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THERMAL ANALYSIS ON DISC BRAKE ROTOR

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ABSTRACT

A Brake is a device by means of which artificial frictional resistance is applied for stopping a moving vehicle. In disc brake rotor is the component on which the pads are squeezed on when brake pedal is applied. Disc brake rotors are subjected to both mechanical and thermal stresses. The cyclic thermal stress is more significant as the heat generated due to friction must be dissipated to the surrounding. In this study three types of disc brake rotors are selected to investigate the Thermal analysis of the disc brake rotors. The main objective of the study is to investigate and analyze the Thermal analysis of disc brake rotor analytically and numerically. accordingly, the results obtained from the finite element analysis by ANSYS Workbench are validated by analytical calculation of the disc brake rotor. The Analysis of thermal behavior of disc brake develops a three-dimensional (3D) thermo-structural coupling model, implements transient thermal analysis and static structural analysis of disc brake profiles with a frictional heat variation.

Keywords: Transient Thermal Analysis, ANSYSs, Solid Works.

I. INTRODUCTION

Background of the brake system

A brake is a device by means of which artificial frictional resistance is applied to a moving vehicle to retard or stop the motion of a vehicle. In the process of retarding or breaking the brake's function is to take the kinetic energy of the moving member. The energy absorbed by the brake is dissipated in the form of heat. The heat is emitted to the ambient air so that excessive heating of the brake lining does not take place. Brakes are one of the most significant safety systems in any automobile. Functioning of brakes is based on the conservation of energy.

Brake System Description

Disc brakes are used on the front wheels and in most cases also on the rear wheels. The key purpose of a disc brake system is to retard the vehicle by converting the kinetic energy of the car into thermal energy by means of friction between the disc rotor and the pads.

II. LITERATURE REVIEW

Byeong-choon and Choong-hwan studied the thermal fatigue of cast iron brake disc materials. This paper investigates brake discs made of cast-iron with high heat resistance to thermal shock loading in order to develop three candidate materials. The main components were Fe, C, Si, Mn, Ni, Cr, Mo, Cu and Al. The mechanical and thermal properties of the candidates were measured. After doing the above literature survey it is decided that the dissertation work is to develop for weight optimization of disc and increase cooling effect with compared to the existing disc and make modifications for further weight reduction and cooling effect.

Tirovic, and Ali (2001) published a paper regarding friction brakes. The study focuses on friction brakes that are exposed to extremely high mechanical and thermal stresses. Clamping, friction and centrifugal forces and brake acceleration in different direction are the causes for mechanical load generation. Thermal stress is caused by frictional heat generation on the brake friction surface. The paper elaborates the thermal loads that are usually critical mechanical loads which are also difficult to predict accurately. The paper has concluded that the design process for most brake concepts must focus on thermal loads.

Samie and Sheridan studied the effects of contact friction on the distribution of pressure between the pads and the rotor with a floating caliper under using finite element method. The Analytical results by neglecting the frictional forces (static case) showed that the inner and outer pressure distributions varied because of the normal force acting were different on the piston and finger sides of the floating caliper. Considering the friction

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forces in to account the pressure distributions were different from the static case due to the moment setup between the abutment and the friction interface.

Talati, Faramarz (2009) published a paper which investigates heat conduction in a disc brake system. In this paper transient heat equation that is dependent to space and time was used to extract the governing equations of heat for the disc and the pad. Parameters including duration of the braking, geometry, dimensions of the brake, materials of the brake, contact pressure, and vehicle velocity have been taken into consideration. Green's function approach was used to solve the problem analytically. The paper concluded that, heat generated due to the friction between the pad and the disc rotor ideally dissipated to the ambient environment to avoid the temperature rise of the brake system component and brake fluid vaporization due to excessive heating

III. METHODOLOGY

METHODOLOGY OF RESEARCH

This research has been started after reviewing different literatures written about disc brakes. Journals have been cited to get information about the current state of art of the brake discs. Information regarding dimension, material selection and design of brake discs have been collected.

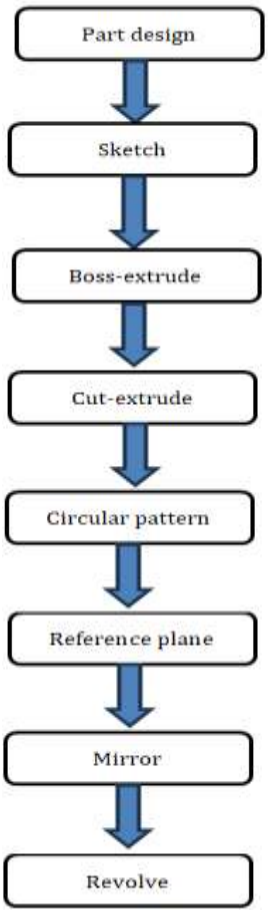
BRAKE ROTOR MATERIAL COMPOSITION

High thermal conductivity, good wear resistance, high thermal diffusivity, and low production cost compared to other disc brake materials make gray cast iron preferable for disc brake rotor.

