Ventilated And Non-Ventilated Disk Brakes

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Abstract- *When a vehicle is in motion the only system that assists in stopping or retarding the motion is the 'brake system'. The next leap in the brake system was the invention of the Disc brake. Earlier disc brakes were mostly made of cast iron, sandwiched between the stationary parts called brake pads situated inside the brake caliper. In this paper, we are presenting a study of temperature distribution and stress distribution of the brake rotor while the brake is applied. In this paper mathematical inputs and thermal loads of brake rotor, calculations of different parameters required for thermal analysis are done by taking suitable assumptions. The design of the brake rotor is done on Catia V5 and analysis is done with the help of any 19. All the results are discussed thoroughly.*

I. INTRODUCTION

Squeal noise generation during braking is an important economic and technical issue in the automotive industry. A re-evaluation of customers' requirements puts comfort high on the list of vehicle's major design considerations, to provide a competitive and attractive product to the public. Akay (2002) stated that the warranty claims due to the noise, vibration, and harshness (NVH) issues including brake squeal in North America alone were up to one billion US dollars a year. Disc brake squeal noise is mainly due to friction-induced vibration caused by the dynamic instability of the brake system, which usually radiates noise in the audible frequency of 1 kHz to 16 kHz. Various theories and methods have been proposed to explain and predict the brake squeal phenomenon. However, it seems quite obvious that none of them can explain all events related to the squealing noise. The theories related to squeal have presented challenging problems for researchers and engineers because of their complex nature, which involves multiple disciplines such as non-linear dynamics, contact mechanics, and tribology.

In the last few decades, a considerable amount of research has been done by many researchers on the possibility of eliminating brake squeal to improve vehicle users' comfort and reduce the overall environmental noise level. A good deal of progress has been made and several solutions have been suggested, for example, reducing the impulsive excitation, adding damping shims, and shifting modal coupling. Despite these efforts, squeal still occurs frequently within the audible frequency range. Therefore, it is one of the most important issues that require a detailed and in-depth study for prediction as well as eliminating brake squeal.

II. LITERATURE REVIEW

TING-LONG HO Et al. (1974), Investigated the effect of frictional heating on brake material (Aircraft) [1]. In this paper simplified analysis is conducted to determine the most significant factors which affect surface temperature. Where there are size and weight restrictions the specific heat and maintaining the contact area appear as criteria suggested for determining the number and thickness of brake disks, within the limited space available in a wheel. Frictional variations at high temperatures could result from three different phenomena: softening of the material, formation of oxides, and surface melting. A metallographic study approach is been used here. It was found that minimum surface temperature would result under material with a minimum values of $(1/\rho c)$ and $(1/k\rho c)$ when there is maximum contact

Masahiro Kubota et al. (2000), presented a paper on the development of a lightweight brake disc rotor: a design approach for achieving an optimum thermal, vibration, and weight balance [2]. This paper presents a parametric study that was conducted based on an analysis of airflow through the ventilation holes as well as thermal stress analysis and a vibration analysis during braking. Based on the relationships obtained between rotor weight, shape, and each performance requirement, a method is presented for designing a lightweight disc rotor. The computational fluid dynamics (CFD) analysis approach is used to visualize the actual process. Short and gourd-shaped fins arrangement had been used and the results verified that anti-squeal performance was improved, and also a substantial weight reduction was achieved compared with the baseline rotor shape without causing cooling performance and heat resistance to deteriorate.

