Transient Thermal Analysis of Automotive Disc Brake

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Abstract— A disc brake is an automobile component is used to suddenly stop or retard the motion of a vehicle in running condition. When the vehicle is in the running condition it has kinetic energy and by application of brake it stops, but as the energy cannot be destroyed it is going to be converted in some other form of energy and this energy is nothing but the heat energy which is produced due to rubbing surfaces of the brake and wheel base which is not desired and the heat must be dissipated quickly in surrounding. The present study is fully based on the heat flux generation and its dissipation rate in low and high speeds of a vehicle so that the failure condition can be obtained. The speed is varied from as low as 2.5 m/s to as high as 8m/s. The results are being plotted in form of graphs also to see the time based variation in heat dissipation rates.

Key words: Transient Analysis, Disc Brake, Heat flux, Ansys 14.0, Computational Fluid Dynamics

I. Introduction

Brake is a device for slowing or stopping a moving vehicle, typically by applying pressure to the wheels. The aim of braking system is to transform mechanical energy of moving vehicle into the some other form, which results by decreasing of the vehicle speed. The kinetic energy is transformed into the thermal energy, by using the dry friction effects and, after that, dissipated into the surroundings.

Because high temperatures can lead to overheating of the brake fluid, seals and other components, the stopping capability of a brake increases with the rate at which heat is dissipated due to forced convection and thermal capacity of the system.

In this study, we will present a numerical modeling in three dimensions to analyze the thermo mechanical behavior of the full and ventilated disc brake .The strategy calculation based on the finite element method will be carried out using code ANSYS 14.0

The study aims in watching the heat dissipation rate for low as well as high speed vehicles. The velocity of 2 m/s is taken for analyzing the heat dissipation in low speed vehicle and a velocity of 8 m/s is taken for high speed vehicle.

Fig. 1: Schematic diagram of disc brake

II. Literature survey:

Ali Belhocine et al. investigate that the ventilation system plays an important role in cooling disks and provides a good high temperature resistance. The analysis results showed that, temperature field and stress field in the process of braking phase were fully coupled. The temperature, Von Mises stress and the total deformations of the disc and contact pressures of the pads increases as the thermal stresses are additional to mechanical stress which causes the crack propagation and fracture of the bowl and wear of the disc and pads. [1] A. Belhocine et al. presented results of the thermal behaviour of full and ventilated discs in a transient state. By means of the computer code ANSYS 11. In addition, the influence of disc ventilation on the thermal behaviour of the discs brake was analysed. The numerical simulation shows that radial ventilation plays a very significant role in cooling of the disc during the braking phase. [2] Manjunath T V et al. Comparing the different results of temperature rise, deflection, and stress field obtained from analysis it shows that in the ventilated cast iron disc reduction in temperature, stresses and deformation and concluded and concluded that ventilated type disk brake is the best for the braking application. [3] Mr.Ingale S.P. et al. analyses the performance of disc brake system by taking a comparative study on different materials and concluded that Plane carbon steel is best material for Disc Brake.[4] K.Sowjanya et al. compare the different results obtained from the analysis and concluded that Cast Iron is the best possible combination for the present application. [5] Viraj Parab et al. The transient thermo analysis of Disc brakes in brake applications has been per-formed. It is observed that the stainless steel can provide better brake performance than others from deformation point of view whereas cast iron provides better performance from stress point of view. The presented study can provide a useful design tool and improve the brake performance of Disc brake system. [6] Guru Murthy Nathi et al. analyzes an Axis-symmetric analysis of disc brake using Plane 55 and Plane 42 through ANSYS 5.4 (F.E.A) software, Transient thermal analysis is carried out using the direct time integration technique for the application of braking force due to friction .[7] G. Babukanth et al. presented the computational results are for the distribution of heat flux and temperature on each friction surface between the contacting bodies. Also, thermo elastic instability (TIE) phenomenon is investigated in the presented study, and the influence of the material properties on the thermo elastic behaviors (the maximum temperature on the friction surfaces) is investigated to facilitate the conceptual design of the disk brake system. Based on these numerical results, the thermo elastic behaviors of the carbon-carbon composites with excellent mechanical properties are also discussed. [8]

III. PROBLEM FORMULATION

The aim is to prepare a disc brake assembly in CAD software package for and to simulate it using some FEA package and to validate the results with the analytical data. For the present analysis the design software package used is PRO-E/CREO and the analysis is done using ANSYS 14.0 which is most commonly used for thermal and CFD simulations.

