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Analytical Investigation of Heat Thermal Strain of Disc Brake Using CFD

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***Abstract*—**

Disc (Rotor) brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. The aim of the project is to design, model a disc. Modeling is done using CATIA. Structural and Thermal analysis is to be done on the disc brakes using three materials Stainless Steel and Cast iron & carbon carbon composite. Structural analysis is done on the disc brake to validate the strength of the disc brake and thermal analysis is done to analyze the thermal properties. Comparison can be done for deformation, stresses, temperature etc. form the three materials to check which material is best. CATIA is a 3d modeling software widely used in the design process. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements.

INTRODUCTION

In the field of transportation, braking is a major problem. The goal is to acquire a systematic reliability with an acceptable cost.

A difficulty of this type of problem is knowing the heat flux generated at the interface between the pad and the disk, and the way in which it is distributed. [1] With the actual computing resources, numerical studies concerning thermo mechanical coupling have been carried out , and show that the mechanical deformations generate a spatial distribution of the pressure which is not regular, and which varies according to the time, the scenarios of load and speed.

Moreover, to these mechanical deformations are added phenomena of rupture (tearing of particles), physicochemical reactions (phase changes), and the presence of adhesion forces (attraction forces of the atoms of the two surfaces in contact with each other). [2]The characterization of the coefficient of friction is generally done empirically, from tribological or chemical analyzes during experimental tests. Finally, the particles which are torn off the pad during the braking contain some of the energy generated by the friction and can be trapped between the disk and the pad, and form a bed of debris that is ejected from the friction interface according to a speed whose profile can be complex.[3]

So the experimental observation is particularlyimportant, but then, major difficulties arise, related on the one hand to the movement of the disc, and on the other hand to the non-accessibility of the contact zone between the disc and the pad.[4-6]

I. PHYSICAL PROBLEM

We consider a car brake pad for which the complexity of the geometry is respected. It is composed of two materials:

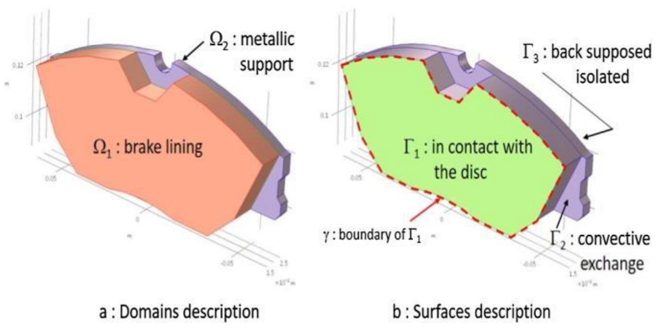
The brake lining and its metallic support, whose characteristics are presented in this brake pad undergoes three types of boundary conditions:

A. The surface C1 in contact with the disk receives a heat flux density which varies in space and time.

B. On the boundary C2, we consider a convective exchange with the external environment whose temperature is T= 0 C, with a stationary exchange coefficient h= 20W/m^2 $^\circ$K.

C. For the back C3, the brake pad is considered perfectly isolated from the brake caliper and piston assembly.

Fig. 1. Brake disc surface characteristics



A. Material & Specification

Table 1. Material specification of brake disc

Material	Grey Cast Iron
Disc Dimension (mm)	D = 220 d = 80
Yield Strength (MPa)	210
Density (g/cc)	7.2
Force applied on each pad (N)	4450
Speed (rpm)	1000
Coefficient of Friction	0.35
Poission Ratio	0.28

II. MODELLING IN ANSYS

The first stage is to create the model which contains the fields to be studied in Ansys Workbench. In our case, we took only one quarter of the disc, then we defined the field of the air surrounding this disc. ANSYS workbench prepared various surfaces for the two fields in order to facilitate the mesh on which it will export the results to CFX using the command "Output to cfx". After obtaining the model on CFX Pre and specifying the boundary conditions, we must define the physical values on CFX to start calculation. The disc is related to four adiabatic surfaces and two surfaces of symmetry in the fluid domain whose ambient air temperature is taken as equal to 280°C. An unsteady-state analysis is necessary.

(a) Physical Model In this step, one declares all of the physical characteristics of the fluid and the solid. After the meshing, all the parameters of the different models are defined in order to start the analysis.

(b) Definition of the Domains Initially, one validates and activates the elaborated models in the option "Thermal Energy" and performs the calculation of heat transfer in "Heat Transfer".

(c) Cast Iron Materials We introduce into the library the physical properties of used materials. In this study, we selected the cast iron material with their thermal conductivities.

