COMPARATIVE ANALYSIS FOR SUITABLE CLUTCH FRICTION PLATE MATERIAL

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Abstract—**Single-plate clutches are essential components in automotive transmissions for smooth power transfer from engine to gearbox. This abstract examines their design, materials, and performance optimization. A single-plate clutch features a friction disc with linings sandwiched between flywheel and pressure plate, actuated by springs and release mechanism. Key components include clutch plate, pressure plate, flywheel, and helical coil or diaphragm springs.**
Material analysis is crucial to evaluate performance, durability, and compliance with safety and environmental standards. The frictional force depends on the vehicle's mass and velocity , higher mass or velocity produces more heat during engagement. Excessive heat causes thermal cracks, permanent deformation, glazing of friction surfaces, and loss of torque capacity, leading to premature failure. Thermal analysis identifies stress concentrations and optimizes cooling via convection or material properties. Therefore, the clutch friction plate must withstand high temperatures and have good wear resistance. Hopefully , this effort will make it easier for everyone to comprehend clutch plate thermal analysis and how friction plates operate more effectively. ANSYS 19.2 was used for modelling and thermal analysis.

Index Terms—**Clutch, friction plate, flywheel, thermal analysis and wear resistance**

I. Introduction

Clutch friction plates are essential components in automotive and mechanical transmission systems, responsible for transmitting torque while managing friction, heat, and wear. Material analysis is crucial to evaluate performance, durability, and compliance with safety and environmental standards. Here aim is on identifying material composition, properties, and potential improvements for enhanced system stability, particularly in vehicles under varying loads and conditions.

Common applications include passenger cars, heavy-duty trucks, and industrial machinery, where failures can lead to inefficiencies or safety issues. Thermal analysis of clutch plates is crucial to predict and mitigate heat-related failures during engagement and slip. It ensures reliable performance under high thermal loads in automotive applications. Clutch plates generate significant frictional heat during slip, with temperatures rising rapidly to 200-400°C or higher in repeated cycles. Accurate temperature distribution mapping prevents hotspots that degrade friction material.

Main advantages of a single plate clutch:

Simple construction: Fewer parts than multi-plate or cone clutches, so it is easy to design, manufacture, assemble, and understand for maintenance.

Smooth engagement: Provides smooth and gradual engagement, giving comfortable gear shifting and good drivability.

Low cost: Cheaper to produce and repair than multi-plate or more complex clutch systems.

Less maintenance: Fewer components and a dry, open design mean relatively low maintenance requirements in normal service.

Low power loss: Very little slip after engagement, leading to low power loss and good transmission efficiency.

Less heat generation: Only one friction plate, with ample surface area exposed to air, so heat generation is lower and heat dissipation is better compared with multi-plate clutches in the same duty.

Fast response: Engagement and disengagement are quick, which aids faster gear shifting and good vehicle response.

Compact and lightweight: For a given torque range of normal cars, buses, and trucks, the single plate clutch is relatively compact and light, helping overall vehicle performance.

II. Literature Review

In a wet multidisc clutch, Zagrodzki et al. [1] simulated unstable thermoelastic friction system behaviour (caused by material composition and geometry failures). They discovered that, taking manufacturing constraints into account, thermoelastic stability can be enhanced by reducing the thickness of the steel disc, and hotspots can be managed by the modulus of elasticity.

Because shrinkage affects surface and thermal qualities, curing may be the most important and unpredictable step in the production process for determining the final shape. The resin of friction composites exhibits volume shrinkage due to chemically induced shrinkage, which obviously affects the warpage phenomena and residual stresses as described by Xiong J.J. [2]

However, Menday et al. [3] discovered evidence that the behaviour of dry-friction clutch facings can be impacted by fatigue response. They demonstrated that if the gradient of the change in the coefficient of friction of the friction face during lifetime stays positive or at least 0, judder—an undesired axial vibration that happens as an impact load—is less likely to damage the transmission system.

Patel et al. [4] talked about the wear formation on several clutch materials and their specifications in this project. Additionally, in order to find the optimal material for the clutch's friction plate, several material specifications were examined. They used the Pin-on-disk test method to do wear analysis based on load. Additionally, wear resistance can be quantitatively compared using wear rate.

