THERMAL ANALYSIS OF DISC BRAKE USING FINITE ELEMENT METHOD

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REZUMAT. Implementarea noilor reglementări privind comportamentul și dinamica vehiculului a avut ca rezultat crearea, îmbunătățirea și optimizarea programelor avansate de analiză pentru subansamble și componente auto. Astăzi, modelarea cu elemente finite se remarcă ca una dintre metodele principale de analiză teoretică în industria auto. În zilele noastre, au existat progrese semnificative în tehnologia automobilelor. Piața este plină de concurență în ceea ce privește viteza vehiculului. Cu toate acestea, această viteză crescută poate duce adesea la accidente dacă vehiculele nu se opresc la timp. Frânele cu disc oferă performanțe mult mai bune în comparație cu frânele cu tambur atunci când vine vorba de oprirea unui vehicul, precum și permit o disipare mai ușoară a căldurii generate în timpul frânării datorită designului lor deschis la atmosferă.

Cuvinte cheie: software Ansys, analiză termică, disc de frână, fontă.

ABSTRACT. The implementation of new regulations on behavior and vehicle dynamics has resulted in the creation, enhancement, and optimization of advanced analysis programs for automotive subassemblies and components. Today, finite element modeling stands out as one of the primary methods for theoretical analysis in the automotive industry. Nowadays, there have been significant advancements in automobile technology. The market is filled with competition in terms of vehicle speed. However, this increased speed can often lead to accidents if the vehicles do not stop in time. Disc brakes provide much better performance compared to drum brakes when it comes to stopping a vehicle, as well as allowing for easier dissipation of the heat generated during braking due to their open design to the atmosphere.

Keywords: Ansys Software, Thermal Analysis, Brake Disc, Cast Iron

1. PROLEGOMENA

Braking systems are subject during braking to temperatures and high stresses in the event of emergency braking.

In order to conduct a temperature analysis for this research, a model assembly will be created and examined utilizing specialized software.

2. FINITE ELEMENT SIMULATION

The finite element method is a numerical technique that handles all engineering issues, ensures that it is used to aid in physical phenomena, and lessens the requirement for building tangible prototypes.[2] [6] [9]

These are the basics from the 1970s, since it was used by engineers to solve the most complex problems in the field structures. The fundamental idea of finite element methods consists in the fact that irregularly shaped pieces are transformed into one smaller volume assembly called elements. These elements are connected inside them by points known as nodes.

Finite element analysis programs involve three stages of analysis, preprocessing (which involved the preparation of the FEM model, real constant, material property and discretization), process area and the post process area which consists of the analysis and interpretation of the results.[1] [3][8][10]

As the studies in the specialized bibliography show, the surface of contact between the brake pads and the disc generates heat due to friction between the elements. [4] [7] [12]

The theoretical research of the braking system was carried out by finite element analysis of the behavior of the elements of the braking system when driving with/without a trailer, the latter being loaded at maximum load. The ANSYS program, version 2019 R3, was used for the analysis.

Finite element analysis was chosen because it is a

method widely used in the automotive industry and can generates results comparable to the data obtained experimentally.

At the end of the research, the data obtained from the FEM analysis will show results obtained in the case of braking from 60 km/h to 0 km/h.

For the theoretical research in the pre-processing phase, a 1:1 scale model of the brake discs and pads it will come with equipped the car for the experiment. The model was created with Catia v5 software. The model was created from the dimensions provided by the component manufacturer.

The studied braking system is a system with medium performance, comparable to the original system with which the car was equipped.

The created model was entered in the second stage of the analysis in the finite element analysis program ANSYS (fig. 2.1). [5][11][12]

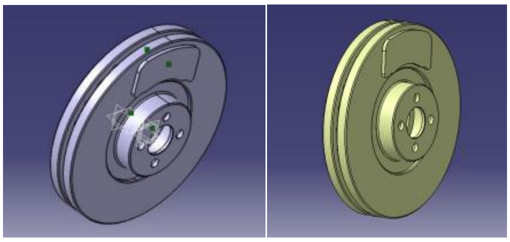


Fig. 2.1. The geometry of the brake disc-pad assembly made in for finite element analysis.

The geometry and constructive properties of the disc and pads chosen for the analysis are similar to those of the car equipment. The initial data used for the finite element analysis are:

• the brake disc is made of cast iron having the properties

presented in table 2.1.

• following the bibliographic study for brake pads, it was chosen a composite material having the properties in table 2.2.

