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Finite element analysis of disc brakes for thermal effect

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ABSTRACT

Disc brakes are used to stop or slow down the rotation of the wheel. In this paper, there is discussion regarding heat distribution on the disc brake during the phenomena of braking. Due to change from kinetic energy to mechanical energy heat is been distributed on the disc brake. The reason for Energy change during braking process is friction between the surface of the disc and disc pad. As a result of friction, the temperature rises extremely high. The aim of this study is to perform finite element analysis of disc brake and analyze the thermal effect through examining heat distribution on disc brake using 3-dimensional model. After the analysis, it has been obtained that due to friction between disc pad and disc rotor the temperature rises. Obtained results are used for identifying the effect of heat distribution during the braking process.

Keywords: *Disc Brake, FEM, Thermal, Temperature.*

1. INTRODUCTION

The disc brake is a wheel brake which slows the rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. The disc brake is usually made of structural steel, but may in some cases be made of the composition such as reinforced carbon-carbon or ceramic matrix composition. This is associated with the Wheel or the axle. To stop the wheel, the frictional material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc [1-3]. Disc brake consistence of a structural steel disc bolted to the wheel hub and a stationery housing called caliper. The caliper is connected to some stationery part of the vehicle like the axle casing or the stub axle as is cast in two parts each part containing a piston. In between each piston and the disc, there is a frictional pad held in position by retainment pins, spring plates. The passages are so connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston [4-5].

The main aim of this paper is to investigate and compare the thermal effect of the solid disc brake and ventilated disc brake through Finite Element Analysis.

2. METHODOLOGY

In the analysis, the material of rotor disc is grey cast iron and stainless steel. In general car, accidental cases braking performance is the critical issue. During Analysis heat flux is calculated for a car which is moving with the velocity of 33.33m/s (120 kmph) and the following is the calculation procedure:

- Mass of the vehicle:- 600 kg
- Initial Velocity (u) :- 33.33m/s (120 kmph)
- Vehicle speed at the end of braking application (v):- 0 m/s
- Brake rotor diameter:- 220 mm
- Axle weight distribution of 30% on each side (ϒ) = 0.3
- Percentage of kinetic energy that the disc absorbed (90%) k =0.9
- Acceleration due to gravity = 9.81 m/s^2
- The coefficient of friction for dry pavement (μ) = 0.7

Disc brake generates heat due to friction between surface area contacts of the brake pad. Law of conservation of energy and finite

element methods are two methods which are used for calculation of heat theoretically and numerically.
Law of conservation of Energy is used for calculating continuous heat on both sides of the rubbing surfaces where the kinetic energy of vehicle during motion is equal to lost of heat after the vehicle stop. Finite Element method is used for solving the numerical solution.

The material parameters and properties used in the calculation are shown in Table 1

Table 1. Material Properties

Material	Grey Cast Iron	Stainless Steel
Thermal Conductivity (W/mk)	56	40
Mass type, ρ (kg/m^3)	7400	7200
Specific Heat, c (J/Kg)	447	320
Thermal Expansion, α (10^{-6}/k)	0.18	0.14
Modulus of Elasticity E (GPa)	110	210
Coefficient of friction, μ	0.5	0.5
Heat Transfer coefficient, h (w/km^2)	150	180
Angular Velocity, (rad/s)	80	80
Hydraulic Pressure, P (M pa)	1	1

FEM Model

In this paper, the model of a disc brake is developed for two types which are solid disc brake and ventilated disc brake. The material used is grey cast iron and the thickness of the edge of the disc is varied to 60, 225 and 35 mm. Figure 1 shows the two types of disc brake of thickness 225 mm.