Pin-on-disc and dynamometer tests are the primary methods used in this analysis to analyze wear. The findings show that while organic materials provide adequate friction and comfort, they are more prone to wear and fade at higher temperatures than metallic or composite facings. According to Patel et al., metal-matrix composites and sintered iron facings can greatly enhance wear performance and thermal resistance, but they may also raise costs and put more strain on the mating surface. In order to establish the multi-criteria nature of clutch friction-material selection, the article concludes that material selection must balance friction stability, wear resistance, thermal capacity, manufacturability, and cost.

Coupling between volume variation and thermal gradients was considered by Nawab et al. [5] for modelling residual strains and stresses to investigate chemical shrinkage of thermoset polymers. They concluded that, since for an equal mass the chemical shrinkage of fibre carrying resin is less than that of neat resin, composite material residual stresses resulting from shrinkage are hindered by fibres.

Jang et al. [6] demonstrated the change in hotspot position upon cooling in a frictional sliding system using a thermo-elastoplastic instability (TEPI) using a two-dimensional contact problem-solving transient finite element simulation.

The wide range of components that make up modern hybrid composites makes it difficult to identify and characterize them. These elements of a hybrid composite material are often grouped according to their mechanical function and functionality.

Even reinforcing fibers are crucial when it comes to tribological friction and wear characteristics as described by Zhang X. et al. [7] However, a single component typically impacts many distinct characteristics in addition to the intended feature.

Mello et al. [8] investigate hybrid polymer composite clutch facings typical of modern dry single plate automotive clutches. They develop a micromechanical model to predict effective elastic and thermal properties starting from the constituents (fibres, fillers and resin) and validate it with experimental measurements. The work focuses on dry friction hybrid polymer composites designed to provide stable friction, good thermal tolerance and structural integrity under cyclic loading.

Mello (Biczó, de Mello, Belingardi and Gola) conclude that their work successfully provides a complete mechanical and thermal description of a modern dry friction hybrid polymer composite clutch facing. They identified fibre reinforced hybrid composite exhibits anisotropic expansion, stable specific heat over the operating range and moderate thermal conductivity (≈0.4 W/m·K), all of which are suitable for use in thermo mechanical modelling of clutch facings. Their results indicate that appropriate combinations of reinforcement type, orientation and volume fraction can enhance thermal conductivity without excessively increasing stiffness, improving heat dissipation and reducing local thermal gradients.

This line of study is expanded upon by Németh et al. [9] who investigate the precision of mass difference-based wear measurement for dry clutch friction plates. They examine the effects of specimen handling, test circumstances, and measurement uncertainty on the accuracy of mass-loss data, which is frequently used to estimate clutch material wear. Their results highlight the need for a meticulous experimental technique for meaningful material comparisons and the possibility that minor mass losses at early wear stages could be equivalent to measurement noise.

A structural analysis of a single-plate friction clutch is carried out by Mane and Naik [10], who describe the maximum stresses and displacements under normal engagement loads. They show that while local stress concentrations may still affect fatigue life and wear at the interface, the clutch plate is often safe against yielding for ordinary steels. In order to measure torque capacity and engagement characteristics, Kedar and Patil integrate design calculations with practical research of a single-plate clutch, which may be used as a standard for verifying torque capacity and engagement characteristics with validating simulations.

Kedar and Patil [11] conclude that changing clutch plate and lining materials has a significant effect on stress and deformation, and therefore on durability and performance of a single plate clutch. In their work, materials such as Kevlar based or ceramic linings on suitable steel plates show lower deformation and acceptable stress levels compared with conventional grey cast iron. They also emphasise that finite element analysis is a practical tool to compare candidate materials before fabrication, helping engineers to select friction and plate materials that enhance clutch life.

III. Objectives

The specific objectives of this project are as follows:

To build a 3D model of the clutch friction plate incorporating real geometrical dimensions.

To conduct a static structural and transient thermal analysis in ANSYS 19.2 software.

To determine equivalent elastic strain and maximum principal elastic strain of the friction plate.

To determine the temperature distribution on friction plate, analyze the thermal

characteristics like heat flux, directional heat flux.