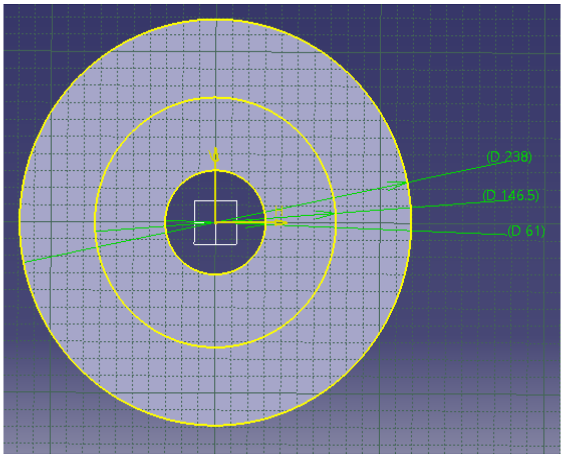
Choi and Lee, (2004) presented a paper on Finite element analysis of transient thermal elastic behaviors in disk brakes [3]. Transient analysis for the thermo elastic contact problem of disk brakes with frictional heat generation is performed using the finite element method. To analyze the thermal elastic phenomenon occurring in disk brakes, the coupled heat conduction and elastic equations (cylindrical coordinates) are solved with a contact problem. The material used is carbon-carbon composite and wear is assumed negligible. The numerical simulation for the thermal elastic behavior of the disk brake is obtained in the repeated brake condition. The computational results are presented for the distributions of pressure and temperature on each friction surface between the contacting bodies. It is observed that the orthotropic disc brakes can provide better brake performance than the isotropic ones because of uniform and mild pressure distribution.

JIANG LAN et al. (2011), presented a paper on thermal analysis for brake disk of Sci/6061 Al. Alloy co-continuous composite for CRH3 during emergency braking considering airflow cooling [4]. The thermal and stress analyses of SiCn/Al brake disk during emergency braking at a speed of 300 km/h considering airflow cooling were investigated using finite element (FE) and computational fluid dynamics (CFD) methods. All three modes of heat transfer were analyzed. The highest temperature after emergency braking was 461 °C and 359 °C without and with considering airflow cooling, respectively. The equivalent stress could reach 269 MPa and 164 MPa without and without considering airflow cooling, respectively. The airflow through and around the brake disk was analyzed using the Solidwork2012 simulation software package. The results suggested that the higher convection coefficients achieved with airflow cooling will not only reduce the maximum temperature in the braking but also reduce the thermal gradients since heat will be removed faster from hotter parts of the disk.

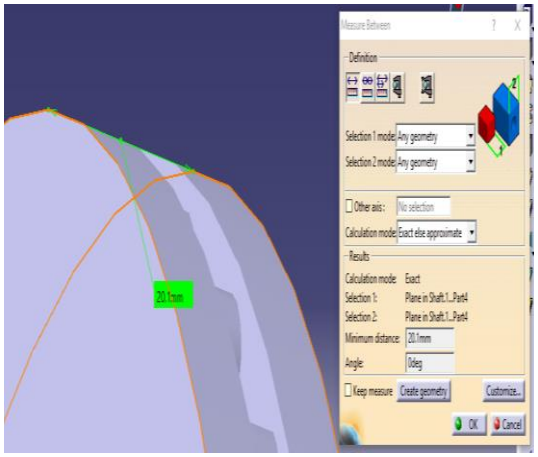
Oder G. et al. (2009), worked on thermal and stress analysis of brake discs in railway vehicles [5]. The performed analysis deals with two cases of braking; the first case considers braking to a standstill; the second case considers braking on a hill and maintaining a constant speed. In both cases, the main boundary condition is the heat flux on the braking surfaces and the holding force of the brake calipers. In addition, the centrifugal load is considered. The finite element method (FEM) approach is been used, the 3D model has been modeled for analysis. Brake disc material is rounded graphite; two types of the disc are considered for studies one without wear and one with 7mm wear on both sides. The maximum speed is 250 km/hr and the ambient and initial disc and the surrounding temperature is 50 C Temperatures and stress in discs under different loads are very high. Although they are fulfilling the buyer's requirements for safety, this investigation does not consider shearing forces, residual stress, and the cyclic loads during brake discs' lifespan. The results need to be compared with experimental results

