COMPUTATIONAL FLUID DYAMICS PROJECT

Abstract

This project leverages the capabilities of Ansys software suite to perform a comprehensive multi-physics analysis and optimization of a structural component subjected to thermal and mechanical loads. The study integrates steady-state thermal analysis with computational fluid dynamics (CFD) to evaluate temperature distributions and heat transfer mechanisms under predefined boundary conditions. The resulting thermal data is then coupled with a static structural analysis in Ansys Mechanical to determine the stress and deformation patterns induced by combined thermal and mechanical loads.

To enhance the design's performance, the project employs topology optimization techniques in Ansys to identify material distribution that meets structural integrity requirements while minimizing weight. The optimization considers design constraints such as load-bearing capacity, thermal conductivity, and manufacturability.

The workflow demonstrates the synergistic use of multi-physics simulations and optimization tools to improve component efficiency, reduce material usage, and ensure reliability in harsh operating conditions. The results provide a pathway for designing innovative and lightweight structures suitable for industrial applications such as aerospace, automotive, and energy systems.

Introduction

Modern engineering demands the development of efficient, lightweight, and durable components that can withstand complex operating conditions. This challenge is particularly pronounced in industries such as aerospace, automotive, and energy, where components are exposed to simultaneous thermal and mechanical stresses. Effective design under these conditions requires a multidisciplinary approach, combining advanced simulation techniques with optimization strategies to ensure reliability while minimizing resource consumption.

This project addresses this need by employing a comprehensive workflow within the Ansys software suite, integrating computational fluid dynamics (CFD), thermal analysis, and structural analysis with topology optimization. Initially, a steady-state thermal analysis is conducted using CFD to accurately model heat transfer and temperature distribution under realistic boundary conditions. The thermal data from this analysis is then coupled with static structural analysis in Ansys Mechanical to evaluate the stress and deformation behavior caused by the combined thermal and mechanical loads.

To optimize the performance and material usage of the component, topology optimization is performed. This process identifies the optimal material distribution that satisfies structural and thermal requirements while minimizing weight and ensuring manufacturability. By combining these advanced techniques, the project not only provides a detailed understanding of the component's performance but also delivers an optimized design that is robust, efficient, and tailored to real-world applications.

This study demonstrates the power of integrating multiphysics analysis and optimization, offering a robust methodology for addressing the challenges of modern engineering design. The workflow and results serve as a valuable framework for developing innovative solutions in various industrial domains.

Problem Definition

The Jupiter 125 Disk Brake is a key component in ensuring the safety and performance of the bike, operating under significant thermal and mechanical loads during braking. Repeated braking events generate high temperatures due to friction, which can lead to thermal stresses and material deformation over time. Coupled with mechanical stresses from rider weight, road conditions, and braking forces, the disk brake experiences complex loading scenarios that can compromise its efficiency, durability, and safety.

The challenge lies in accurately simulating these coupled thermal and mechanical behaviors to understand their impact on the disk brake's structural integrity. Additionally, optimizing the brake's design to reduce material usage while maintaining safety and performance is critical for improving efficiency, lowering costs, and meeting industry standards.

Objective

The primary objective of this project is to enhance the design and performance of the Jupiter 125 Disk Brake by leveraging advanced simulation and optimization tools in Ansys. The key goals include:

- Conducting a steady-state thermal analysis using CFD to evaluate heat transfer and temperature distribution during braking operations.
- Performing a static structural analysis in Ansys Mechanical to assess the combined effects of thermal and mechanical stresses on the disk brake
- Optimizing the disk brake design using topology optimization to minimize weight while maintaining structural integrity and thermal efficiency.
- Developing a robust methodology to improve safety, durability, and material efficiency for application in automotive components.

This study aims to provide a detailed understanding of the disk brake's performance under realistic conditions and deliver a lighter, more efficient design without compromising safety or functionality.