We have taken two materials for the disc brake rim which are cast iron and stainless steel.

Property	Cast Iron	Stainless Steel
Density (Kg/M^3)	7100	7750
Youngs Modulus (G Pa)	125	190
Poisons Ratio	0.25	0.3
Thermal Conductivity (W/M-K)	54.5	26
Specific Heat (J/Kg-K)	586	500
Coefficient Of Friction	0.2	0.22

Table 1:

The heat flux can be calculated using the following relation:

Calculation for obtaining heat flux:

$$T_{max} = \frac{0.527.q.\sqrt{t}}{\sqrt{\rho.c.k}} + T_{amb}$$

Where:

T_{max} = Maximum disc temperature (^{0}C)
q = Heat Flux (Watts/m^2)
t = Brake on time (Seconds)
ρ = Density of disc material (Kg/m^3)
= 7250 Kg/m^3
C = Brake disc specific heat capacity (J/kg/K) = 500 J/kg/K
K = Brake disc thermal conductivity (W/m-k)
=58 W/m-k
T_{amb} = Ambient temperature (^{0}C)
= 22 ^{0}C

Here we can see that the heat flux is directly proportional to the time and so we have analyzed the transient thermal performance of the disc brake for low and high velocities and to see the heat dissipation rate relation with respect to time as the one with higher heat dissipation rate will be considered batter for the disc brake system.

Secondarily a disc brake setup is also established for the validation of analytical and software results.

IV. MODELING AND ANALYSIS

Figure below shows the model of disc brake by using PRO-E/CREO modeling software:

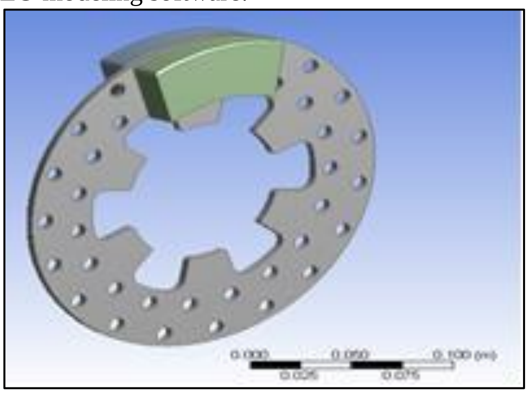

Fig. 2: Disc Brake Model

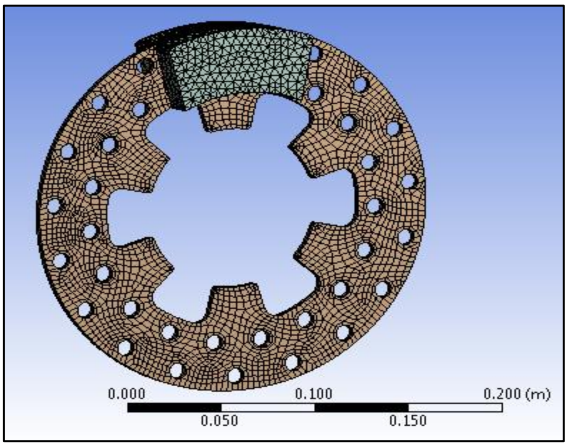

Fig. 3: Meshing of disc brake

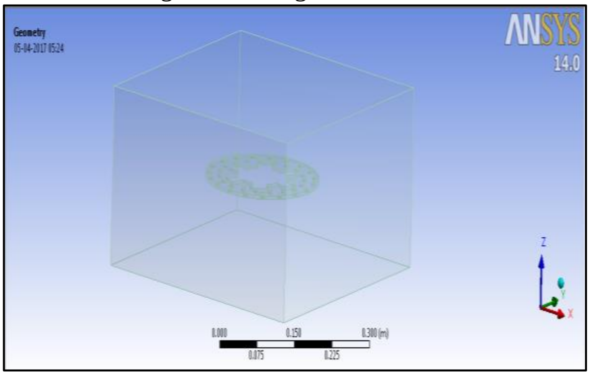

Fig. 4: Disc with bounding box

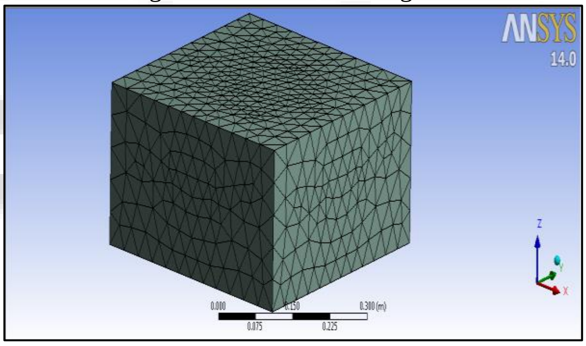

Fig. 5: Meshing Model

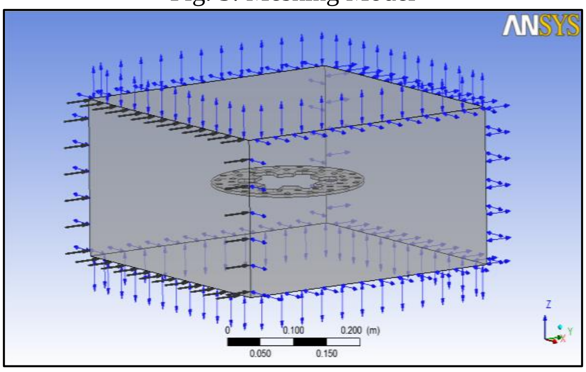

Fig. 6: Boundary Conditions

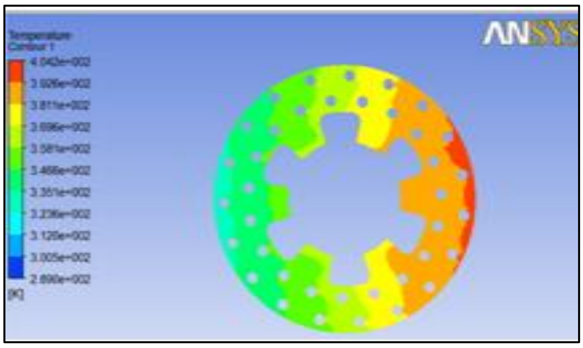

Fig. 7: Temperature distribution for steel material (T=0.1 Sec)

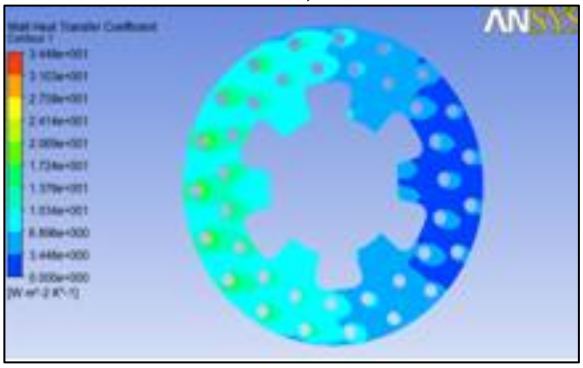

Fig. 8: Wall heat transfer coefficient for steel material (T=0.1 Sec)

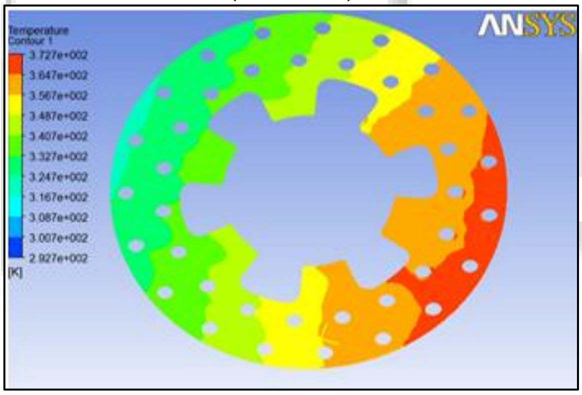

Fig. 9: Temperature distribution for cast iron material (T=0.1 Sec)

