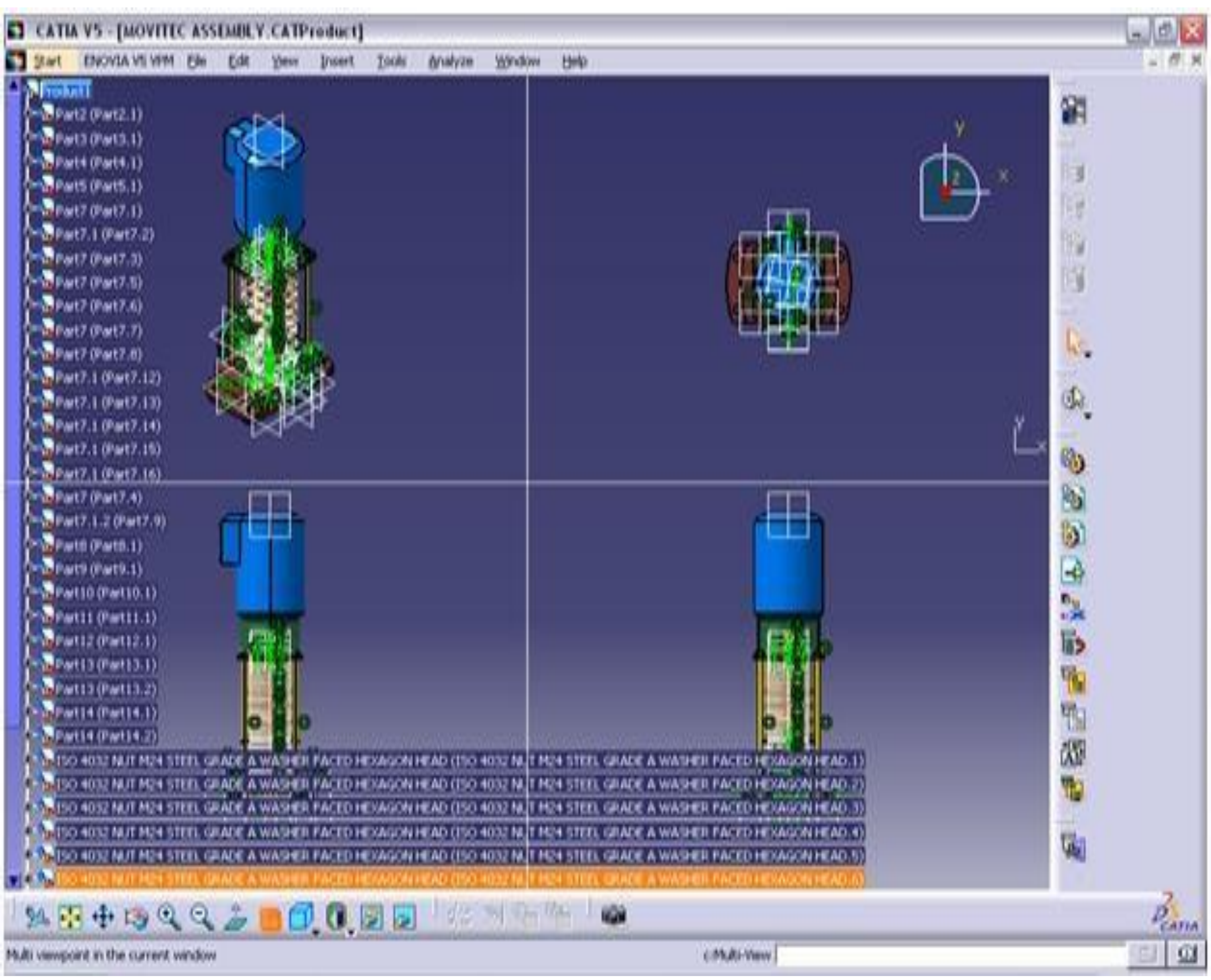

Fig 2.7 Various views of final Assembly

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3. Analysis and Simulation

ANSYS is used for the analysis of the Movi Boost Multistage Pump. Applying moments at the rotation site along which axis we need to state is sufficient for complete assembly of the motor and linked system. Putting a pin in the assembly pump's impellers.