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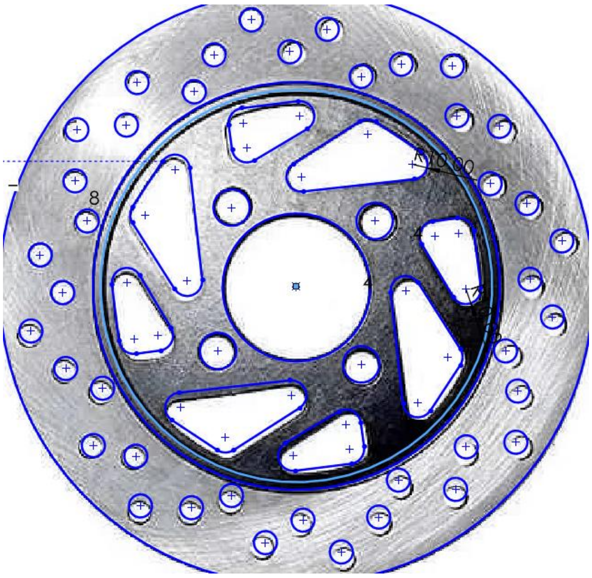
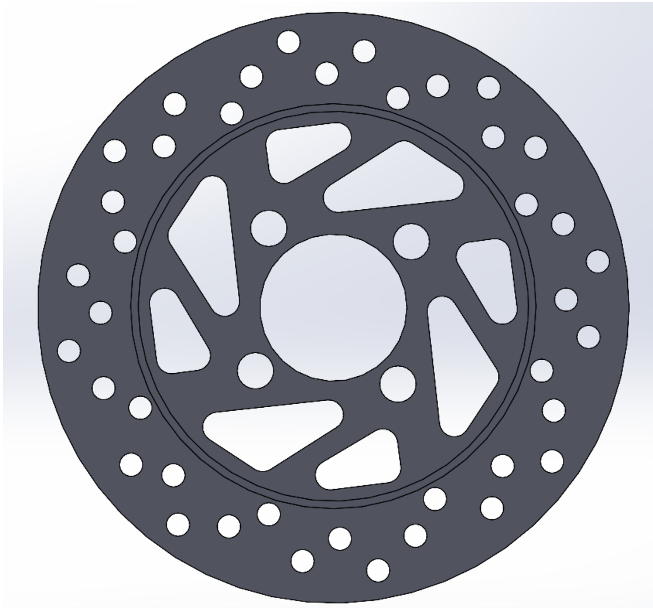
Model

Actual picture from the bike Jupiter 125cc front disc brake was used as reference to make the model. The outer diameter of the disk is considered to be 220mm and the other features are put to ratio using the picture reference.