PROPERTIES OF MATERIAL

The properties of gray iron are primarily dependent on its composition. Normally, cast iron contains two main elements: graphite (carbon) flakes and matrix of ferrous metal. Both constituents have a significant impact on the stress-strain response of the material. This is due to the weak bonding between the graphite flakes and metal matrix which causing gaps or voids to open in the material under tension.

SOLIDS WORK



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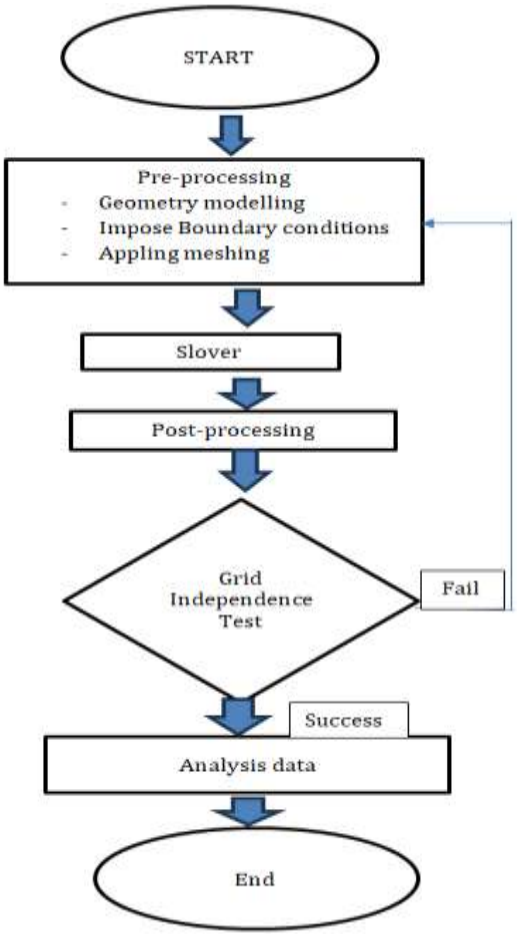

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IV. MODELLING AND ANALYSIS

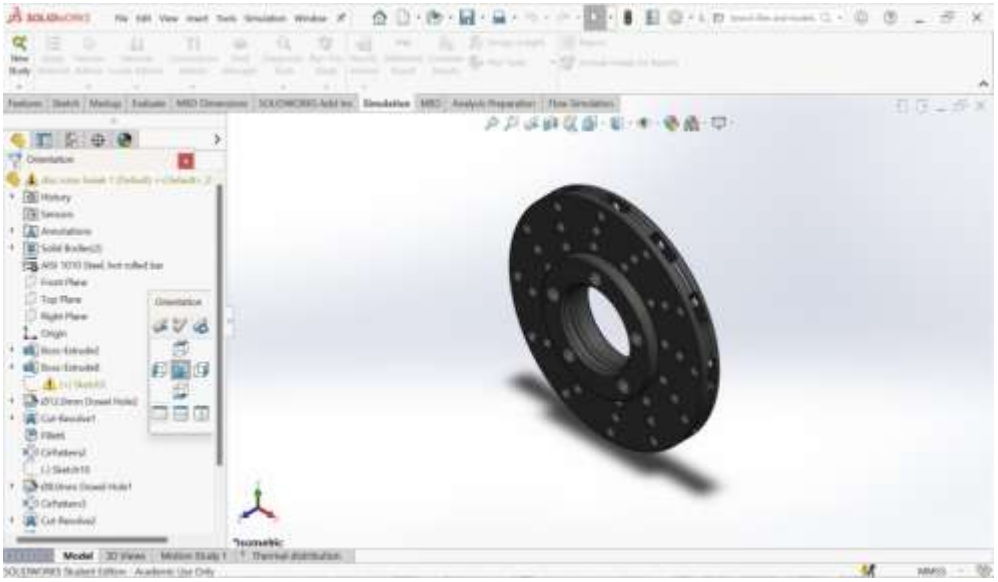

Fig 1: 3D view of disc brake rotor.

This project involves developing a 3D CAD model of disc brake rotor in SOLIDWORKS, a software popular in mechanical engineering for its precision and efficiency in design. Once the CAD model was completed, it was exported to ANSYS for an in-depth analysis. ANSYS, known for its robust simulation tools, enabled a finite element analysis (FEA) to predict the model's real-world performance. The process involved defining boundary conditions and applying loading scenarios to examine the temperature distribution.

TRANSIENT THERMAL ANALYSIS

A transient thermal analysis examines how temperature changes over time within a model when subjected to time-dependent heat loads or varying boundary conditions. It captures how heat diffuses and impacts temperature gradients within the material, allowing for the study of temperature evolution and transient heat effects, such as those seen in a brake disc during and after braking. This analysis requires defining time-stepped heat loads and boundary conditions.

