Theoretical research on the issue of heat stress that appears in mechanism of automotive braking system and their influence

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Abstract. The braking system is one of the most important car systems with application in traffic safety. The thermal stress in this system, especially when the brake is intensively used, is affecting the efficiency of the system, its response and therefore the road safety.

1 Introduction

Efficiency of the braking system and good functionality, in correlation with his main roles, improves the average travel speeds of car, but also the passenger safety. The studies show that much of the vehicle's kinetic energy is converted into heat, which leads to poor functionality of the entire braking system.

As negative effects of brake system warming can be mentioned: rapid wear of the brake pads or brake disc, cracks or deformation of the brake disc, occurrence of the "fading" phenomenon.

In this context, one of the important challenges of the automotive industry is to improve the braking performances. To obtain a reliable constructive solution have been done a series of theoretical and experimental research based on numerical modeling, finite element analysis and laboratory studies.

2 Modeling of brake disc - pads assembly

In this paper, the numerical modeling of disc brake – pads assembly was performed, customized to the braking system of the car. The model has considered the constructive solution, based on an unventilated disc. To perform the simulation, firstly the components of the braking system were modeled, in order to reproduce as faithfully as possible the geometry and their position during operation. This modeling was performed using CATIA V5 R19 design environment, widely used in the automotive design.

In Figure 1-5 are shown the 3D models of the unventilated brake disc, caliper, the piston inside the caliper, brake pads and whole disc pads.

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Fig. 1. Brake disc.

Fig. 2. Caliper.

Fig. 3. Piston.

Fig. 4. Brake pads.

Fig. 5. Brake disc – brake pads assembly.

Modeling of the disc and brake pads, in discretized form is shown in Figure 6 and Figure 7.

Fig. 6. Meshed brake disc.

Fig. 7. Meshed brake pads.

3 Simulation and study of the temperature distribution

The analysis of temperature distribution on the friction surface between the brake disc and brake pads was done by using finite element analysis (FEA), based on ABAQUS 6.14 software, produced by Dassault Systèmes Company. This program provides a very accurate analysis, being able to identify areas with critical mechanical and heat stress, in order to offer viable technical solutions.

Fig. 8. Distribution of temperature of the brake disc at intense braking (50 km/h) - achieved at the start of braking.

Fig. 9. Distribution of temperature of the brake disc at intense braking (50 km/h) - achieved at the end of braking.

For this analysis, it was considered the following situation: an intense braking from two representative values of speed, 50 km/h and 100 km/h to 0 km/h. This analysis is based on the following assumptions:

- caliper, support of caliper and the piston are considered rigid bodies, which will not conduct heat, generated during braking;
- disc initial temperature is 20 °C;

In order to realize a complex and relevant investigation it was considered useful an analyze on achieving the maximum temperature of the disc starting from intermediate moments, characterized by lower temperatures. This approach is aimed to obtain an evolution in the temperature distribution on the brake disc.

Fig. 10. Distribution of temperature of the brake disc at intense braking (100 km/h) - achieved at the start of braking.

Fig. 11. Distribution of temperature of the brake disc at intense braking (100 km/h) - achieved at the end of braking.

Distributions of temperature obtained in this way are shown in Figure 8, Figure 9, Figure 10 and Figure 11. The analysis highlights the thermal storage areas exposed to extreme heat stresses.

4 Results

The analyses can take a few theoretical results, summarized below. Thus, during the braking from the speed of 50 km/h until 0 km/h, the disc can reach temperatures up to 150 °C. Also, from the speed of 100 km/h until 0 km/h, the disc may reach temperatures up to 360 °C, which represents a high risk and may cause cracks and premature wear of the braking system. In Figure 12 and Figure 13 are presented two diagrams which show the evolution of the temperature of the disc brake in time, during braking and cooling after stopping the vehicle. The temperatures were considered on a network node placed in the maximum temperature.

Fig. 12. Time-Temperature diagram for a particular node (50km/h).

Fig. 13. Time-Temperature diagram for a particular node (100km/h).

5 Conclusions

The performed simulation leads to the possibility of viewing the phenomenon of braking from thermal point of view. The evolution of the temperature distribution in the specific braking cases is also highlighted.

These researches provide the temperature distribution on surface of the disc, thus identifying the areas with high heat stress and high mechanical stress. Based on these, we can determine the areas considered with high risk.

Is envisaged, in order to develop the study, an extension of simulation by considering a higher number of brake modes, with the expansion of the input data (materials, forces etc.), so that the results will cover a larger area of issues.

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