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THERMAL ANALYSIS OF SLOTTED AND DRILLED DISC BRAKE

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ABSTRACT

The current tendencies in automotive industry need intensive investigation in problems of interaction of safety systems with brake system equipments. At the same time, the opportunities to decrease the power take-off of single components, disc brakes systems. When the brakes are applied, a calliper squeezes the brake pads against the disc, slowing down the wheel. Repetitive braking of the vehicle leads to heat generation during each braking event. Transient Thermal Analysis of the Rotor Disc of Disk Brake is aimed at evaluating the performance of disc brake rotor of a car under severe braking conditions and there by assist in disc rotor design and analysis. Disc brake model and analysis is done using ANSYS workbench 16.0. The coupled thermal-structural analysis is used to determine the thermal stresses and to calculate the Heat fluxes in x-y-z planes. This is established with two discs they are, Drilled type and Slotted type and analysis is done by taking two different materials such as Cast Iron and Stainless Steel and comparing which material is best suited for making of a disc brake.

Key words: *Disc Brake, Slotted, Drilled, Thermal Analysis.*

I. INTRODUCTION

A disk brake consists of a cast iron disk bolted to the wheel hub and a stationary housing. The calliper is connected to some stationary 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 disk there is a friction pad held in position by retaining pins, spring plates etc. passages are drilled in the caliper for the fluid to enter or leave each housing. The passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston. Disk brake types: 1. Drilled type 2. Drilled and slotted. 3. Disk with internally slotted.

Nevertheless, they are certain issues arising in the disc brakes while braking. Some of the issues which generally occur while braking are:

Nvh issues
Noise, vibration and harshness are complex issues that involve the entire system of components from the brake system. Ongoing investigations in the industry have identified several initiating factors relating to the brake elements themselves which can be grouped into the following sections: 1. Brake disc hot spots which typically result in thermal judder.
2. Uneven rotor thickness wear and rotor thickness variation.
3. Rotor deflection and oscillation

Thermal management issues

1. Uneven heating of brake rotors can temporarily cause, or increase, thickness variation, and sometimes can produce a primary thermal buckling that warps the rotor.
2. Uneven rotor cooling in the case of a vehicle parked immediately following strenuous braking activity can cause the area of rotor under the brake pads to cool more slowly than the portion of the rotor open to the atmosphere, resulting in uneven thermal stresses in the rotor and leading to pad imprinting, residual internal stresses and material failure.

II. LITERATURE

Piotr GRZEŚ [1] The aim of this paper was to investigate the temperature fields of the solid disc brake during short, emergency braking. In this paper transient thermal analysis of disc brakes in single brake application was performed. To obtain the numerical simulation parabolic heat conduction equation for two-dimensional model was used. The results show that both evolution of rotating speed of disc and contact pressure with specific material properties intensely. Lee [2] stated that inconsistent dissipation of heat inside the brake disc could cause deformation of the disc. Even worst, the disc deformation could also cause friction loss and consequently led to brake fade [3]. Furthermore, high temperatures of the brake disc could cause cracking in the brake disc material due to high thermal stresses. On top of that these factors also cause vibration [4, 5]. It is become common in the brake research RESEARCH A. Belhocine et al., Tribology in Industry Vol. 36, No. 4 (2014) 406-418 407 community to fully utilize finite element approach in order to identify and predict disc/drum brake structural performance. For instance, Koetniyom [6] performed temperature analysis on brake discs under heavy operating conditions. He found that the physical shape of vehicle brake discs play a significant role in determining the temperature characteristics including the overall brake efficiency. Kamnerdtong et al. [7] attempted to link the interaction between mechanical and thermal effects with disc movements and heat caused by frictions. They concluded that, from finite element analysis, temperatures on the disc surface changed at each point over the period, which indicates inconsistent dissipation and temperature differences in each side of the disc. Hence, inconsistent contact between disc and pad could affect material deformation. Belhocine et al. [8] used the finite element Sofware ANSYS to study the thermal behaviour of the dry contact between the discs of brake pads at the time of braking phase. Temperature distribution obtained by the transient thermal analysis was used in the calculations of the stresses on disc surface. Abdullah and Schlattmann [9] used finite element method to calculate the heat generated on the surfaces of friction clutch and temperature distribution for case of bands contact between flywheel and clutch disc, and between the clutch disc and pressure plate (one bad central and two bands) and compared with case of full contact between surfaces for single engagement and repeated engagements. In other work, Abdullah et al. [10] used the finite element method used to study the contact pressure and stresses during the full engagement period of the clutches using different contact algorithms. Moreover, sensitivity study for the contact pressure was presented to indicate the importance of the contact stiffness between contact surfaces. Akhtar et al. [11] employed finite element (FE) method to explain the transient thermo elastic phenomenon of a dry clutch system. The effect of sliding speed on contact pressure distribution, temperature and heat flux generated along the frictional surfaces was analyzed. Sowjanya and Suresh [12] conducted a static structural analysis of the disc brake whose some composite materials were selected to compare the results obtained such as deflection and stresses.