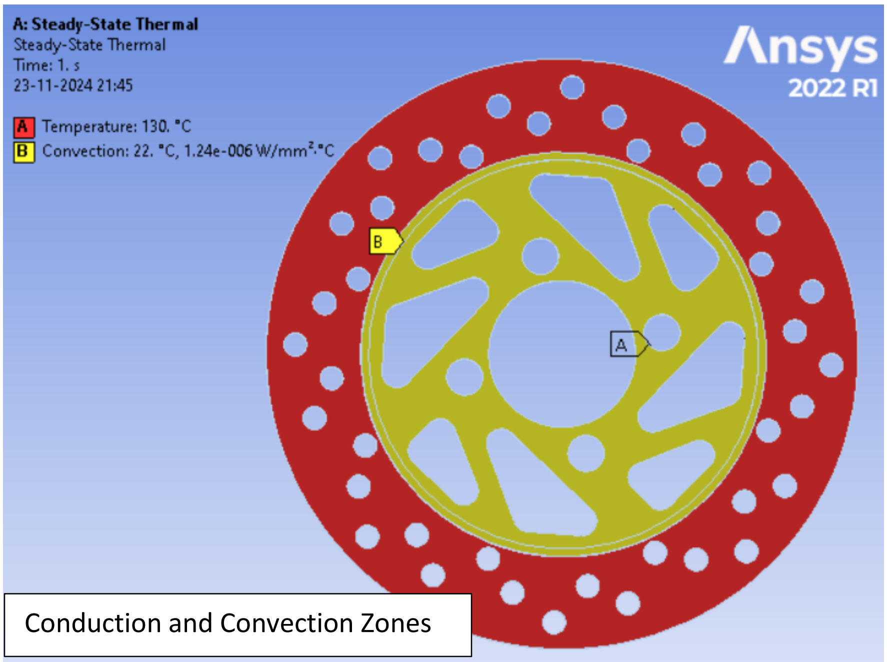




Static Conditions

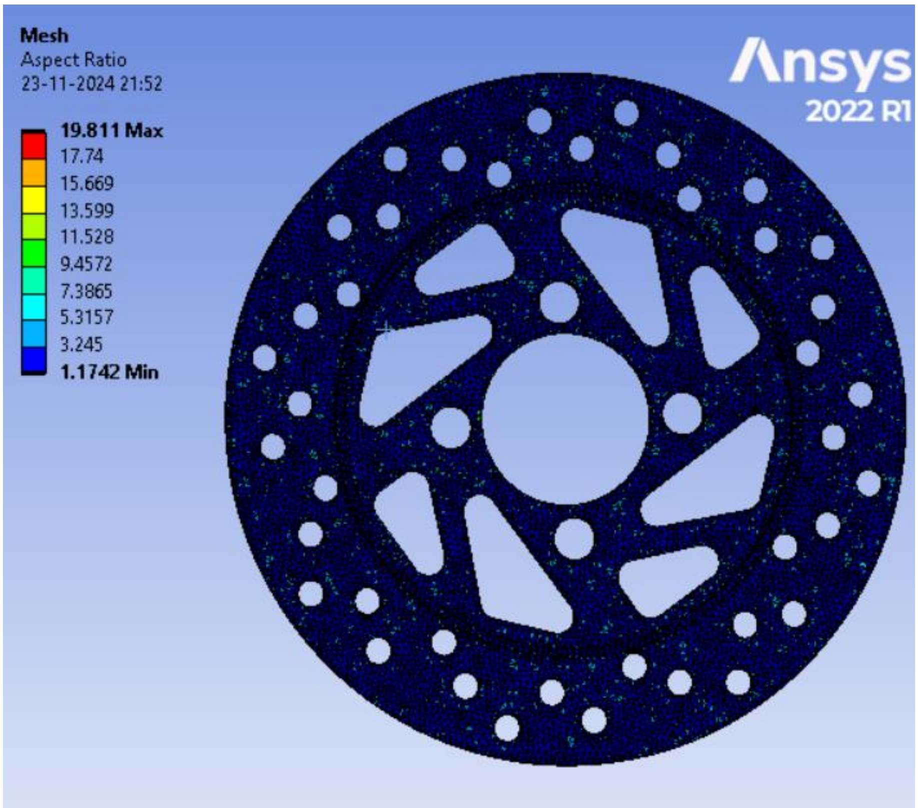
Assuming the motorbike was brought to rest, after operating at maximum conditions (convection happens with the surrounding environments) .

The Peak Disk Brake Temperature was assumed to be 130 C.
The faces that go through conduction and convection has been opted.
Material properties of Grey Cast Iron has been assumed.