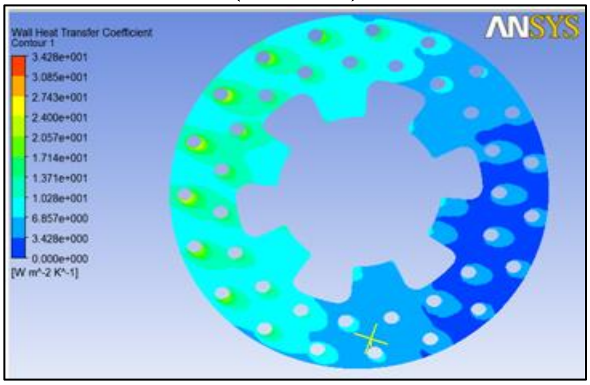

Fig. 10: Wall heat transfer coefficient for cast iron material (T=0.1 Sec)

Similarly the Temperature distribution and Wall heat transfer coefficient of steel and cast iron material are obtained using Ansys workbench and the results are listed in results table in next section.

V. Result and Discussion

From the above analysis we plot graph between temperature v/s time as well as heat transfer coefficient v/s time for both the materials steel as well as cast iron which are as follows:

Time in Sec.	Temperature Distribution in Kelvin	
	steel	Cast Iron
0.1	366.22	348.13
0.2	323.85	318.77
0.3	298.61	300.12
0.4	294.54	296.57

Table 2: Result Table showing comparative study of two different material disc brakes for low air speed temperature (2.5 m/s)

Time in Seconds	Temperature Distribution in Kelvin	
	steel	Cast Iron
0.1	319.60	314.91
0.2	295.63	295.63
0.3	298.17	298.17
0.4	300.83	300.83

Table 3: Result Table showing comparative study of two different material disc brakes for high air speed temperature (8 m/s)

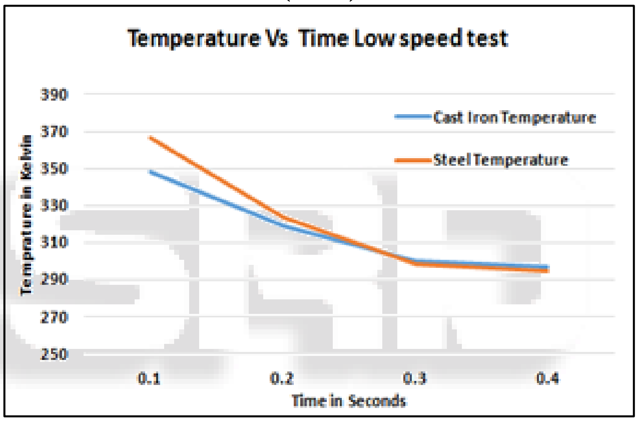

Fig. 11: Temperature v/s time graph for low speed test

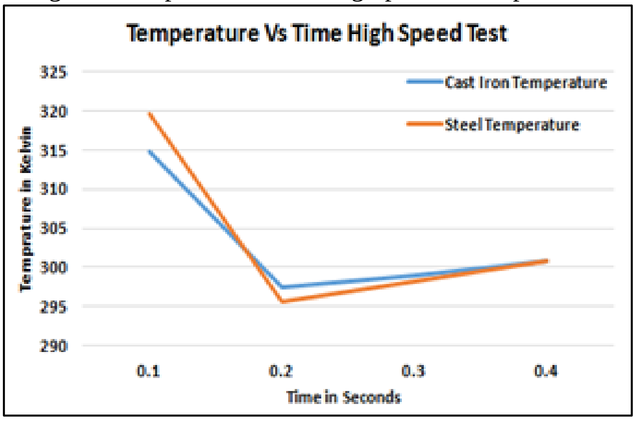

Fig. 12: Temperature v/s time graph for high speed test

VI. Conclusion

From the above graphs and results following points can be concluded:

1) For any material the time taken to dissipate a large amount of heat in transient thermal analysis is approximately 0.4 seconds for low speed i.e, up to 2.5 m/s and is approximately 0.2 seconds for high speed vehicles i.e, up to 8.0 m/s

2) The heat transfer coefficient is also suddenly increases after application of brake for the first 04 seconds and become again steady as required.
3) From the result table it can be concluded that the material cannot play very important role in case of heat transfer coefficient but is significantly affect the temperature distribution rate.
4) The finite element solver plays a very important role and is a affective tool to solve and analyze the automobile braking system.

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