Thermal Analysis on Disc Brakes

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***Abstract*—Braking system is one of the most essential functions of an automobile. Therefore, it is a must for all vehicles to have proper brake system. Due to critical system in the vehicle, many of researchers have conducted a study on brake system and its entire component. In this project, we has conducted a study on normal & drilled disc brake rotor of normal passenger vehicle with full load of capacity. The study is more likely concern of heat and temperature distribution on disc brake rotor .The motive of undertaking this project of "Thermal Analysis of Disc Brake" is to study and evaluate the performance under severe braking conditions and there by assist proper design of disc rotor out of thermal analysis. Transient state response has been conducted through the heat transfer analysis where to predict the worse case scenario and temperature behaviors of disc brake rotor. In this study, finite element analysis approached has been conducted in order to identify the temperature distributions and behaviors of disc brake rotor in transient responses. Ansys has been used as finite elements software to perform the thermal analysis on responses. Thus, results provide better understanding on the thermal characteristic of disc brake rotor and assist the automotive industry in developing optimum and effective disc brake rotor.**

Keywords: Disc Brake, Ansys, Temperature, Solid works

I.INTRODUCTION

Brakes are most important safety parts in the vehicles. Generally all of the vehicles have their own safety devices. Brakes function to slow and stop the rotation of the wheel. To stop the wheel, braking pads are forced mechanically against the rotor on both surfaces. They are compulsory for all of the modern vehicles and the safe operation of vehicles. In short, brakes transform the kinetic energy of the vehicle into heat energy, thus slowing its speed.

The braking system must be decelerate a vehicle in a controlled and repeatable fashion and when appropriate cause the vehicle to stop. The braking should permit the vehicle to maintain a constant speed when traveling downhill. The braking system must hold the vehicle stationary when on the flat or on a gradient.

Nowadays, there are lot of software has been developed in order to cater the modeling and the finite element analysis on the vehicle component such as (Automatic Dynamic of Mechanical Systems), SOLIDWORKS, ANSYS. There is an advantage of using that powerful computational analysis software where by using those would make it easier, less cost better accuracy and less computing time. Most of the software is used in the wide range of industries such as automotive, oil and gas, aerospace, marine, heavy duty engineering, construction, electro-mechanical and general mechanical industries. In this project, design package SOLIDWORKS and finite element package will be used to generate model and run analysis on the chosen component.

II.STATEMENT OF PROBLEM

Beside overall automotive parts, like engines, there are more crucial parts that engineers need to look into consideration. Suspension, brake, electrical, hydraulic and gear are all the crucial systems in the automotive areas. Each of the parts has their own functionality which brings life to the automation industries. Brakes are the crucial system in stopping the vehicle on all moving stages including braking during high speed, sharp cornering, traffic jam and downhill. All of those braking moments give a different value of temperature distribution and thermal stress. Good performance of disc brake rotor comes from good material with better mechanical and thermal properties. Good designs of disc brake rotor are varying across the range of the vehicles. There are different design and performance of disc brake rotor if compared between passenger, commercial and heavy duty vehicle. There are also other constraints such as cost, weight, manufacturing capability, robustness and reliability, packaging, maintenance and servicing.

This paper concerns of the temperature distribution and constraint of the disc brake rotor. Most of the vehicles today have disc brake rotors that are made of grey cast iron Grey cast iron is chosen for its relatively high thermal conductivity, high thermal diffusivity and low cost . In this paper, we will investigate on the thermal issues of normal two wheeler motor vehicle disc brake rotor, where the investigation is to determine the temperature behavior of the disc brake rotor due to severe braking of the disc brake rotor by using Finite Element Analysis (FEA).

Braking performance of a vehicle can be significantly affected by the temperature rise in the brake components. High temperature during braking will caused to Brake fade, premature wear, Brake fluid vaporization, Bearing failure, Thermal cracks, Thermally-excited vibration. Therefore, it is important to study and predict the temperature rise of a given

brake component and assess its thermal performance in the early design stage. Finite element analysis (FEA) has been preferred and chosen method to investigate some of the above concerns such as disc brake rotor temperature rise and thermal cracks.