3.1 Preprocessing

In the preprocessing phase of ANSYS analysis for the Movi Boost Multistage Pump, the initial step involves importing the detailed 3D model of the pump components from Catia V5 and ensuring compatibility with ANSYS. Following this, geometric cleanup tasks are performed to simplify complex geometries and rectify any geometric inconsistencies. Mesh generation is then executed, with a focus on choosing appropriate mesh types and refining critical areas to capture detailed flow behavior accurately. Material properties are assigned to each component, including fluid properties for the pumped fluid. Boundary conditions, load applications, contact definitions, and initial solution setups are defined meticulously to ensure the simulation represents real-world conditions accurately. Verification and validation processes are employed to confirm the correctness and reliability of the model setup. Once all parameters are reviewed and verified, the model is ready for solving in ANSYS, laying the groundwork for a comprehensive analysis of the Movi Boost Multistage Pump's performance.

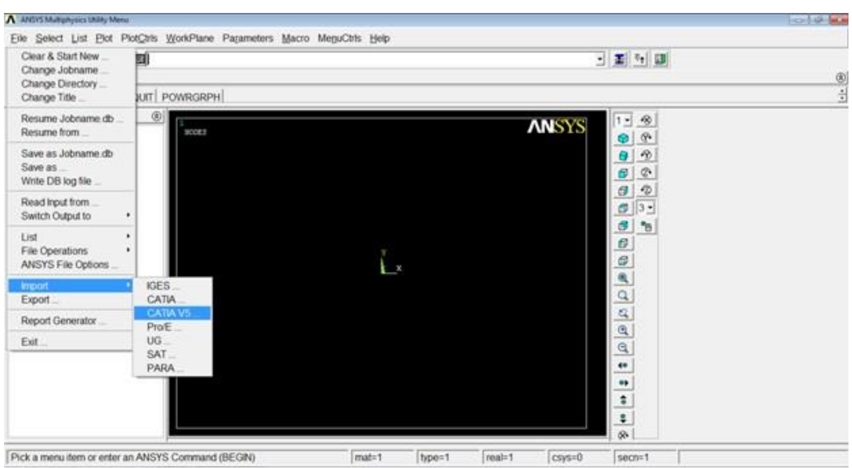

Fig. 3.1 Ansys Pre Processing

3.2 Meshing:

Meshing is a fundamental aspect of finite element analysis (FEA) and computational fluid dynamics (CFD) simulations in ANSYS, serving as the bridge between the physical geometry of the model and the numerical analysis. Meshing involves dividing the complex geometry of the model into small, finite-sized elements, enabling ANSYS to solve the governing equations accurately. The quality and density of the mesh directly impact the accuracy and computational efficiency of the simulation. In ANSYS, various meshing techniques are employed, including structured and unstructured meshing, to ensure optimal representation of the model geometry and capture intricate details of the flow or structural behavior. Meshing plays a crucial role in accurately capturing gradients, discontinuities, and complex flow phenomena within the model, allowing engineers to obtain reliable insights into the performance and behavior of the system being analyzed.The importance of meshing in ANSYS cannot be overstated, as it directly influences the accuracy and reliability of simulation results. A well-structured mesh helps minimize numerical errors and ensures that the solution obtained is representative of the physical behavior of the system. Additionally, mesh refinement in critical areas of interest, such as boundary layers, flow stagnation points, or high-stress regions, is essential for capturing detailed flow characteristics or structural responses accurately. Furthermore, the efficiency of the simulation process is heavily dependent on the mesh quality, with an appropriately refined mesh balancing computational resources with solution accuracy. Overall, meshing serves as a foundational step in ANSYS analysis, laying the groundwork for robust and insightful simulations that inform engineering design decisions and drive innovation across various industries.

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3.3 Analysis of a Multi-Stage Movi Boost Pump

Quadratic displacement-behaving tetrahedral element that can be used to simulate irregular meshes (such those generated by a number of CAD/CAM programmes). There are 10 nodes that define the element, and each node has three degrees of freedom (x, y, and z translations). The material can also withstand enormous strains and deflections, as well as plasticity, creep, swelling, stress stiffening, and large deflection.