Geometry

Dimensions of disk



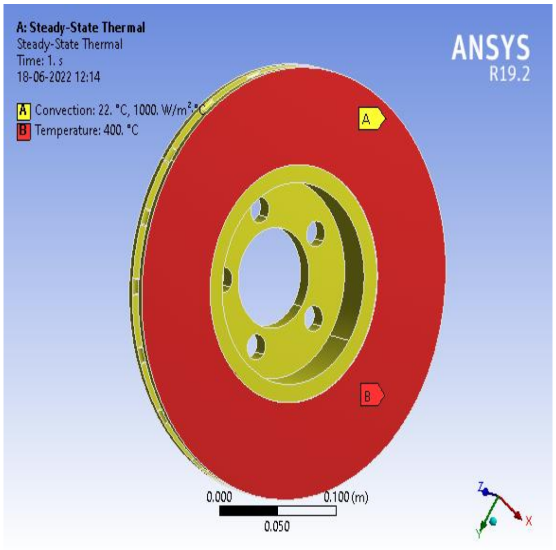
Thickness of disk



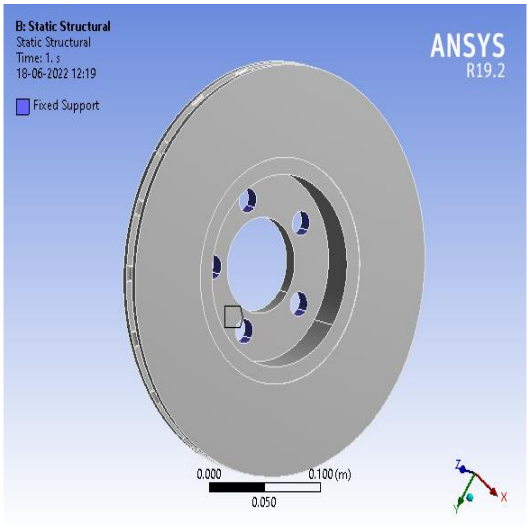
Selection 1 mode: Any geometry
Selection 2 mode: Any geometry
☐ Other axis: No selection
Calculation mode: Exact else approximate
Calculation mode: Exact
Selection 1: Plane in Shaft.1...Part4
Selection 2: Plane in Shaft.1...Part4
Minimum distance: 20.1mm
Angle: 0deg
☐ Keep measure