STEADY STATE THERMAL ANALYSIS

The steady-state thermal condition of a disc brake rotor is the point at which the temperature distribution across the rotor remains constant over time. This occurs when the heat generated from braking friction is balanced by the heat dissipated through conduction, convection, and radiation. In steady-state, the rotor's temperature no longer fluctuates with each braking cycle but stabilizes, reflecting the average thermal load. This analysis is critical for ensuring that the rotor material and design can handle consistent braking demands without overheating

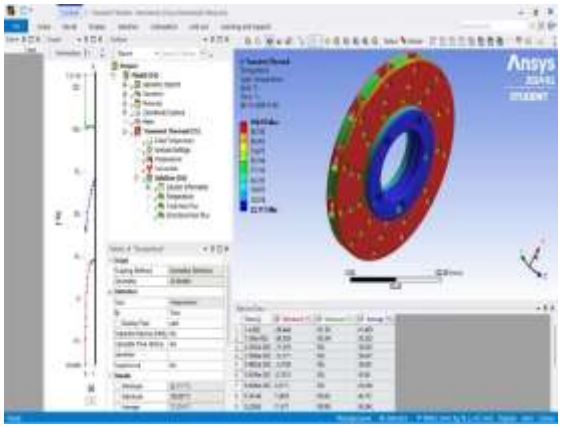

Fig 2: Transient Thermal Analysis

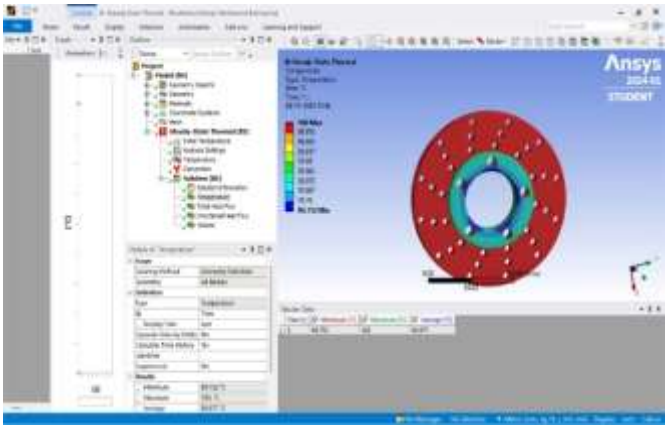

Fig 3: Steady State thermal Analysis

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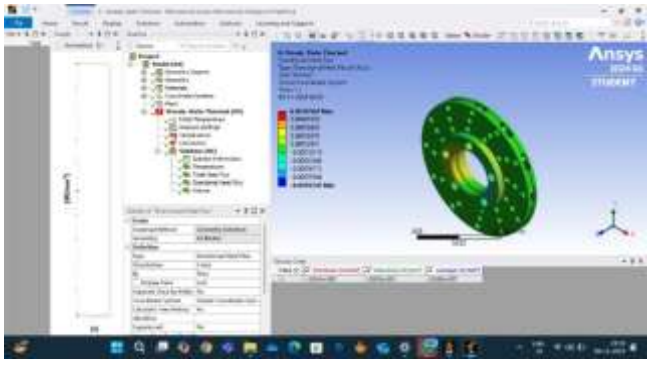

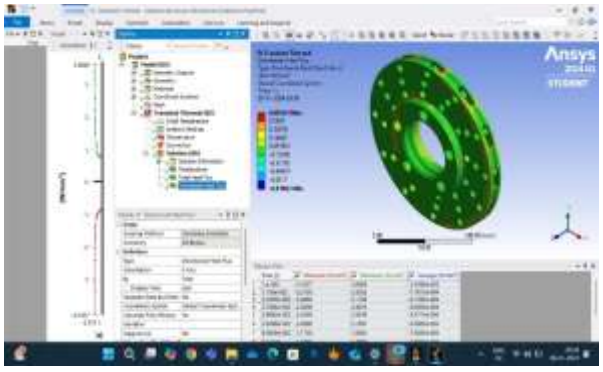

Fig 4: Directional Heat Flux of Steady State Analysis **Fig 5:** Directional Heat Flux of Transient Thermal Analysis

V. RESULT AND DISCUSSION

S.NO	Condition	Temperature		Heat flux	
		Max	Min	Max	Min
1.	Steady state	100.05	22.117	0.0010502	-0.0010241
2.	Unsteady state	100	99.752	0.68361	-0.6175

VI. CONCLUSION

The Thermal analysis of transient thermo-mechanical properties of disc brake have been studied, comparison between the analytical and numerical analysis has been made and consistent result has been found. The finite element analysis has been performe.d with the same methodology to assess the performance of the various types of the disc brake rotor profiles.

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