IV. Plan of Work

1. Design single plate clutch friction plate, choose suitable plate and facing materials, and evaluate structural and thermal behaviour.

2. Select a baseline clutch (existing vehicle or standard design) and perform analytical calculations.
3. Modelling and material selection: Choose material for clutch plate and friction lining (e.g., structural steel)
4. Create 3D model of the clutch friction plate in Ansys Spacelaim.
5. Numerical analysis (structural, thermal) : Perform static structural and transient thermal analysis (FEM) in ANSYS by importing the model to obtain stresses, strains and heat flux.

V. Methodology

5.1 Modelling

ANSYS R19.2 was used to model the solid friction plate in three dimensions.

The dimension of the clutch friction plate were determined to be standard, and this model serves as the foundation for the project's future development. The friction plate's outer flange thickness was fixed at 10 mm. Figure 1 shows 3D model of Clutch Friction Plate.

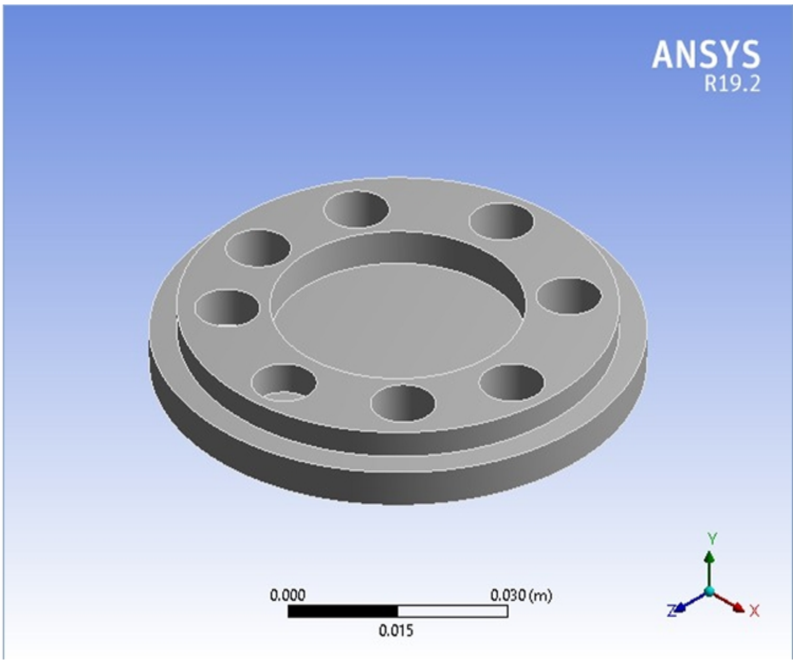

Figure 1: Shows 3D Model of Clutch Friction Plate

5.2Meshing

The meshed clutch plate model for the thermal analysis procedure is displayed in Figure 2. The clutch plate model was tampered with in ANSYS for study. This meshing uses 6231 elements and 8670 nodes. To obtain the detailed result, the model is meshed and analysed.

This is crucial since the temperature rises dramatically in this area due to high contact friction. In order to obtain the precise and accurate result of the contact surface stress, the model is meshed and then analysed.