The characteristics of the materials were chosen from the literature of specialty of manufacturers of brake system components. It can list the following characteristics of materials: resistance to wear and shock, vibration and noise damping capacity, low coefficient of expansion, chemical stability at high temperatures.

Table. 2.1. **Brake disc material characteristics**

Gray Cast Iron

Density	7200 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.1e+11 Pa
Poisson's Ratio	0.28
Bulk Modulus	8.3333e+10 Pa
Shear Modulus	4.2969e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	1.1e-05 1/°C
Compressive Ultimate Strength	8.2e+08 Pa
Compressive Yield Strength	0 Pa
Tensile Ultimate Strength	2.4e+08 Pa
Tensile Yield Strength	0 Pa
Thermal	
Isotropic Thermal Conductivity	52 W/m·°C
Specific Heat Constant Pressure	447 J/kg·°C
Electric	
Isotropic Resistivity	9.6e-08 ohm-m
Magnetic	
Isotropic Relative Permeability	10000

Table 2.2. **Material characteristics for brake pads**

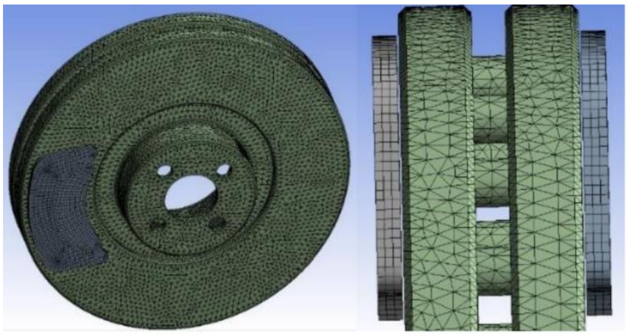
Metal matrix composite (MMC), Alumin...

Aluminum matrix (2009), silicon carbide particulate reinforced (Vf:20%), Al(2009)-20%SiC(p), metal matrix composite (MMC) (Al 2009-SiC(p))

Data compiled by the Granta Design team at ANSYS, incorporating various sources including JAHM and MagWeb. ANSYS Inc. provides no warranty for this data.

Density	2855 kg/m³
Structural	
Isotropic Elasticity	
Derive from	Young's Modulus and Poisson's Ratio
Young's Modulus	1.095e+11 Pa
Poisson's Ratio	0.2925
Bulk Modulus	8.7952e+10 Pa
Shear Modulus	4.236e+10 Pa
Isotropic Secant Coefficient of Thermal Expansion	1.52e-05 1/°C
Tensile Ultimate Strength	5.993e+08 Pa
Tensile Yield Strength	4.41e+08 Pa
Thermal	
Isotropic Thermal Conductivity	125 W/m·°C
Specific Heat Constant Pressure	924.9 J/kg·°C
Electric	
Isotropic Resistivity	3.935e-08 ohm-m

The discretized model for finite element analysis is shown in figure 2.2.



Statistics	
Nodes	238574
Elements	121175

Fig. 2.2. Discretization of the model in finite elements.

The discretization of the model was carried out after the analysis of several node sizes. Choosing a number of nodes and elements a lot higher would lead to system overload and the required time processing would be very high. Program input data for analysis with FEMs are shown in figure 2.3.

Fig.2.3. Initial data required for analysis.

Brake pad pressure considered a was 0.5 MPa. Moving the tiles from the fixed point to the time at the start of braking was considered 0.51 mm.

3. THE RESULTS OBTAINED

The minimum total brake disk displacement of 0.0179 mm is shown in figure 3.1.

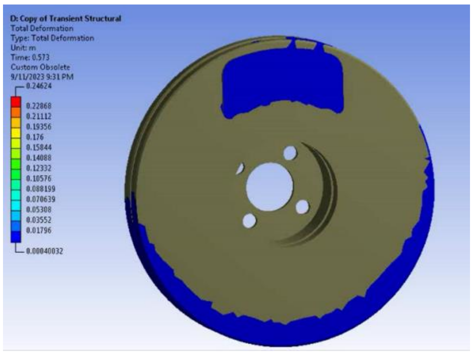


Fig. 3.1. Minimum deformation of the brake disc.

The maximum total brake disk displacement of 0.246 mm is shown in Figure 3.2.