III. MODELLING

A solid model is the most complete type of geometric model used in CAD systems. It contains all the wireframe and surface geometry necessary to fully describe the edges and faces of the model. Modelling is done using solidworks Fig.1 shows solid modelling of slotted and slotted with drilled hole brake.

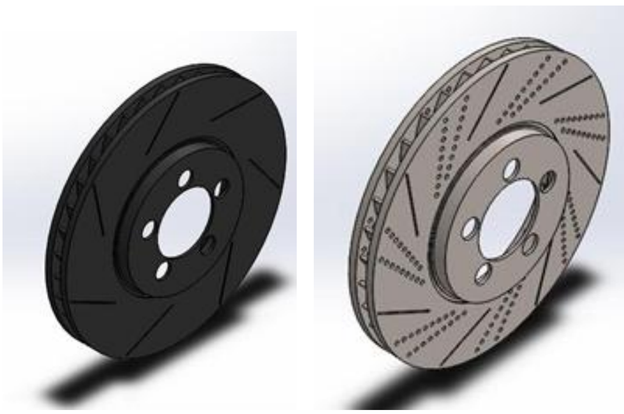

Fig.1Modelling of slotted and slotted drilled hole disc brake

After Modelling of the disc brakes are done, the thermal analysis of the disc brakes are done in ANSYS workbench 16.0.

Meshing of the disc

The goal of meshing in Workbench is to provide robust, easy to use meshing tools that will simplify the mesh generation process. The model using must be divided into a number of small pieces known as finite elements. Since the model is divided into a number of discrete parts, in simple terms, a mathematical net or "mesh" is required to carry out a finite element analysis. A finite element mesh model generated is shown in Fig. 2 and 3.

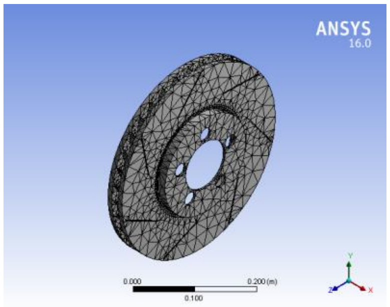

Fig. 2 FEA Model Mesh for Slotted disc

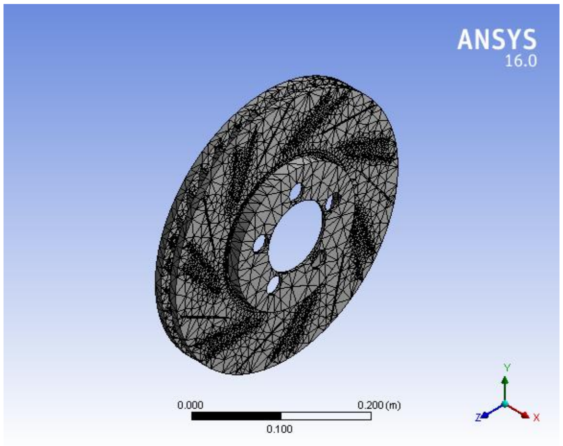

Fig. 3 FEA Model Mesh for Slotted and Drilled Disc

Table 1 Number Of Nodes and Elements For Two Discs

Type Of Disc	Nodes	Elements
Slotted and Drilled Disc	73572	400042
Slotted Disc	33534	18768

Heat flux calculation :

Item values: (Mazda rx80)

1. Disc diameter = 349.08mm.
2. Disc inner diameter =198.88mm.
3. Hub internal diameter = 90mm.
4. Hub external diameter =190.55mm.
5. Thickness of the rotor disc= 9mm.
6. Drill hole diameter= 5.12mm.
7. Slots length=80mm.