Boundary conditions

thermal

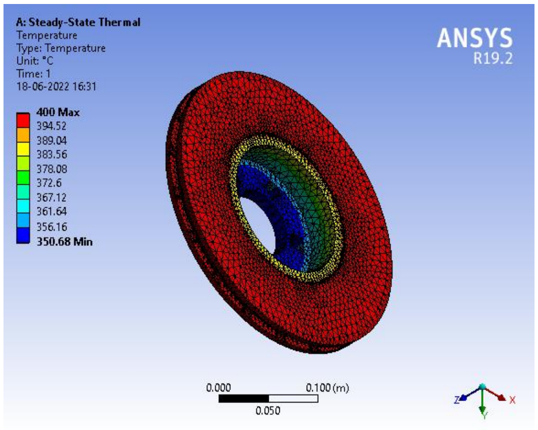


structural

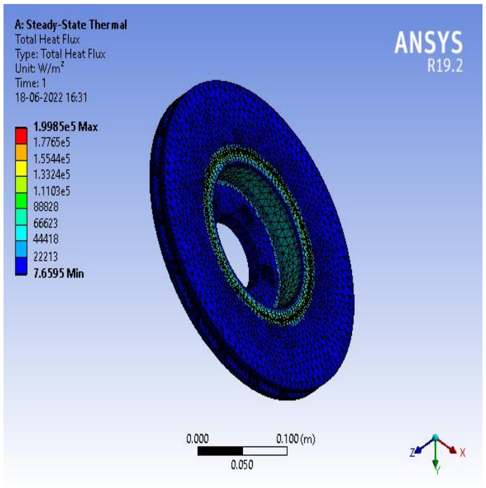


Results

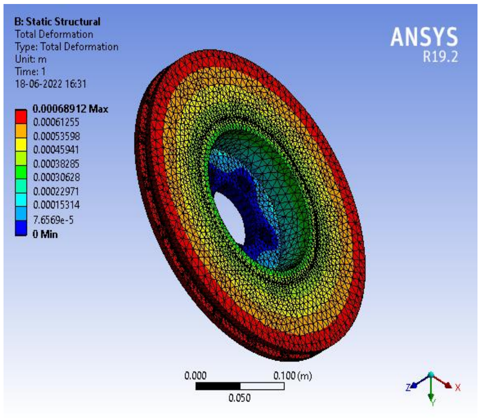
Temperature (°C)



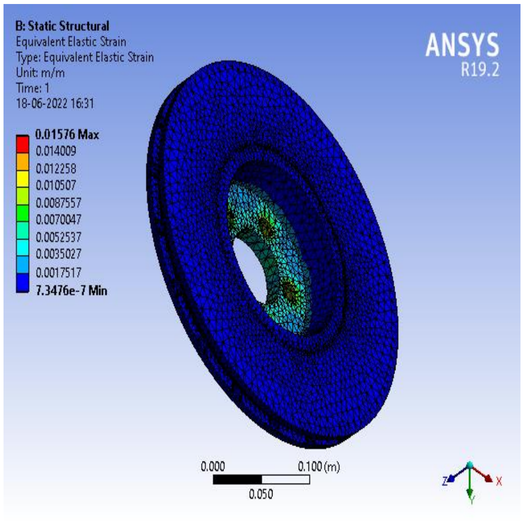
Total Heat Flux (W/m²)



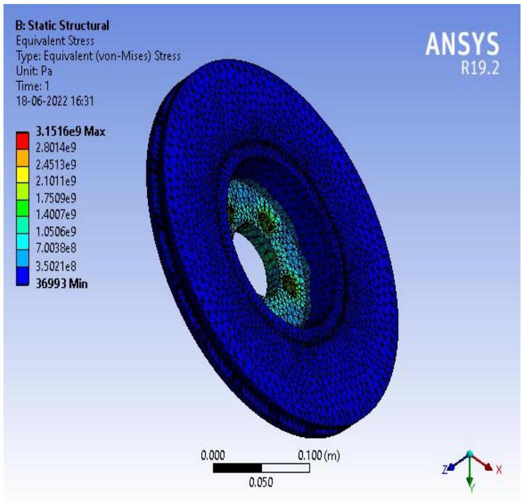
Total Deformation (m)



Equivalent Elastic Strain (m/m)



Equivalent (von-Mises) Stress (Pa)



III. RESULTS

Vented model 1

Thermal analysis

vented model 1	Temperature (°C)			Total Heat Flux (W/m²)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Structural Steel	348.93	400	397.63	121.17	2.19E+05	13458
Aluminium Alloy	381.05	400	399.13	121.37	2.29E+05	13826
Magnesium Alloy	378.85	400	399.03	121.35	2.29E+05	13801

Structural analysis

vented model 1	Total Deformation (m)			Equivalent Elastic Strain (m/m)			Equivalent (von-Mises) Stress (Pa)		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Structural Steel	0	3.98E-04	3.03E-04	1.48E-06	1.35E-02	2.18E-04	82671	2.71E+09	3.98E+07
Aluminium Alloy	0	7.66E-04	5.83E-04	7.50E-07	2.84E-02	4.29E-04	19968	2.01E+09	2.79E+07
Magnesium Alloy	0	8.66E-04	6.59E-04	5.46E-07	3.22E-02	4.86E-04	16717	1.45E+09	2.00E+07