III.RESEARCH METHODOLOGY

Begin with a literature review, a lot of paper and journal has been read up and a part of it has been considered in this paper. Meanwhile, vernier calipers and steel rule used to measure the major coordinate of real disc brake rotor. Later, the precise dimensions have been used to translate in 2D and 3D drawing by using SOLIDWORKS.

In the second stage, load analysis has been done where the heat flux and convectional heat transfer coefficients has been calculated. Load analysis calculated based on full load of passenger in the two wheeler vehicle. Later, value of load analysis has been applied on finite element analysis. Next fractional 3D model of disc brake rotor has been transfer to hyper mesh where the inputs are given. Assigning material properties, load and meshing of the model has been done in this stages. Then, completed meshing model has been submitted for analysis. Now the 3D model of disc brake rotor has been transfer to finite element software which is ANSYS. Thermal analysis has been done on transient responses. Finally an expected result from the transient responses of thermal analysis has been obtained.

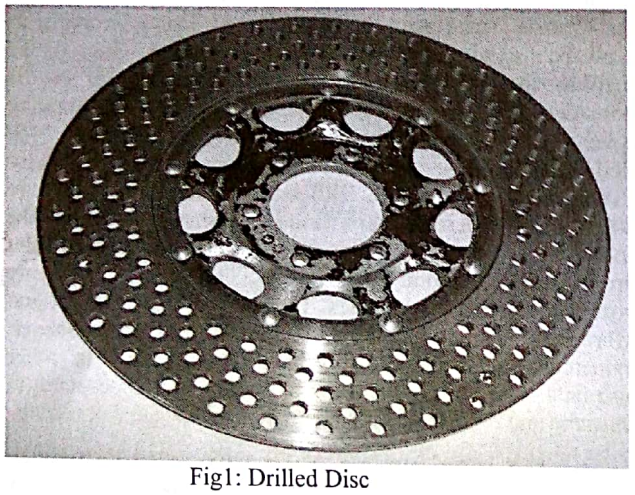

Fig1: Drilled Disc

A. Modeling Softwares

Some of the different software's available for 3D modeling are

- Solid works
- Pro E
- Inventor
- Mechanical desktop
- Unigraphics
- Catia

The Solid Works CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

General Modeling Process for Each Part

- Plan the part
- Create the base feature
- Create the remaining features
- Analyze the part
- Modify the features as necessary

B. Types of modes

3 modes in solid works;

- part modeling
- assembly
- part drawing

C. Part Modeling

A 2D engineering drawing, typically a part or assembly. Parts are the building blocks of every Solid Works model. Each assembly and drawing you create is made from parts.

D. Assembly

A 3D arrangement of parts and other assemblies. In this section, you use the vanity cabinet parts described and built in Parts to build subassemblies, such as the spigot and the faucet handles. Then you bring the subassemblies together to create an assembly, the vanity.

E. Part Drawing

A 3D representation of a single design component. Drawings are 2D documents that convey a design to manufacturing.

IV.THERMAL ANALYSIS

A thermal analysis calculates the temperature distribution and related thermal quantities in brake disk. Typical thermal quantities are

- The temperature distribution
- The amount of heat lost or gained
- Thermal fluxes

A. Types of thermal analysis

- A steady state thermal analysis determines the temperature distribution and other thermal quantities under steady state loading conditions. A steady state loading condition is a situation where heat storage effects varying over a period of time can be ignored.
- A transient thermal analysis determines the temperature distribution and other thermal quantities under conditions that varying over a period of time.