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8. Slots width=1.88mm.
9. Mass of the vehicle=1280kgs.
10. Speed of the automobile=43.33m/sec.
11. Brake time=4.8sec.
12. Specific Heat Cp=910Jkg
13. Axle weight distribution =0.3 (gamma)
14. Acceleration due to gravity =9.8m/sec.

Kinetic Energy Generated = 0.9*0.5*1280*(43.33)2*0.3
= 324430.0819J
= 67589.600watts.
usable disc area= 3.14*(D2 –d2)/4
= 64641.09mm.

Heat flux= wattage/ usable disc area
= 104530.13W/m2.

IV. RESULTS AND DISCUSSION

The main purpose of this study is to analysis the thermo mechanical behaviour of the dry contact of the brake disc during the braking phase. The coupled thermal-structural analysis is used to determine the thermal stresses and the Heat fluxes in x-y-z planes.

4.1 Slotted and drilled disc brake with stainless steel

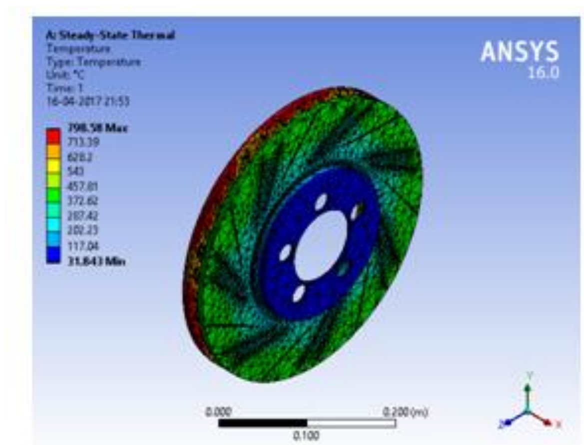

Fig. 4 Steady state thermal temperature (in degrees Celsius) Max=798.58, Min=31.48

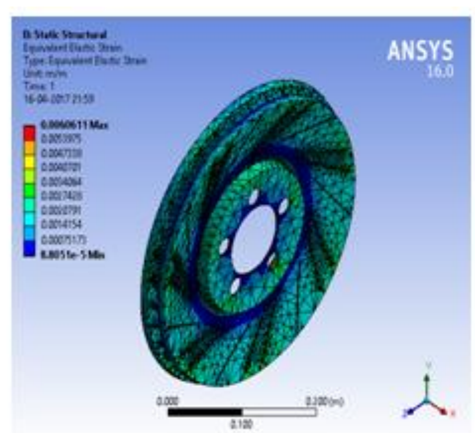

Fig.5 Static Structural (Equivalent elastic strain in m/m) Max=0.0060611, Min=8.8051e-5

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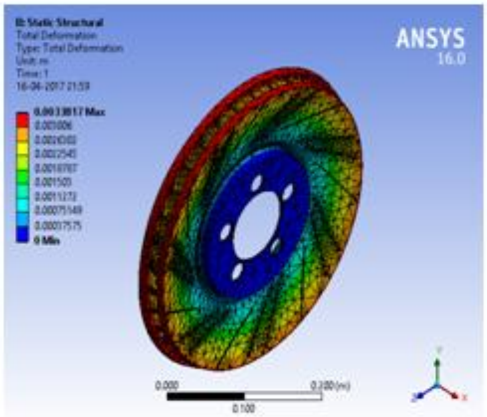