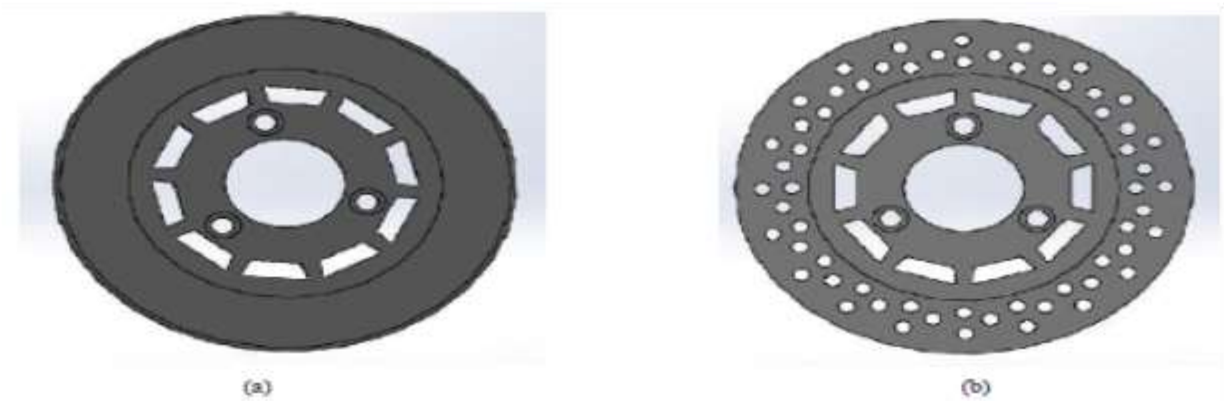

Figure 1. Finite element model for (a) the solid disc brake (b) ventilated disc brake

For providing robust auto meshing is being done and the model is divided into a number of discrete parts. A meshed model is shown in fig. 2. Tetrahedral 3-D elements with 8 nodes were used for the mesh of the model.

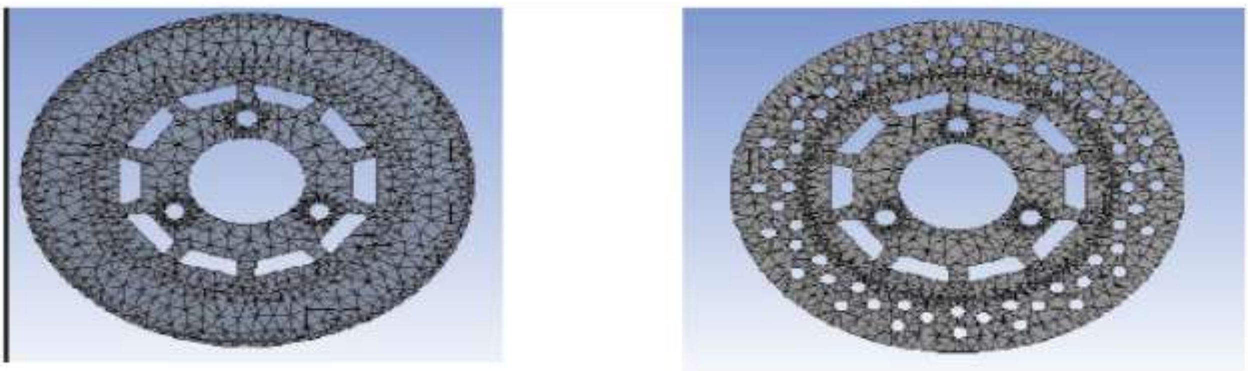

Fig (a) **Fig (b)**

Figure 2. Meshed model for (a) the solid disc brake (b) ventilated disc brake

Thermal Boundary Conditions

After selecting the simulation mode and defining the physical properties and the initial condition of simulation of the material boundary conditions are applied. To investigate the temperature variation of temperature transient thermal analysis is conducted by applying the heat flux 0f 37.632 kW/m^2 for repeated braking. With the pair of thermal analysis included to convective heat transfer coefficient structural analysis is performed to the surface of the ventilated disc shown in Fig.3