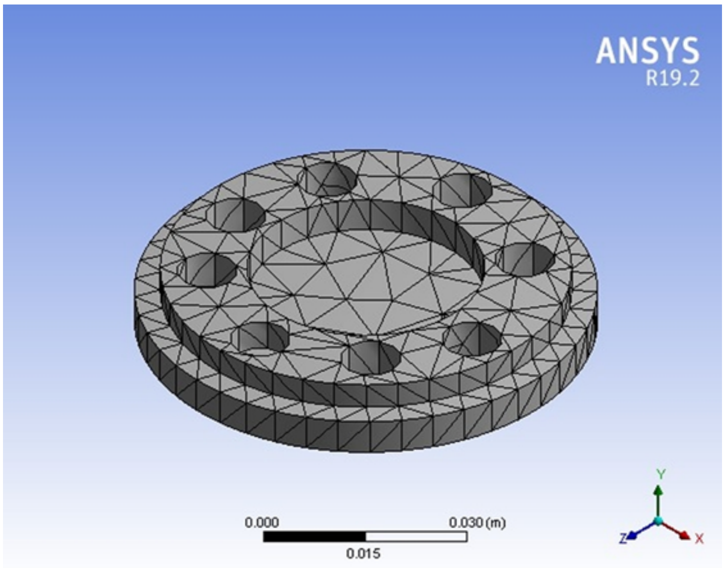

Figure 2 Mesh Model of clutch friction plate

VI. Results and Discussion

A transient thermal analysis of the clutch friction plate was carried out for the operating conditions of a constant pressure of 4 MPa and an angular velocity of 100 rad/s during the clutch operation in order to validate the model. It was assumed that the system's neutral temperature was 32°C . For the single plate clutch application, the ANSYS simulation is acquired. When driving at a constant speed, the system’s engagement time is assumed to be one second. The analysis's findings are contrasted for the model’s transient thermal and structural behaviour. Lastly, a model with the desired property values is proposed.