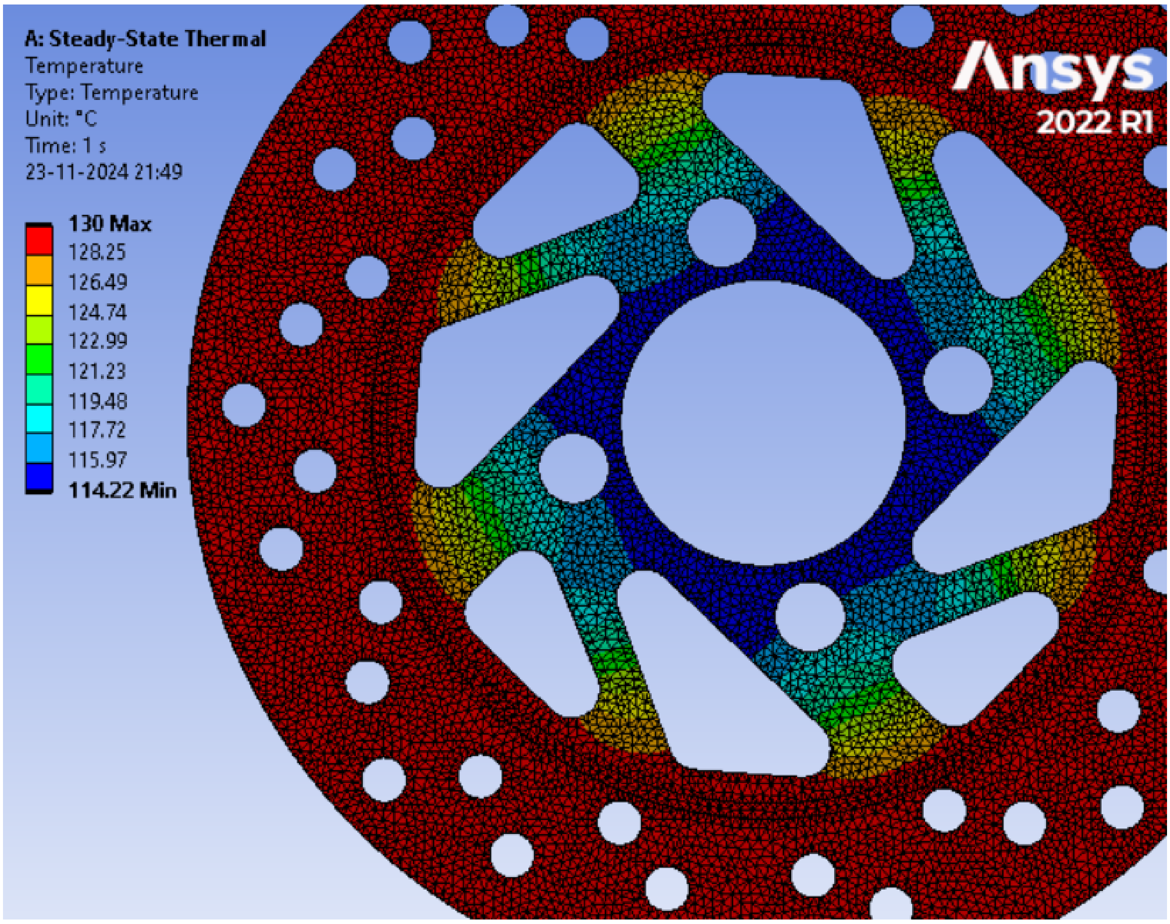


Conduction and Convection Zones

Mesh



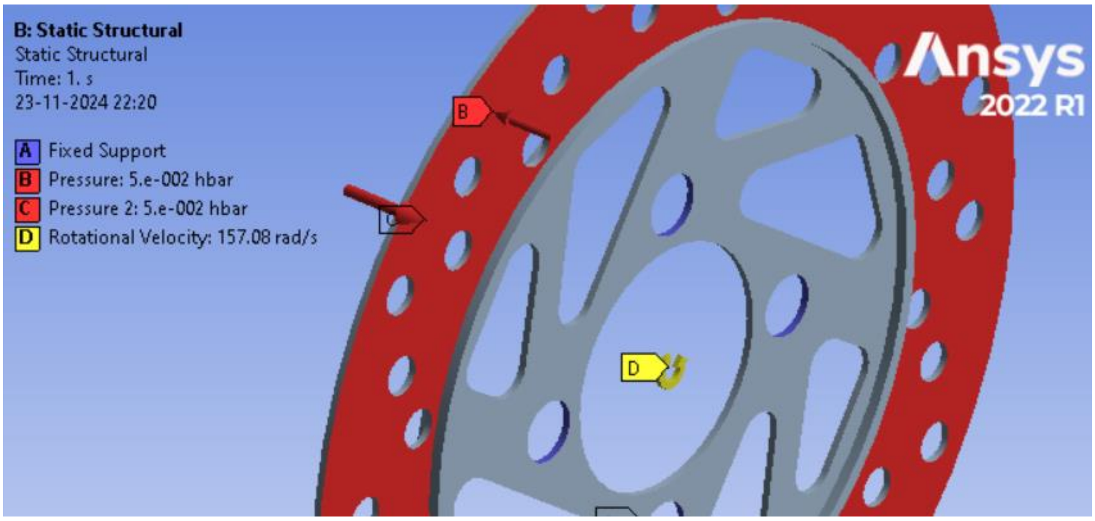
Temperature Distribution



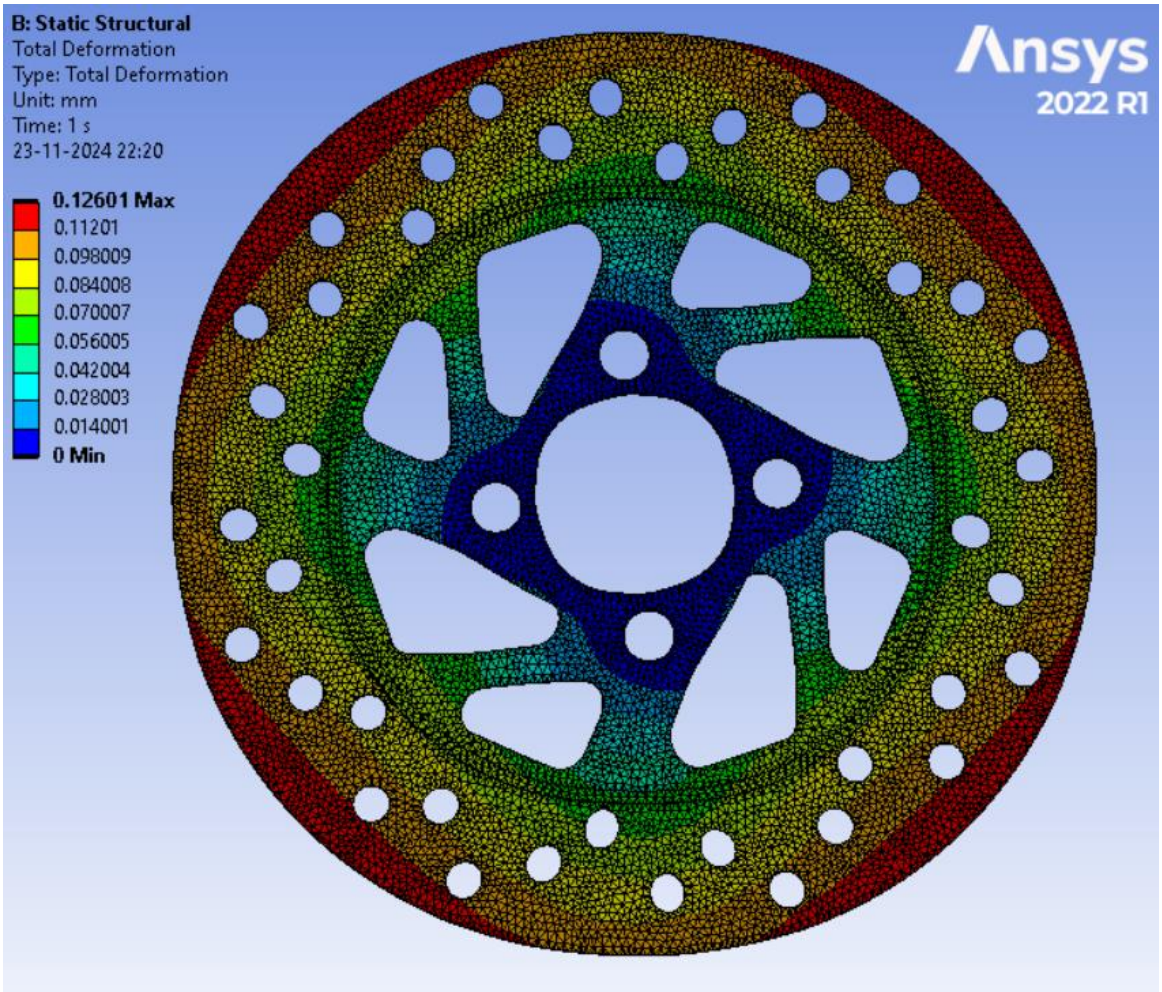
Mechanical

Assuming a mechanical load of 0.05 hbar or 0.5 Mpa of pressure load is applied on both sides of the disk as the brake calipers come in contact with the disk to apply brakes.