B. Planning the analysis

In this step a compromise between the computer time and accuracy of the analysis is made. The various parameters set in analysis are given below

C. Thermal modeling:

- Analysis type .thermal h-method.
- Steady state or Transient? Transient
- Thermal or Structural? Thermal
- Properties of the material? Isotropic
- Objective of analysis- to find out the temperature distribution in the brake disc
- when the process of braking is done
- Units- SI

D. Modeling and analysis

It is very difficult to exactly model the brake disk, in which there are still researches are going on to find out transient thermo elastic behavior of disk brake during braking applications. There is always a need of some assumptions to model any complex geometry. These assumptions are made, keeping in mind the difficulties involved in the theoretical calculation and the importance of the parameters that are taken and those which are ignored. In modeling we always ignore the things that are of less importance and have little impact on the analysis. The assumptions are always made depending upon the details and accuracy required in modeling. The assumptions which are made while modeling the process are given below

- The disk material is considered as homogeneous and isotropic.
- The domain is considered as axis-symmetric.
- Brakes are applied on the entire both sides.
- The specific heat of the material used is constant throughout and does not change with temperature.
- The kinetic energy of the vehicle is lost through the brake disks i.e. no heat loss between
- The tyre and the road surface and deceleration is uniform.
- The disk brake model used is of solid type.
- The thermal conductivity of the material used for the analysis is uniform throughout.
- Only ambient air-cooling is taken into account and no forced Convection is taken

E. Specifications Of Vehicle And Vehicle Disc

- Manufacturer's Name: KTM-Sport motorcycle AG.
- Model Identification Name : KTM 200 DUKE
- Minimum weight :129.5 kg
- Vehicle weight considered with fuel + person weight : 200kg
- Type of Engine : Four Stroke
- Cubic capacity : 199.50 cc

Brakes

- Type of brake : Disc brakes
- Number of pads per wheel : 2
- Number of calipers per wheel : 1
- Caliper Material : Aluminum Alloy
- Thickness of new disc : 4 ± 0.1 4 ± 0.1 mm
- External diameter of disc : 280 ± 0.3 230 ± 0.3 mm
- External diameter of pads rubbing surface : 280 ± 0.2 229 ±0.2 mm
- Internal diameter of pads rubbing surface : 224 ±0.2 169 ±0.2 mm
- Overall friction length of pads : 68.4 ±0.3 55 ± 0.3 mm
- Number of pistons per caliper : front wheel: 4
- Rear wheel: 1
- Outer Diameter of piston in caliper front wheel: 28 mm rear wheel : 32 mm

Finite Element Formulation for Heat Conduction

Kinetic energy $=0.5m\,(v_1^2-v_2^2)$ J

Heat Generated (Qg) = Kinetic Energy generated / unit breaking time W

Rubbing Surface area of the Rotor & Pad $(A_r) = \pi\,(r_1^2-r_2^2)$ m^2

Heat Flux (q) = Heat Generated / Rubbing Surface area of Rotor & Pad (W/m^2)

F. Modeling Drilled rotor

The 3D modeling of drilled rotor of KTM Duke 200 is done in CAD software - Solid works 2012. It is done in Part modeling mode by considering the dimensions mentioned in the above specification of the vehicle.

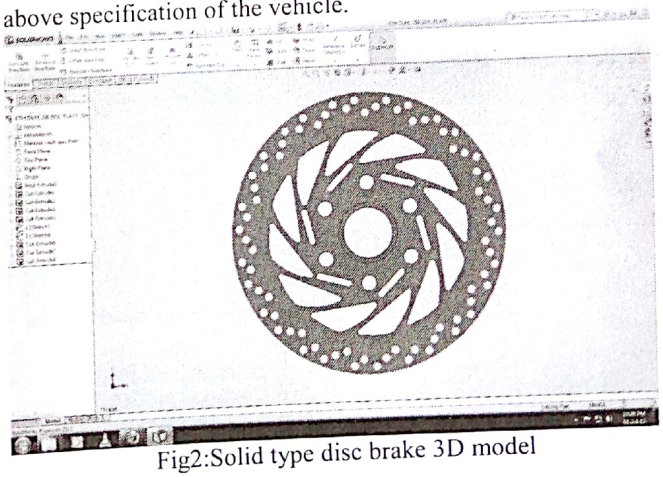

Fig2:Solid type disc brake 3D model

G. Calculations(Drilled Disc)

Weight of the vehicle including body weight = 200 Kg
Velocity of the vehicle (v_1) = 70 KMPH
Velocity of the vehicle is decelerated to (v_2) = 20 KMPH
Braking time = 4 sec
Kinetic energy = 0.5 x 200 x (19.44^2-5.55^2)
= 34705.5575 joule
Heat generated (Qg) =kinetic energy generated/ braking time
= 34705.5575/4
= 8676.38 watt