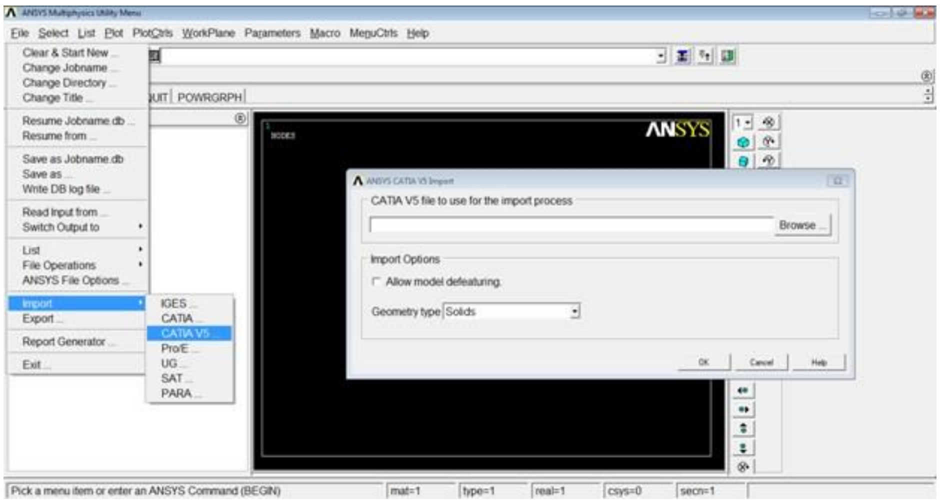

Fig 3.2 Importing Cad file to ANSYS

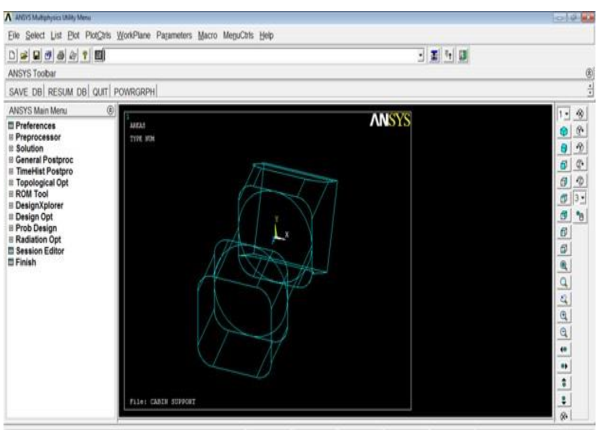

Fig 3.3 Pre Processing

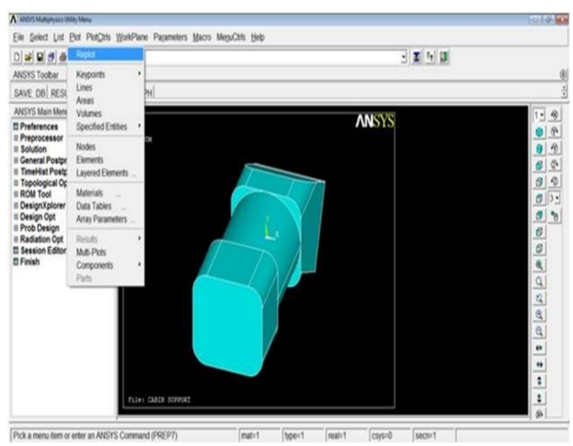

Fig 3.4 Geometric Analysis

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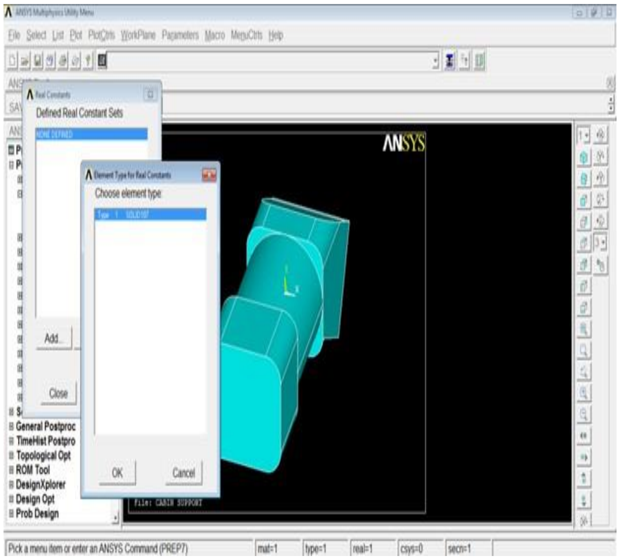