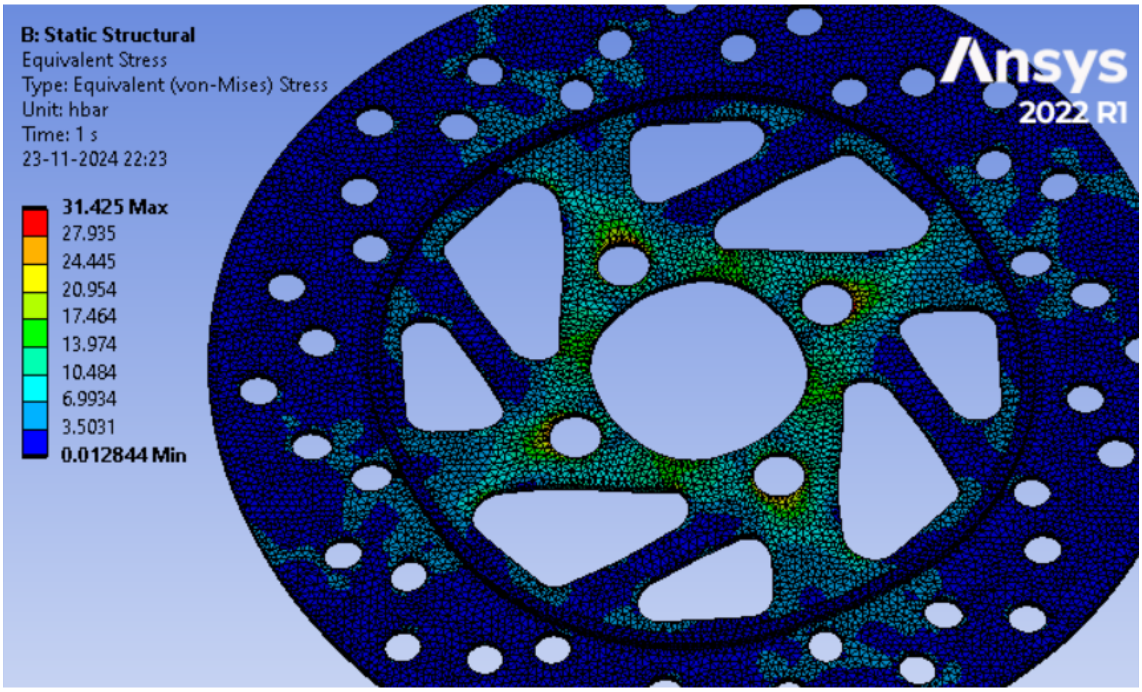
Rotational velocity of disk is assumed 1500 rpm as the maximum speed of Jupiter 125 cc could be close to 90 kmph. The tyre circumference is assumed to be 1 m (304.56 mm wheel dia) hence 1.5km/ min hence 1500 rpm. Converting rpm to 157.079633 rad/ s.