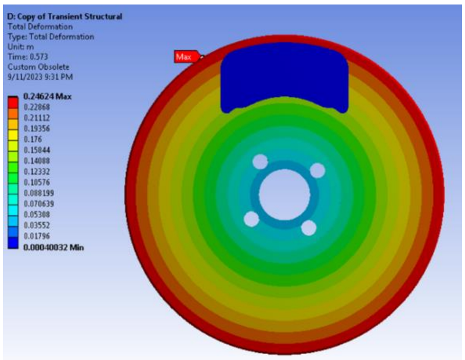


Fig. 3.2. Maximum deformation of the brake disc

The finite element temperature image shows that the maximum equivalent stress has a value that does not endanger the braking system (figure 3.3).

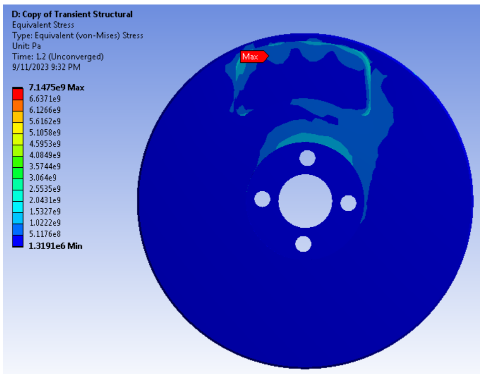


Fig. 3.3. Equivalent (von-mises) stress of disc brake design.

A detail for the equivalent voltage distribution is shown in Figure 3.4.

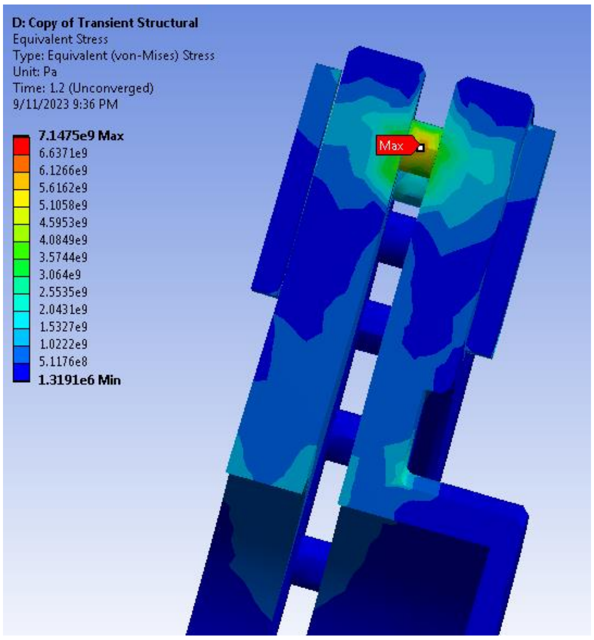


Fig. 3.4. Detail for the distribution of equivalent stresses.

The distribution of the Y-axis (axial) displacements is shown in figure 3.5. Each pad is displaced by 0.527 mm. The initial distance between the pads and the disk was 0.5 mm, the difference being given by the elastic deformation of the disk.

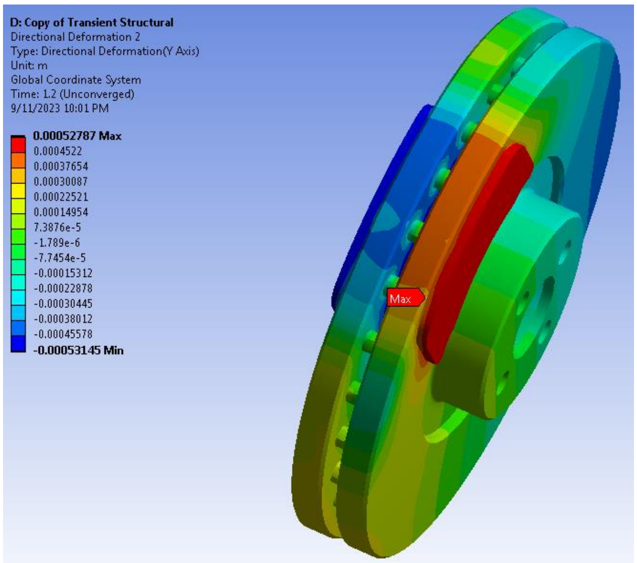


Fig. 3.5. Distribution of displacements along the Y axis.

Brake disk speed distribution (maximum value 125 m/s) (also includes disk deformation rate) (figure 3.6).

The maximum brake disk temperature at the end of a braking cycle, under the stress conditions imposed by The finite element temperature assumption is 228.59 ^{0}C (figure 3.7).