Rubbing surface area of pad and rotor (A_r) = area of rotor contact with brake pad – area of drilled holes

$[\pi (d_1^2-d_2^2)/4] - [(\pi d_{drills}^2/4) \times \text{no. of drills}]$
$[\pi \times (280^2-223.8^2)/4] - [(\pi \times 8^2/4) \times 75\text{drills}]$
22237.41- 3769.9 = 18467.50 mm^2 = 0.018467 m^2

Heat flux (q) = heat generated / rubbing area
= 8676.38/0.018467
= 469810 w/m^2

H. Meshing in Hypermesh

The 3d model of drilled rotor which was done in solid works is imported to hyper mesh to proceed for meshing.

Inputs

Material Properties
Material of disc rotor = cast iron (< 4% C)
Density of cast iron (ρ) = 7272 kg/m^3
Young's modulus (E) = $125x10^9$ N/m^2
Specific heat (Cp) = 420 J/kg k
Thermal conductivity (k) = 520. W/m k
Heat flux (q) = 469810 w/m^2

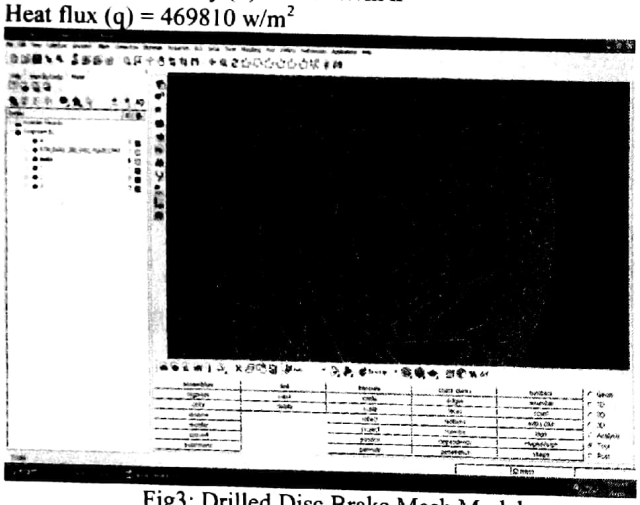

Fig3: Drilled Disc Brake Mesh Model

Number of nodes: 9512
Heat generated per unit element: 471.77

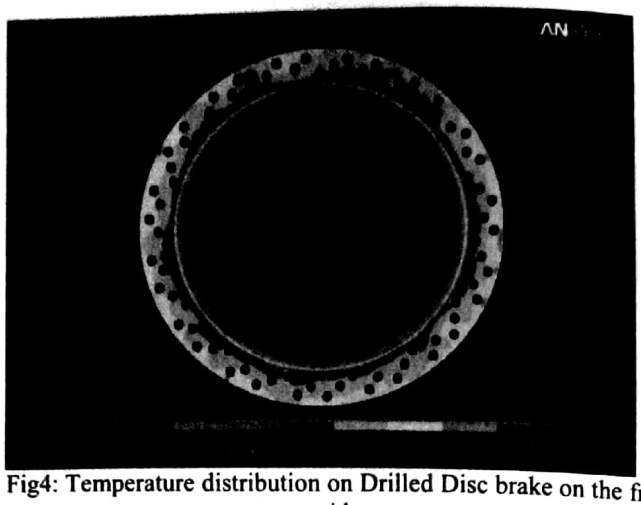

Fig4: Temperature distribution on Drilled Disc brake on the front side

The 3D modeling of drilled rotor of KTM Duke 200 is done in CAD software - Solid works 2012. It is done in Part modeling mode by considering the dimensions mentioned in the above specification of the vehicle.