Figure 3 Represents Directional Heat Flux in the Clutch Plate

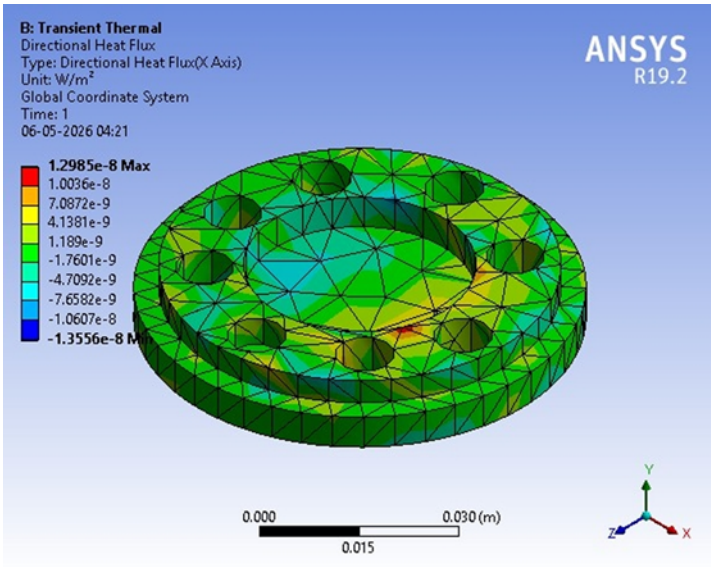

Figure3: Directional Heat Flux

Figure 4 Represents Equivalent Elastic Strain in the Clutch Plate

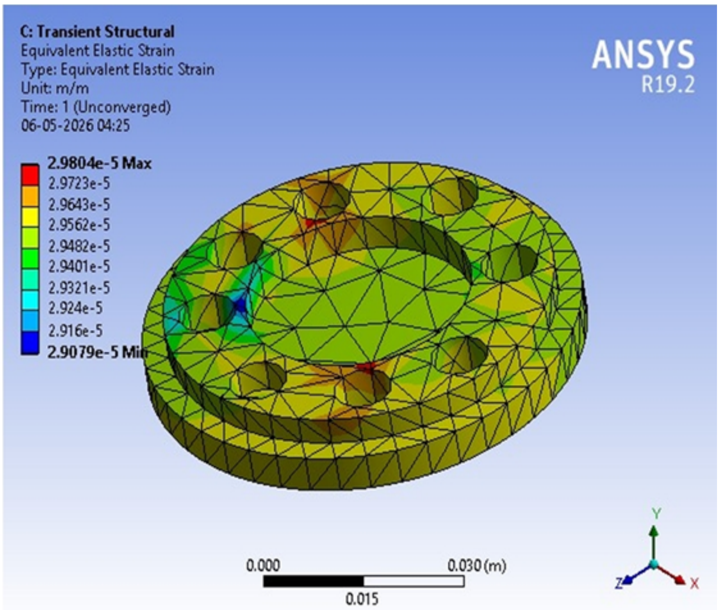

Figure 4 : Equivalent Elastic Strain

Figure 5 shows Total Heat Flux in the Clutch Plate

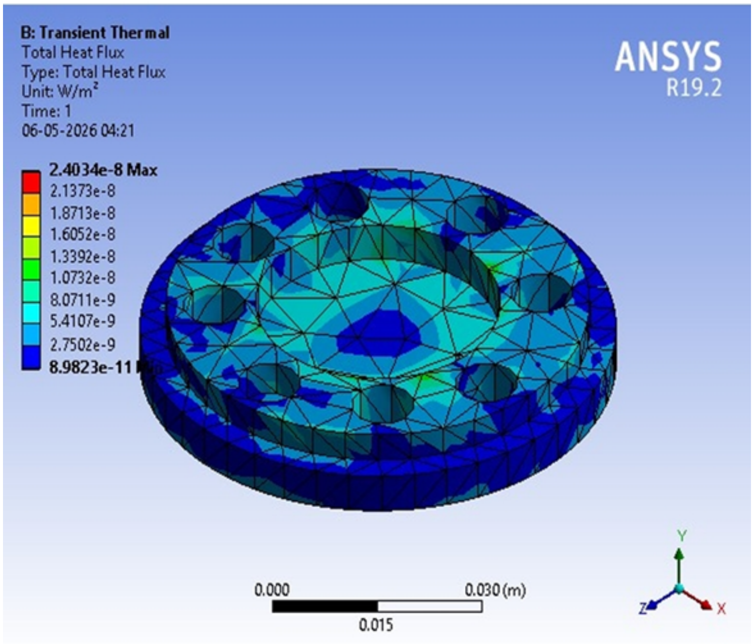

Figure 5: Total Heat Flux

Figure 6 shows Maximum Principal Elastic Strain in the Clutch Plate.