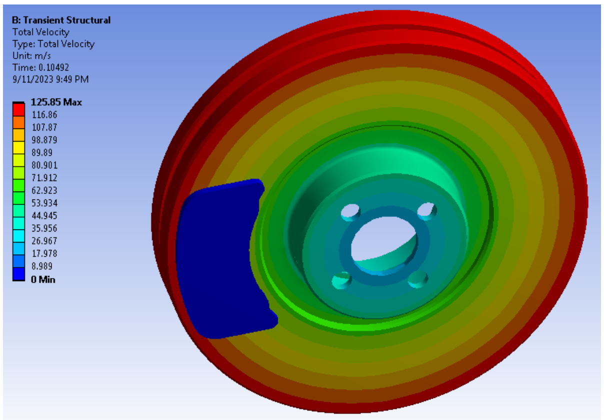


Fig.3.6. Total velocity

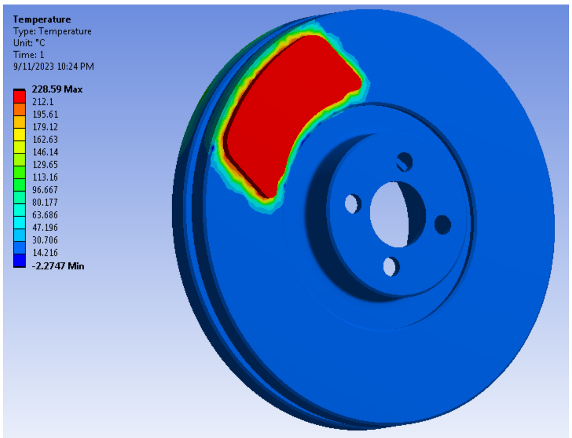


Fig.3.7. Temperatures at the end of braking.

A detail of the instantaneous brake disk temperature is shown in figure 3.8.

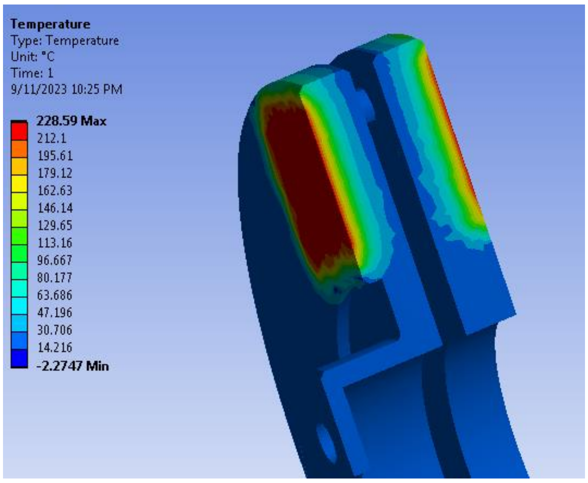


Fig.3.8. Detail of the temperature at the end of the braking cycle.

4. CONCLUSIONS

For finite element simulation of an assembly consisting of brake disc and brake pads specifications were considered dimensional and structure of materials similar to those of components that can equip a vehicle.

In the pre-processing stage, a model was designed after the actual dimensions of a ventilated brake disc using the software Catia V5. The characteristics of materials that have a non-linear behavior are tabulated. I made the discretization of the elements from 238574 nodes and 121175 elements, after which I entered the conditions limit and the loads for carrying out the study.

The ANSYS program was used for the analysis in which I set parameters needed for the analysis.

During the post-processing stage, the variation parameters were visualized, deformations and displacements were analyzed, and the results were examined. The analysis specifically focused on the temperatures resulting from braking, with a temperature of 22°C considered and a pressing pressure of 0.5 MPa applied on both sides of the disk.

The temperature distribution on the disk surface is determined by using the types of analysis, Transient Structural and Transient Thermal. This distribution can vary based on the imposed conditions and the specified analysis period. In this case, the braking period was set for 4 seconds, during which the car decelerated from 60 km/h to 0 km/h.

The maximum displacement value recorded corresponds to time braking and it can be seen that the distribution increases with the time it exists friction between discs and pads. The maximum temperature depends almost entirely by the disc's heat storage capacity.

Following finite element modeling it is found that during braking, the temperature of the disc reaches temperatures above 225 °C.

The analysis showed that the temperatures, stress field and the deformations that occur in the braking process are interrelated and can influence the improper functioning of the disc assembly – brake pad.

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