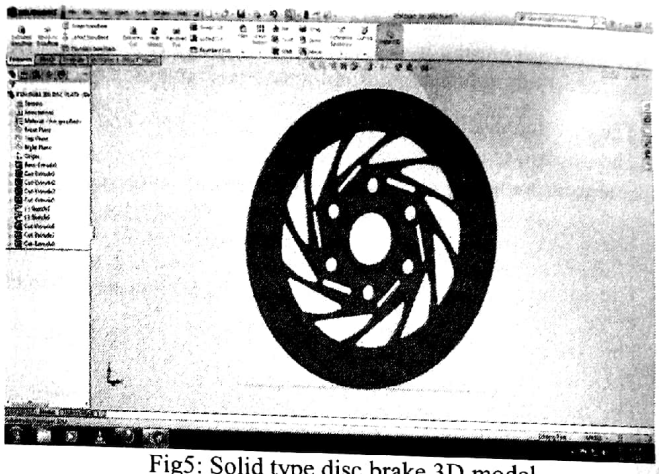

Fig5: Solid type disc brake 3D model

Calculations (Solid Disc)

Weight of the vehicle including body weight = 200 Kg
Velocity of the vehicle (v_1) = 70 KMPH
Velocity of the vehicle is decelerated to (v_2) = 20 KMPH
Braking time (t) = 4 sec
Kinetic energy = 0.5 x 200 x (19.44^2-5.55^2)
= 34705.5575 joule
Heat generated (Qg) =kinetic energy generated/ braking time
= 34705.5575/4
= 8676.38 watt
Rubbing surface area of pad and rotor (A_r) = $[\pi (d_1^2-d_2^2)/4]$
$\pi \times (280^2-223.8^2)/4]$
= 22237.41802mm^2
= 0.0222374102 m^2

Heat flux (q) = Heat Generated / Rubbing Area
= 8676.38/0.0222374102
= 390100 w/m^2

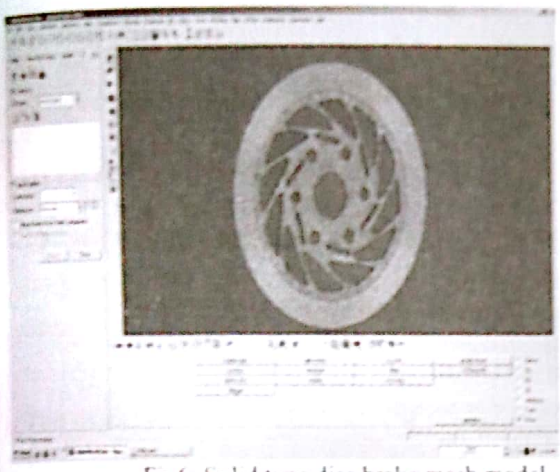

Fig6. Solid type disc brake mesh model

Number of nodes: 11972
Heat generated per unit element: 471.77

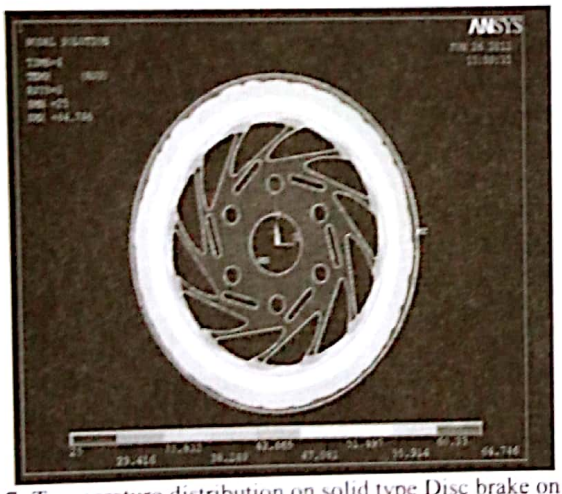

Fig7: Temperature distribution on solid type Disc brake on the front side

V.CONCLUSION

In general discussions, the associates of mechanical engineering opine that more heat is generated in a normal disc is more than in a drilled disc during the braking process. This study provides a clear analysis on the heat generated in both the cases. Nevertheless, More convection can be observed in drilled disk which lead to the above notion.

The present study can provide a useful design tool and improve the brake performance of disc brake system. In this paper we had studied about the process of thermal analysis in disc brake. Here by we studied that the temperature in the drilled disk is more compared to the normal disc.

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