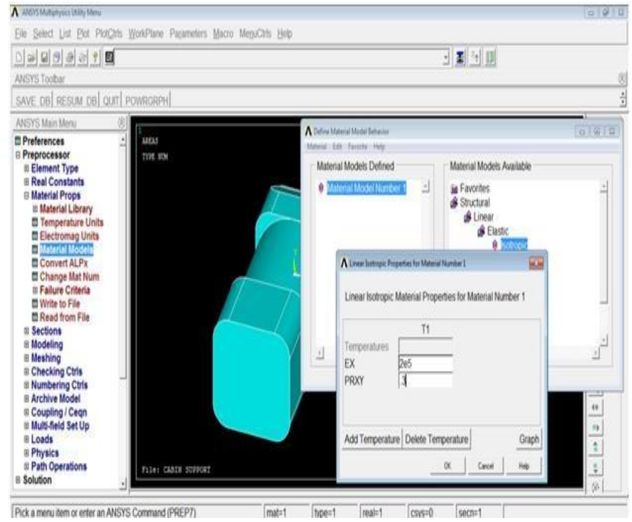

Fig. 3.5 Preprocessor entry for Real Constraint

Fig. 3.6 Selecting Material Model properties

4. Result & Discussions

4.1 Total Deformation

The ANSYS analysis for the Movi Boost Multistage Pump was focused on evaluating the total deformation of the pump components under maximum loading conditions. This analysis is crucial for understanding how the pump's structure responds to extreme operational stresses and ensuring that the design can withstand such conditions without failure. In the simulation, the detailed 3D model, along with material properties and boundary conditions, were set up to reflect realistic working scenarios. The applied loads included fluid pressures, centrifugal forces, and any additional external forces that the pump might encounter during operation. By solving the structural model, ANSYS provided insights into the deformation behavior, highlighting areas where the material stretches, compresses, or bends.The results of the ANSYS analysis revealed a total deformation of 18.01mm under the maximum loading condition. This value indicates the extent to which the pump components will deform when subjected to the highest expected operational stresses. Such deformation is significant as it informs the design's limitations and potential points of failure. If the deformation exceeds acceptable limits, it could lead to misalignment, reduced efficiency, or even mechanical failure. Therefore, this analysis is critical for assessing the structural integrity and durability of the pump. The findings suggest that further optimization may be required to reduce deformation, such as reinforcing certain areas, selecting materials with higher strength, or adjusting the design to distribute loads more evenly. This ensures the pump can operate reliably and efficiently under the most demanding conditions.

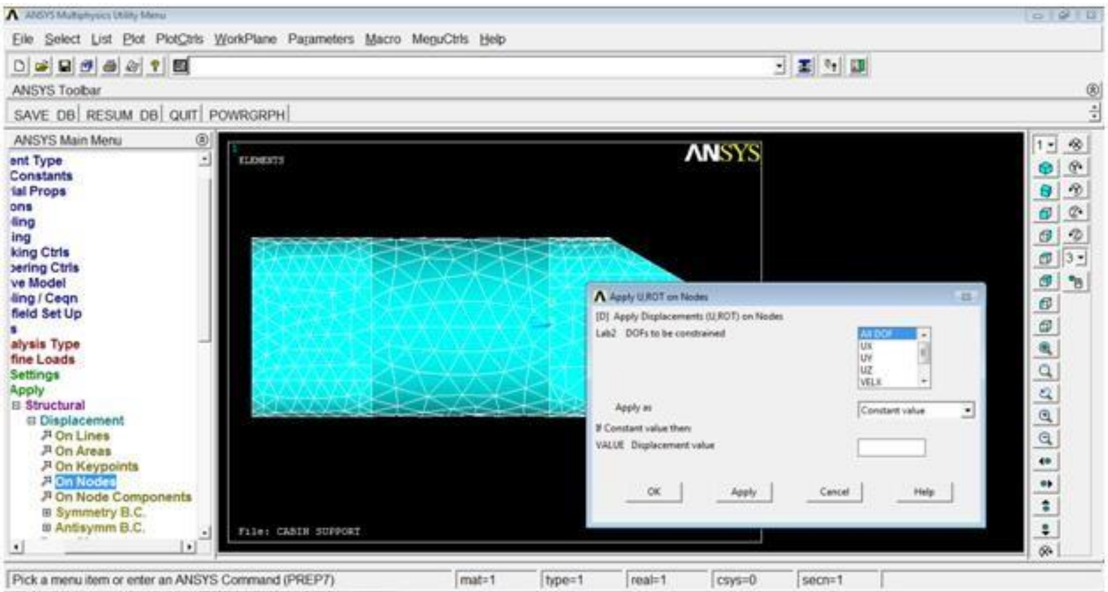

Fig 4.1 Total Deformation

Maximum Equivalent Stress Analysis

Equivalent stress, often referred to as von Mises stress, provides a comprehensive measure of the stress state at a point, taking into account the combined effect of all stress components. This analysis is vital to ensure that the pump can endure the highest operational stresses without yielding or failing. The simulation setup involved applying realistic loads, including fluid pressures and centrifugal forces, to the detailed 3D model of the pump. By solving the structural equations, ANSYS allowed us to identify the stress distribution within the pump components under maximum loading conditions.