Vented model 2

Thermal analysis

vented model 2	Temperature (°C)			Total Heat Flux (W/m²)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Structural Steel	277.86	400	390.75	4.2544	47504	6913.7
Aluminium Alloy	349.32	400	396.34	176.24	53608	7456.4
Magnesium Alloy	343.87	400	395.94	176.19	53152	7416

Structural analysis

vented model 2	Total Deformation (m)			Equivalent Elastic Strain (m/m)			Equivalent (von-Mises) Stress (Pa)		
	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum	Average
Structural Steel	0	5.12E-03	2.84E-03	2.32E-06	1.54E-02	1.08E-03	1.41E+05	3.09E+09	2.03E+08
Aluminium Alloy	0	9.39E-03	5.35E-03	2.14E-06	3.67E-02	2.11E-03	97025	2.60E+09	1.41E+08
Magnesium Alloy	0	1.06E-02	6.02E-03	2.74E-06	4.23E-02	2.37E-03	87078	1.90E+09	1.01E+08

IV. CONCLUSIONS

From the above simulation results the thermal behaviour of disk brakes is characterised and discussed. In this present study three different models of disk brakes are studied, first model is a solid disk break and the remaining are with vents of different geometry, hear heat transfer rate and mean temperatures are calculated using ansys. The following observation are made from the results

1. The temperatures are significantly low in vented models
2. Total heat flux is high in solid model, hence the temperature raises evenly through the body raising the average temperatures.
3. The deformations (change in dimensions due to thermal expunctions) are very low in vented model 1

Stress are also very low in vented model are they are directly proportional to change in dimensions

V. FUTURE SCOPE

This work can be further extended by conducting experimentations and numerical calculations, disk brakes are complex geometries and it is hard to make formulation of them, any work showcasing numerical and experimental study is highly recommended.

REFERNCES

[1] Ting-Long Ho., 1974. “Effect of frictional heating on brake materials”, Wear, 30(1974) 73-91

[2] Masahiro Kubota., 2000. “Development of lightweight brake disc rotor: A design approach for achieving an optimum thermal, vibration and weight balance.” JASE review 21 (2000) 349-355.

[3] Ji-Hoon Chio, 2003. “Finite element Analysis of transient thermo elastic-behaviors in disk brakes”, Wear, 257 (2004) 47-58.

[4] JIANG Lan, 2011, “Thermal analysis for brake disk of Sci/6061 Al. Alloy co-continuous composite for CRH3 during emergency braking considering air flow cooling” ,Trans. Nonferrous Met. Soc. China 22(2012) 2783-2791.

[5] Oder G., “Thermal and stress analysis of brake discs in railway vehicles”, Advance Engineering 3(2009) ,ISSN: 1846-5900.

[6] Faramarz talati, 2009. “Analysis of heat conduction in a disk brake system”, Spinger-Velag- 2009.

[7] Ziad, 2009. “An investigation of disc brake rotor by FEA.”ISSN: 1985-3157, Vol.3, No. 2, July- Dec 2009.

[8] Adam Adamowicz, 2011. “Analysis of disc brake temperature distribution during single braking under non-axisymmetric load”, Applied thermal engineering 31(2011) 1003-1012.

[9] Ali Belchocine, 2012 “Thermal analysis of a solid brake disc”, Applied thermal engineering 32(2012) 59-67.

[10] Harpal Singh, 2012. “Thermal Analysis of disk brake using COMSOL”, International journal on Engineering technologies ISSN No. 2249-3255.

[11] Zhang Jian, 2012 “Research of the transient temperature field and friction properties on disc brakes”, Preceding of the 2012 2nd International conference on computer and information application (ICCIA 2012).

[12] K. Sowjanya, 2013. “Structural analysis of disk brake rotor”, International Journal of computer trends and technology (IJCTT)- volume 4 , Issue 7- July 2013

[13] K. M. Muniswamy, 2013, “Heat transfer enhancement on ventilated brake disk with blade inclination angle variation”, international journal of automotive technology, vol. 14, No. 4, PP.569-577 (2013).