Fig. 6 Static structural (total deformation in m)
Max=0.0033817, Min=0

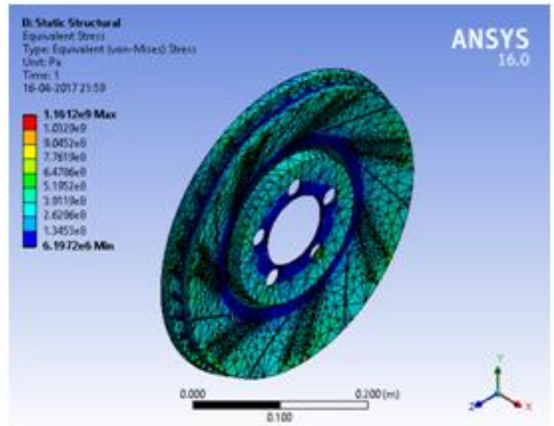

Fig.7 Static Structural (von –Mises Stress in Pa)
Max=1.1612e9, Min=6.1972e6

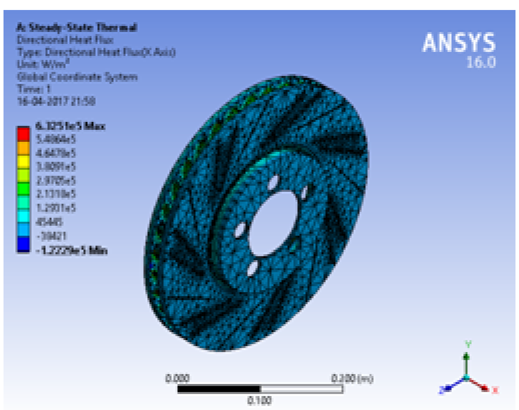

Fig.8 Directional Heat Flux (x-axis in W/m2)
Max=6.3251e5, Min=-1.2229e5.

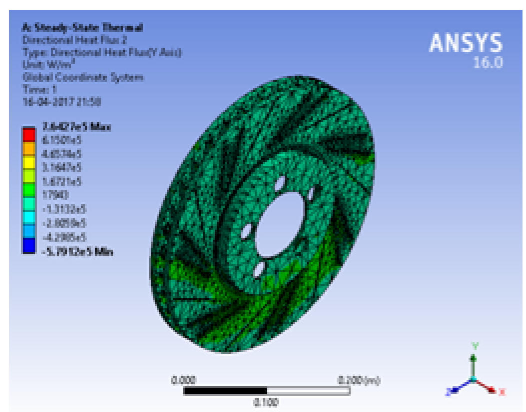

Fig. 9 Directional Heat Flux(Y- axis, in W/m2)
Max=7.6427e5, Min=-5.7912e5.

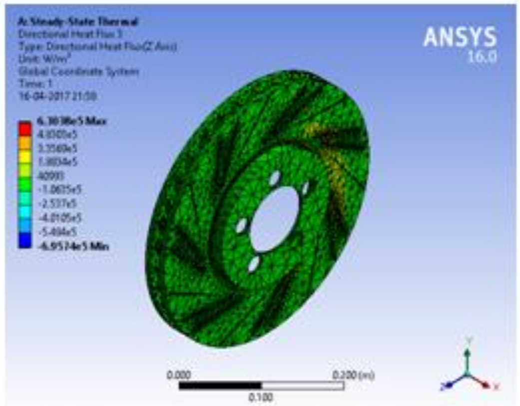

Fig.10 Directional Heat Flux (Z-axis, W/m2)
Max= 6.3038e5, Min=-6.9574e5

4.2 Slotted and drilled disc brake with castiron

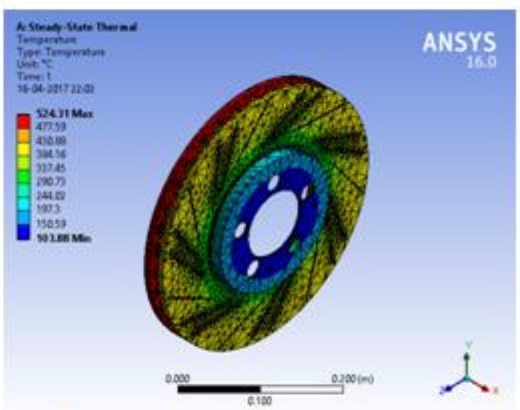

Fig.11 Steady State Thermal Temperature (in degrees)
Max=524.32, Min=103.88

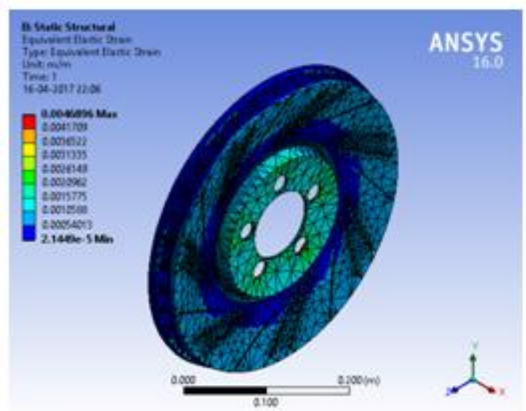

Fig.12 Equivalent Elastic Strain (in m/m)
Max= 0.0046896, Min = 2.1449e-5

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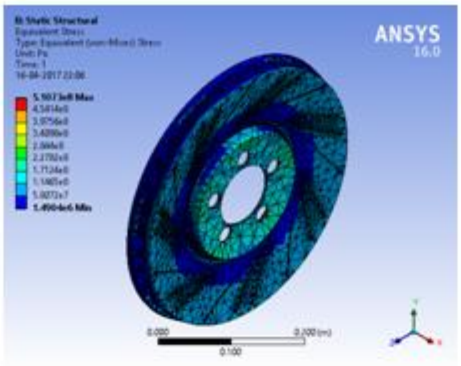

Fig.13 Equivalent Stress (Von-Mises in Pa)
Max =5.1073e8, Min= 1.4904e6.