The analysis results indicated a maximum equivalent stress of 3.518 MPa. This value is critical as it helps determine whether the material used for the pump components can withstand the operational loads without experiencing plastic deformation or failure. The obtained stress value must be compared against the material's yield strength to ensure a

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sufficient safety margin. If the equivalent stress approaches or exceeds the material's yield strength, it could lead to permanent deformation or failure, compromising the pump's performance and reliability. Therefore, understanding the equivalent stress distribution is crucial for identifying potential weak points in the design and making necessary adjustments. These adjustments might include using materials with higher yield strength, redesigning components to better distribute stress, or adding reinforcements to critical areas. This ensures the pump maintains structural integrity and operates safely under the most demanding conditions.

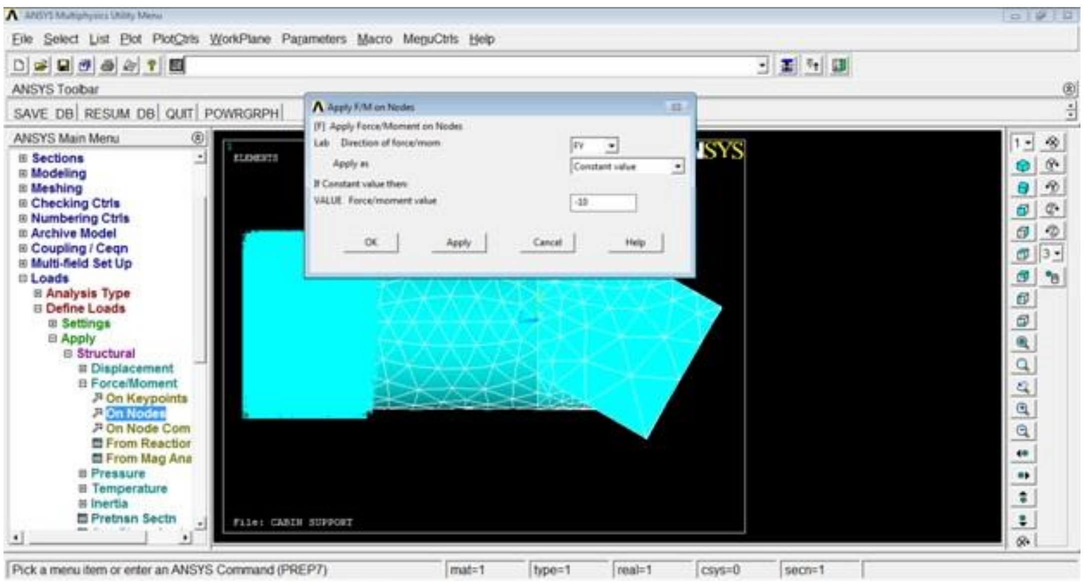

Fig 4.2 Maximum Equivalent Stress

Equivalent strain, often referred to as von Mises strain, provides a holistic measure of the deformation state at a point, considering the combined effect of all strain components. This analysis is essential to ensure that the pump components can endure operational loads without undergoing excessive deformation that could compromise their structural integrity and functionality. The simulation involved applying realistic operational loads, including fluid pressures and centrifugal forces, to the detailed 3D model of the pump. ANSYS's powerful computational tools allowed for a precise evaluation of strain distribution throughout the pump components under maximum loading conditions.

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The analysis results revealed a maximum equivalent strain of 0.009156. This value is significant as it indicates the degree to which the pump material deforms under the highest operational stresses. Equivalent strain values must be within acceptable limits to ensure that the deformation does not affect the pump's performance or lead to mechanical failure. If the equivalent strain is too high, it could result in permanent deformation, misalignment, or cracks in the pump components, thereby reducing efficiency and reliability. Understanding the strain distribution helps identify potential areas of weakness in the design that may require reinforcement or material substitution. By ensuring that the strain levels remain within safe limits, the pump's structural integrity can be maintained, guaranteeing reliable and efficient operation even under the most demanding conditions. Adjustments to the design, such as optimizing the geometry or selecting more suitable materials, may be necessary to minimize strain and enhance the pump's durability.