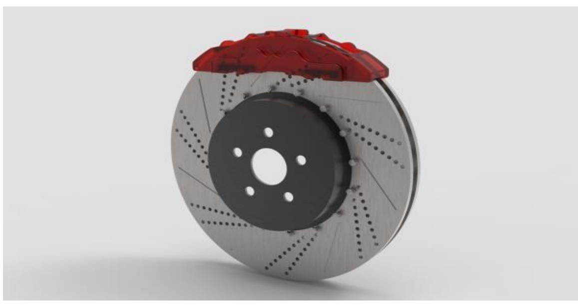
(d) Definition of the Boundary Conditions The first step is to select the inlet and outlet faces of the heat flux. These options are found in the insertion menu "Boundary Conditions" in the CFX Pre. One has to select the options "Wall" and "Symmetry" because there is the possibility of adjusting a certain number of parameters in the boundary conditions, such as flux entering the disc.

(e) Application of the Interfaces Domains The areas of interfaces are commonly used to create connection or linkage areas. Surfaces located between the interactions regions are reported as solid-fluid interface.

(f) Temporary Condition Since the goal of this study is to determine the temperature field in a disc brake during the braking phase of a vehicle of average class, we take the following temporal conditions: - Braking time = 20 [s] - Increment time = 0.01 [s] - Initial time = 0 [s] Before starting the calculation and the analysis with ANSYS, it is ensured that the model does not contain any error.

(g) Launch of the Calculation After verification of the model and boundary conditions, we run the calculation by opening the menu "File" and clicking on "Write solver file". The values of the coefficient of exchange will be taken at average values calculated by the minimal and maximum values obtained using ANSYS as it is indicated.

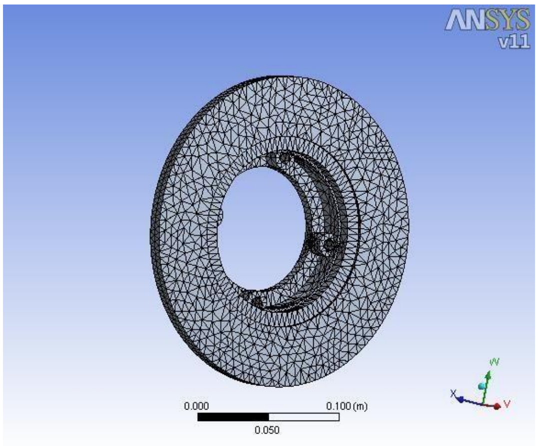
Fig. 2. Brake disc model



III. MESHING OF DISC

The elements used for the meshing of the full and ventilated disc are tetrahedral three-dimensional elements with nodes (iso- parametric). In this simulation, the meshing was refined in the contact zone (disc-pad). This is important because in this zone, the temperature varies significantly. Indeed, in this strongly deformed zone, the Thermo mechanical gradients are very high. This is why an accurate account of the contact conditions involve the use of a refined mesh. Three meshes have been tested automatically using an option called convergence in ANSYS Workbench Multi physics.

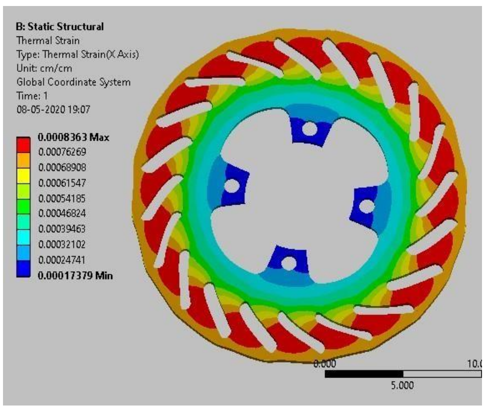
Fig. 3. Meshing of brake disc



IV.RESULT

Results of total deformation, thermal strain and temperature distribution of cast iron after analysis. it was observed that the value of thermal strain was higher along with the value of maximum heat flux. Thus by simply changing the shape of the vane, and without drilling holes, better heat dissipation was observed. In this analysis, the rotor with tapered vanes with holes had the best performance.

Fig. 4. Thermal strain of brake disc



V. CONCLUSION

This study allowed to show that the use of Branch modal models can be used, not only to reduce a thermal problem, but also to parametrize a spatial field, in this case the flux density received by the brake pad. The transient thermo analysis of Disc brakes in brake applications has been per-formed. Thus by simply changing the shape of the vane, and without drilling holes, better heat dissipation was observed. In this analysis, the rotor with tapered vanes with holes had the best performance.The present study can provide a useful design tool and improve the brake performance of Disc brake system. The values obtained from the analysis are less than their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria.

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