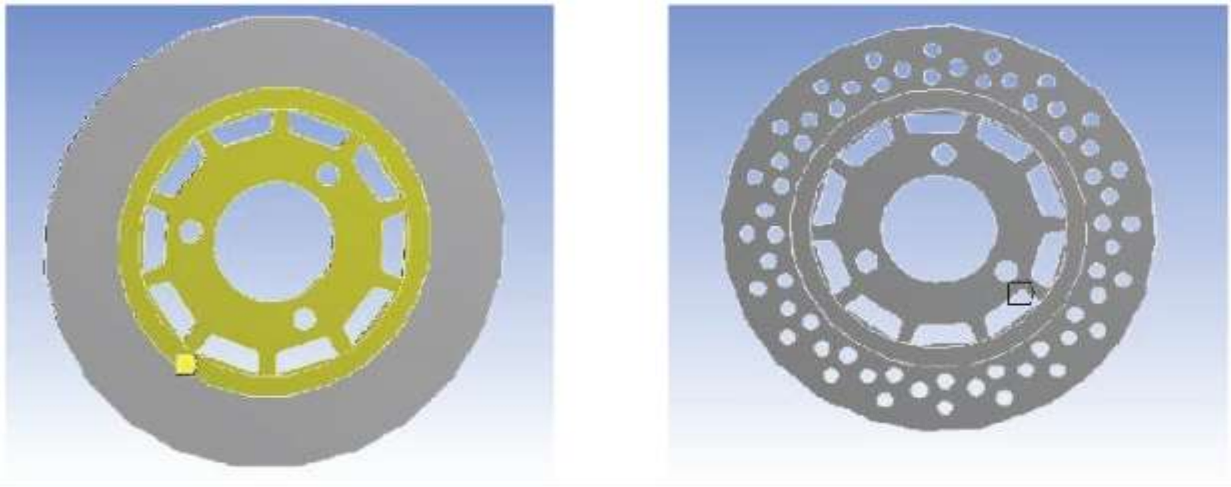

Figure 3. The thermal boundary condition for solid & ventilated disc brake

3. RESULTS AND DISCUSSION

To validate the present model, a transient thermal analysis behavior of a disc brake was performed for the operating condition with the constant hydraulic pressure *P* = 1 MPa and angular velocity ώ= 50 rad/s (drag brake applications) for 10 seconds. FEM simulations are obtained in 6 repeated brake applications. One cycle is composed of a braking time of 4 seconds and constant speed driving. The time step ΔT = 0.001 seconds was used in computations. In each process, the heat flux distributed on the friction surface after the time of *t* = 6 seconds scarcely occurs before the steady state is reached. The hydraulic pressure was assumed to decay linearly and finally becomes zero at 6 seconds. The results were obtained from the analysis and FEM solutions for the transient thermal of the model. Finally, the best model is suggested. In addition, based on disc brake performance, ventilated radial vanes disc brake analysis for cast iron materials was carried out for 6 braking conditions. For the brake discs of the gray cast iron material, the temperature on the surface of the disc brake rises. When braking, the temperature rose to a temperature of 34.869^0 C to 88.026^0 C for solid disc brakes. Similarly, in the ventilated disc brake application, the temperature rose to 73.959^0 C. The maximum temperature rise is shown in red and the green colors indicate the increase in the average temperature on the surface of the friction around the circumference of the disc as shown in Fig. 4 and 5.
For the disc brakes of the stainless steel material, the temperature rises from 34.529^0 C to 293.10^0 C for solid disc brakes. For the application of ventilated disc brakes, the temperature reached 169^0 C. The temperature rise in the maximum temperature rise is shown in red and the green colors indicate the increase in the average temperature of the surface of the friction around the circumference of the disc as illustrated in Fig. 6 and 7.