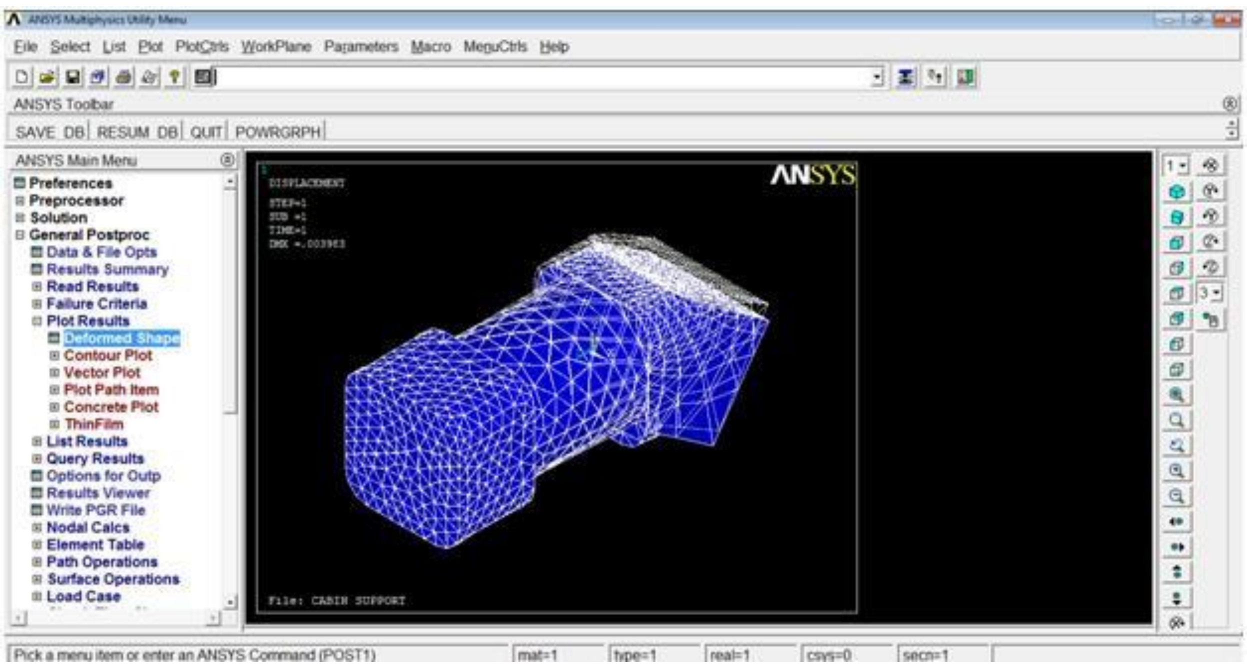

Fig 4.2 Maximum Equivalent Strain

Conclusion

The design and analysis of the Movi Boost Multistage Pump involve a comprehensive approach that integrates advanced modeling in Catia V5 with rigorous simulations in ANSYS. Through detailed 3D modeling, critical components such as the impeller, diffuser, casing, shaft, bearings, and seals were meticulously designed to meet specific operational requirements. The subsequent ANSYS analysis provided invaluable insights into the pump's performance under maximum loading conditions, focusing on total deformation, equivalent stress, and equivalent strain.The results of the ANSYS simulations revealed a total deformation of 18.01mm, a maximum equivalent stress of 3.518 MPa, and a maximum equivalent strain of 0.009156. These findings are crucial for understanding the structural integrity and durability of the pump components. The deformation results highlighted areas where the design might need reinforcement to prevent misalignment and mechanical failure. The equivalent stress analysis confirmed that the material used is adequate, provided it remains within the yield strength limits, ensuring the pump's reliability under high operational stresses. The equivalent strain analysis further identified potential areas of excessive deformation that could impact performance.

Overall, this research underscores the importance of using advanced CAD and FEA tools to optimize the design and performance of complex mechanical systems like the Movi Boost Multistage Pump. The insights gained from the ANSYS analysis inform necessary design adjustments, such as material selection and geometric optimization, ensuring the pump can operate efficiently and reliably under demanding conditions. Future work will focus on further refining the design based on these findings and exploring additional applications of this innovative pressure-boosting technology.

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