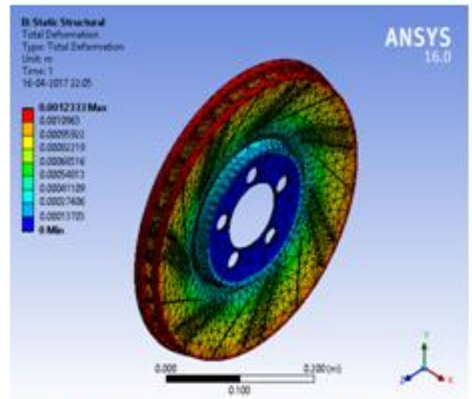

Fig.14 Total Static Structural Deformation (in m)
Max = 0.0012333, Min =0

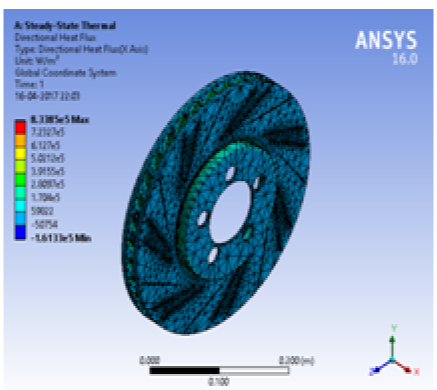

Fig.15 Directional Heat Flux (x - axis in W/m2)
Max = 8.3385e5, Min = -1.6133e5

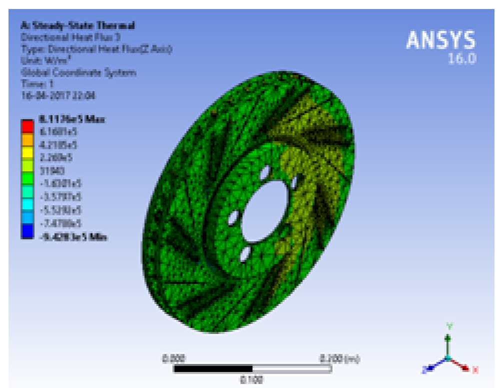

Fig.16 Directional Heat Flux (Z- axis in W/m2)
Max= 8.1176e5, Min = -9.4283e5.

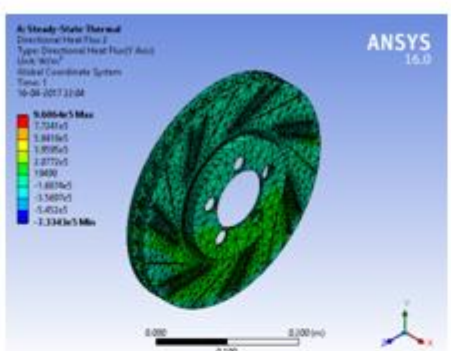

Fig.17 Directional Heat Flux (y- axis in W/m2)
Max= 9.6064e5, Min= -7.3343e5.

Table.2 Comparison of CI and SS disk brakes

Type Of Material	Temperature(˚C)		Thermal Deformation(m)	
	Maximum	Minimum	Maximum	Minimum
Cast Iron	524.32	103.88	0.0012333	0
Stainless Steel	798.58	31.48	0.0033817	0

V. CONCLUSIONS

The following conclusions made from the thermo structural analysis

1. Slotted with drill hole brake with CI developed a less temperature of 524.32 ˚C compared to SS of 798.58 ˚C
2. CI material showed 34% better thermal stability
3. SS slotted drilled brake performed better in terms of structural stability
4. A thermal stress of $5.1073e^{8}$Pa developed in CI against $1.1612e^{9}$ Pa in SS
5. Deformation is about 67% less in CI with respect to SS
6. It is recommended to use slotted with drilled hole disk brake with composite material instead of conventional drilled or slotted disk brakes

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