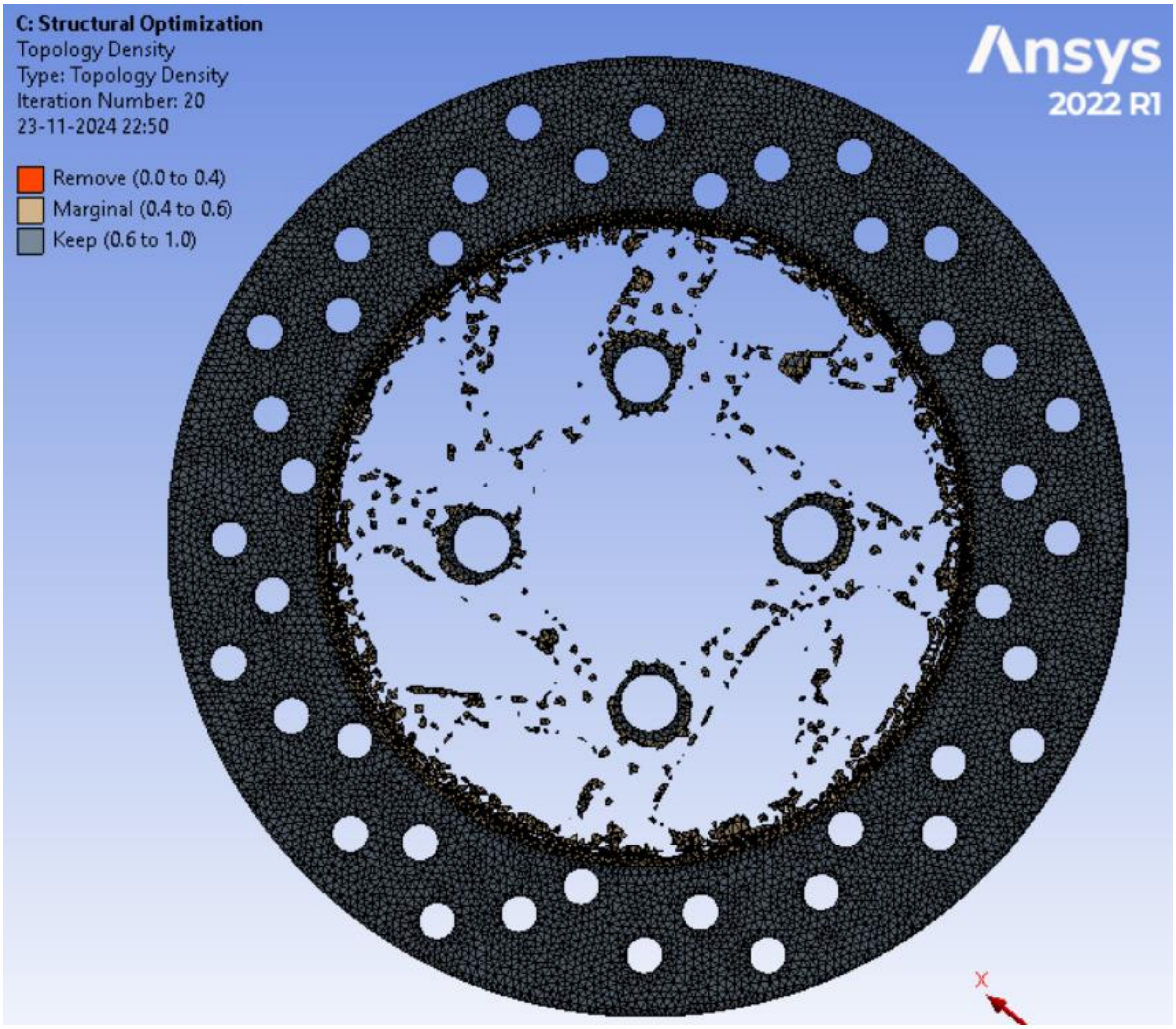
Deformation



Von Mises Stress



Trying to optimise with 95% of the mass retained



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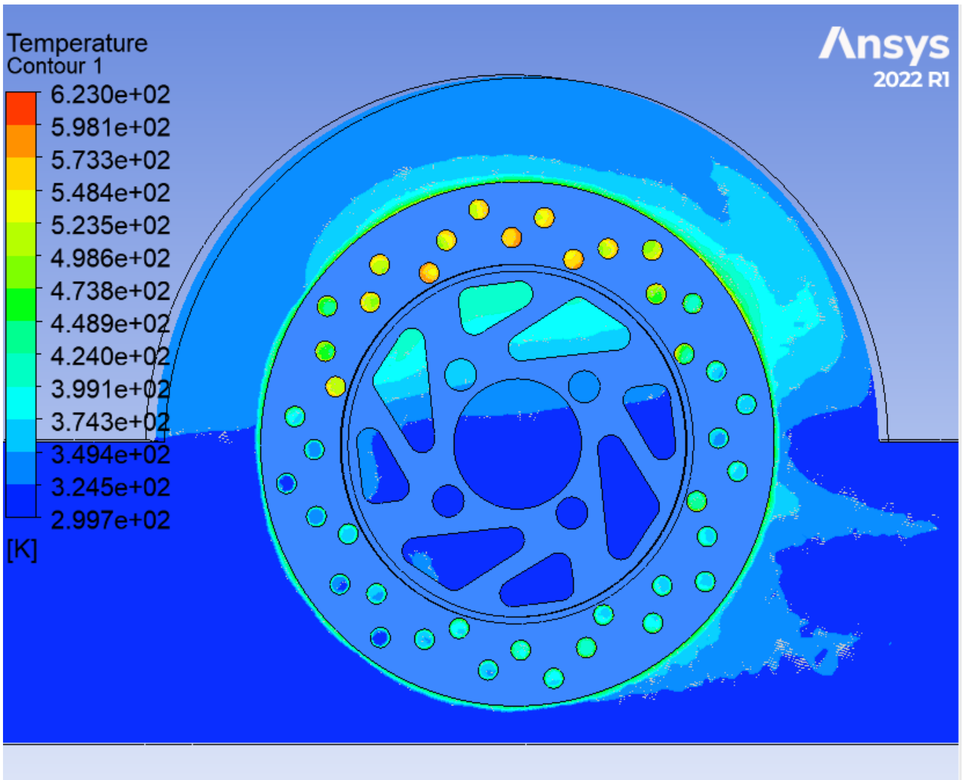
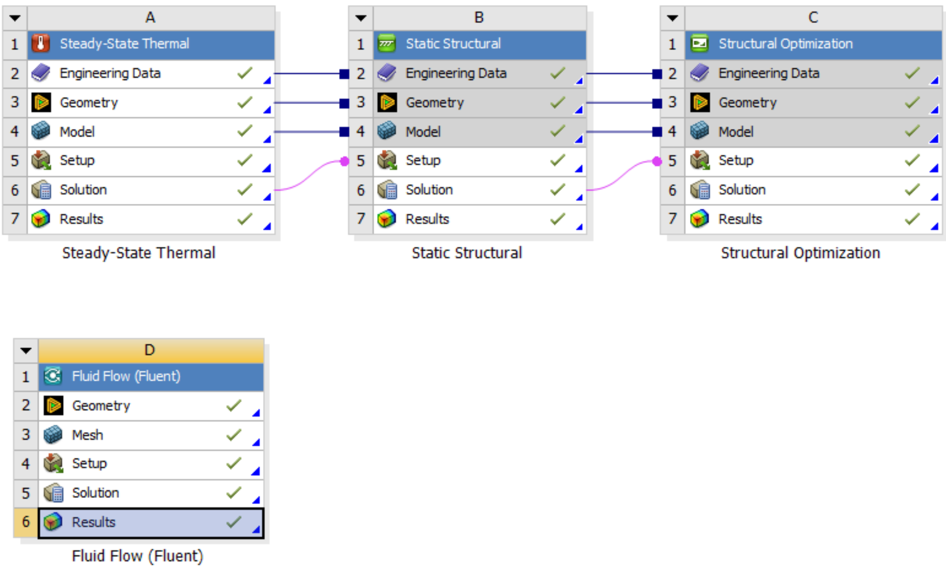
Dynamic Conditions

Average velocity of the motorbike is considered to be 10 m/s. The temperatre on the hot walls of the disk is considered to be 350 C. The domain resembles the mud guard of the motorbike.



Project Schematic



Results

Hence it is found that the disk brake cannot furthur be optimised. It is suggest to opt composite and other ceramic materials to optimise the disk brake and reduce the weight.