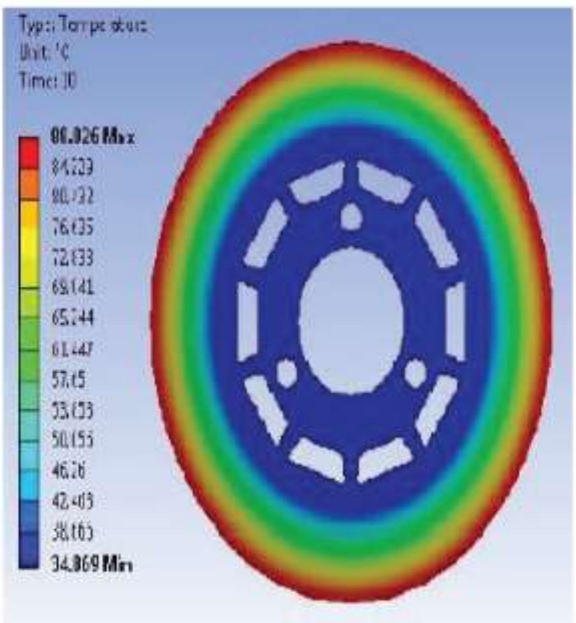

Figure 4.Temperatures of Solid Disc Brakes

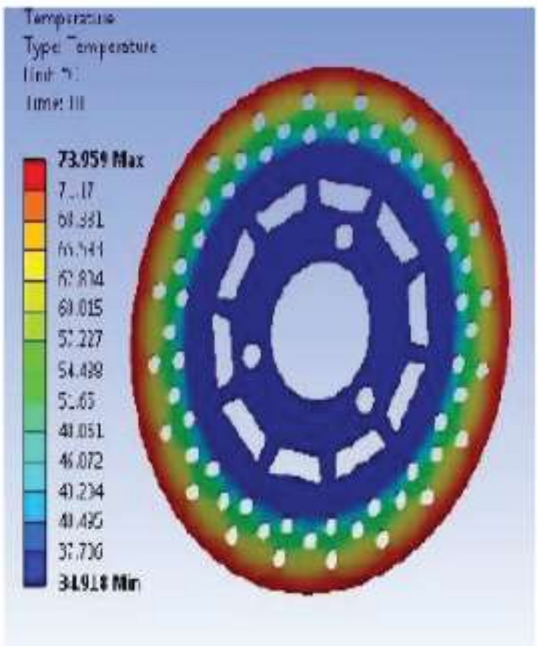

Figure 5. Temperatures of Vent Disc Brakes

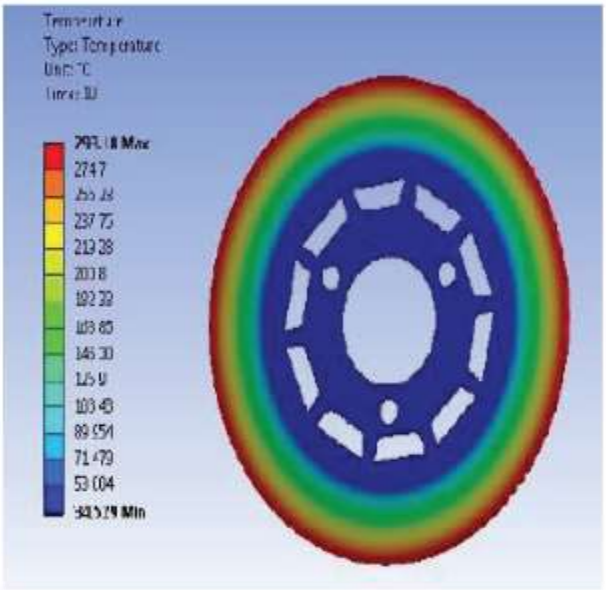

Figure 6.Temperatures of Solid Disc Brakes

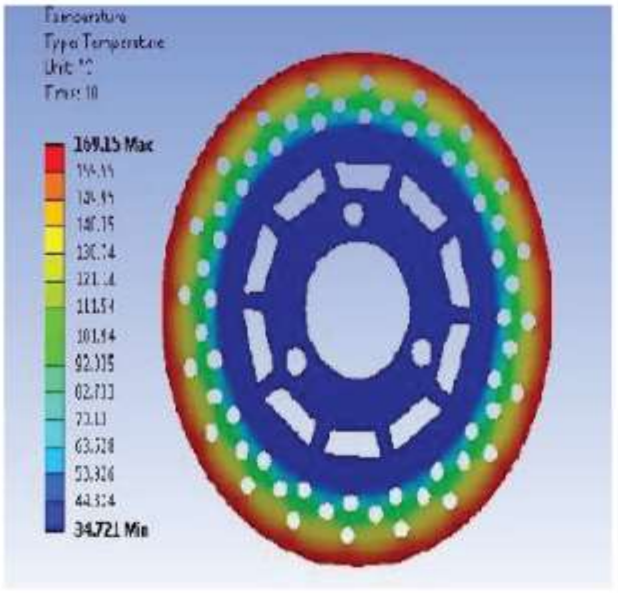

Figure 7. Temperatures of Vent Disc Brakes

4. CONCLUSION

Analysis Result shows that high temperature is generated in both of grey cast iron or stainless steel solid disc brake that is 88.0^{0}C and 293.10^{0}C. But in case of ventilated disc brake, the temperature generated in both of gray cast iron or stainless steel is relatively less i.e 73.9^{0}C and 169^{0}C. It was concluded that the ventilated disc brakes with gray cast iron material are the best for this application.

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