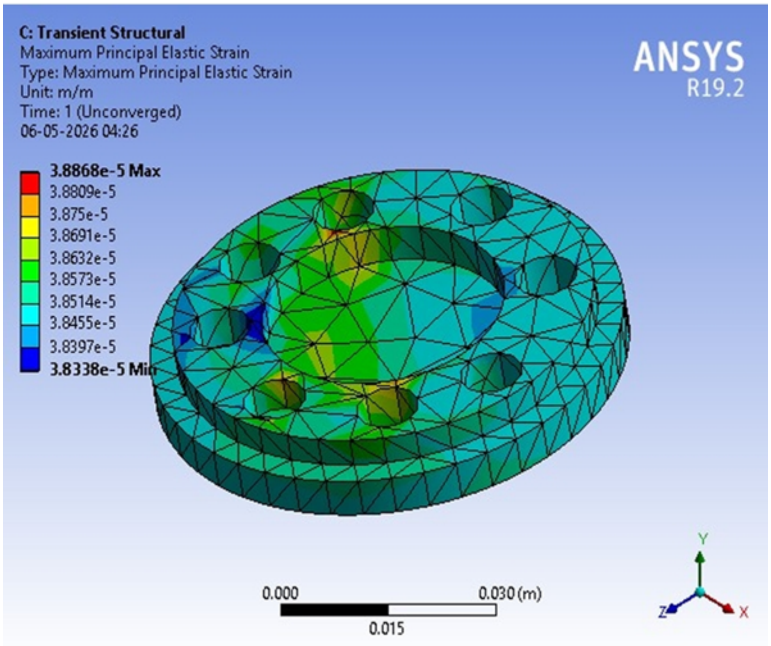

Figure 6 : Maximum Principal Elastic Strain

Figure 7 shows Rotational Velocity vs. Time graph

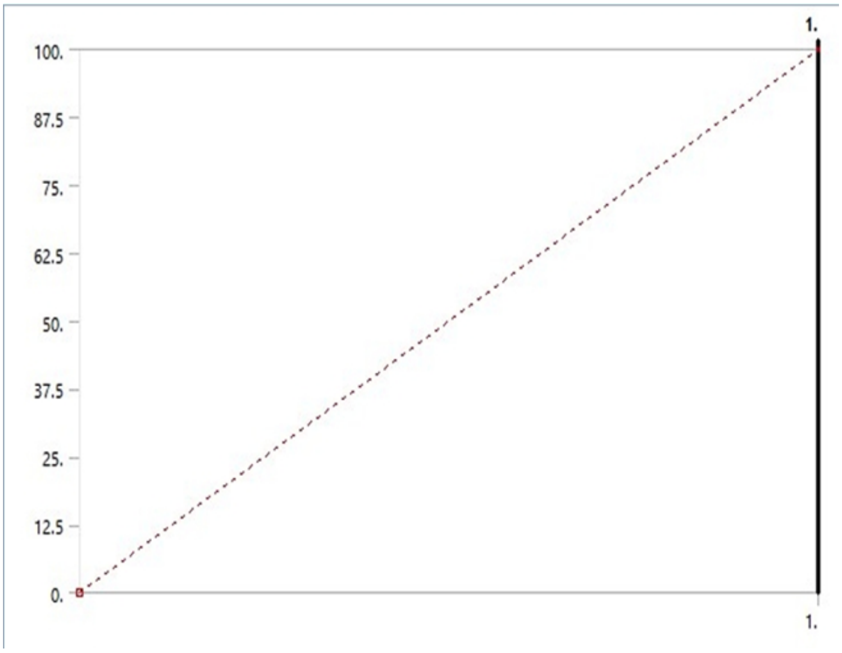

Figure 7: Rotational Velocity vs. Time

Figure 8 shows Directional Heat Flux vs. Time graph

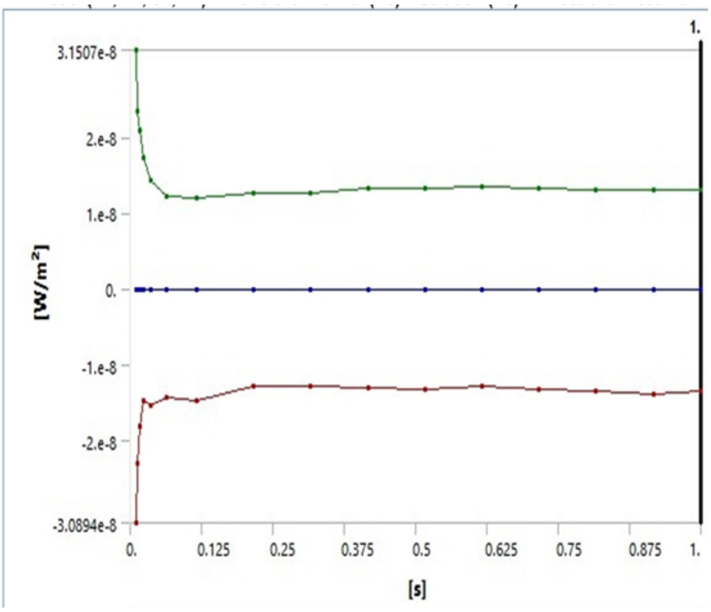

Figure 8: Directional Heat Flux vs. Time

Figure 9 depicted Total Heat Flux vs. Time graph

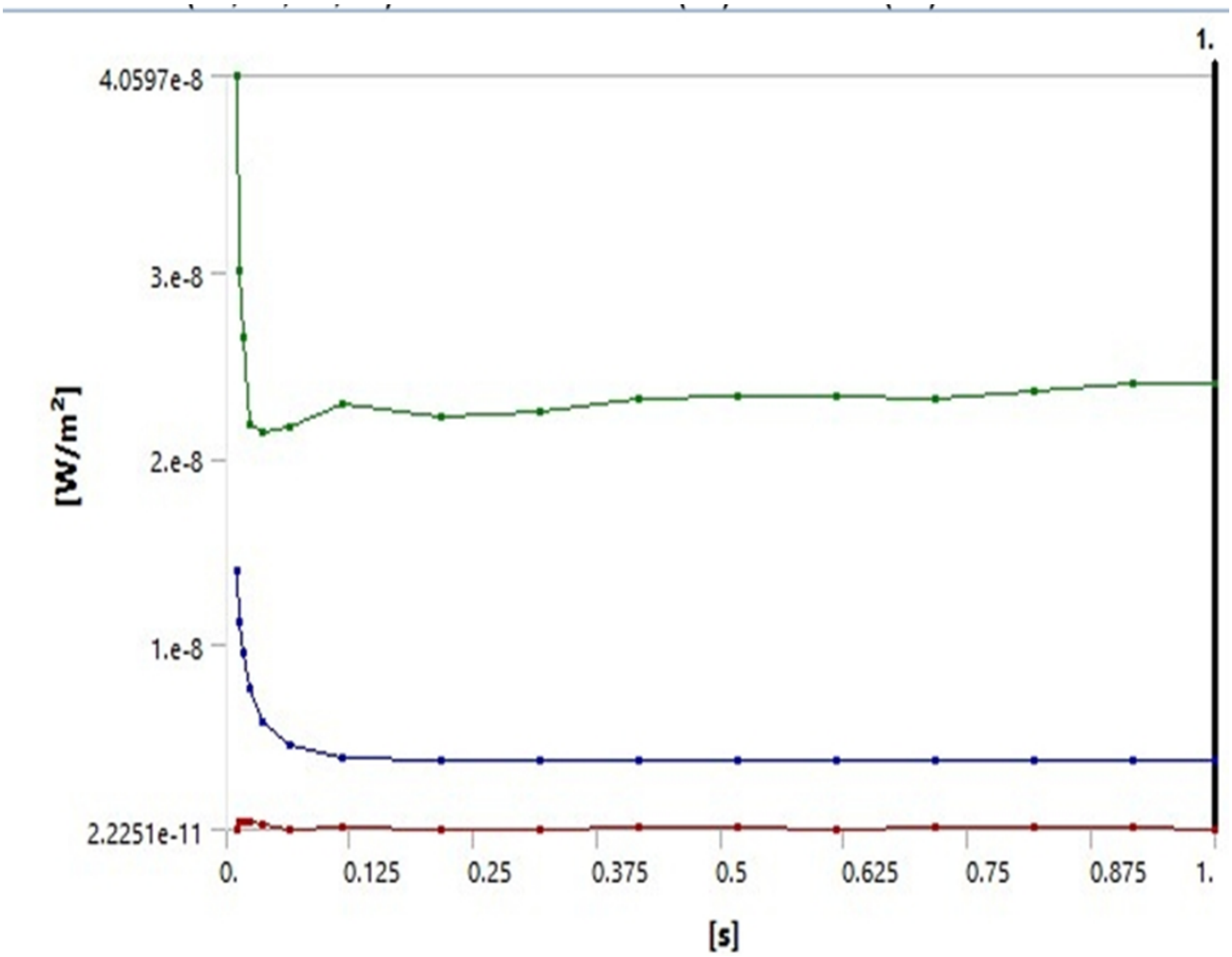

Figure 9: Total Heat Flux vs. Time

Table 1 shows different Parameters and their Maximum and Minimum Values

SI. NO.	PARAMETER	MAXIMUM VALUE	MINIMUM VALUE
I.	DIRECTIONAL HEAT FLUX	0.0000024034 W/MM2	-0.00000013556 W/MM2
II.	TOTAL HEAT FLUX	0.0000024034W/ MM2	0.000000089823 W/MM2
III.	EQUIVALENT ELASTIC STRAIN	O.000029804 w/mm2	0.000029079 w/mm2
IV.	MAXIMUM PRINCIPAL ELASTIC STRAIN	0.000038868 w/mm2	0.000038338 w/mm2
V.	ROTATIONAL VELOCITY	100 rad/s	0 rad/s

Table 1 : Different Parameters and their Maximum and Minimum Values

VII. Conclusion

This project's main objective was to use ANSYS 19.2 to assess the structural and thermal performance of a car clutch friction disc. Under specified running conditions, a realistic three-dimensional model of a friction plate was created, meshed, and put through steady-state thermal and static structural analysis. The outside flange, where there is the most frictional contact, has the greatest reported temperature. showing no appreciable warping or bending when stresses are applied. Heat flux measurements show that the clutch plate efficiently drains frictional heat, which is necessary to prevent wear and sustain engagement and disengagement without slip. Temperature, stress, deformation, and heat flux all remained within allowable bounds, indicating that the existing friction disc design is robust and dependable under typical driving circumstances. In summary, this project effectively illustrates how real-world clutch engagement scenarios can be studied using finite element analysis (FEA) using ANSYS without the need for costly physical prototyping. The results highlight the significance of appropriate design and material selection in controlling thermal loads and guaranteeing structural integrity.

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