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FE MODELLING OF FRICTIONAL HEATING IN A DISC BRAKE AT TEMPERATURE-DEPENDENT COEFFICIENT OF FRICTION

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Frictional heating during braking affects the temperature fields of the brake components. High temperature and its gradients may lead to undesirable effects such as brake fade, fluctuations of the coefficient of friction, brake fluid vaporization, thermal cracks, deformations of the disc, etc. [1]. Numerical calculations of the transient temperature fields of the pad and the disc incorporating the temperature-dependent coefficient of friction are based on either axisymmetric (2D) or spatial (3D) models of frictional heating developed by using the finite element method (FEM). The 2D model is considered when the sliding speed is high or the pad covers the rubbing path of the disc entirely [2]. If none of these conditions is fulfilled, the 3D model is used [3]. The two abovementioned models did not include the influence of temperature dependence of the coefficient of friction on the change of the speed, and in turn on the braking time.

The aim of this paper was to study an influence of the fluctuations of the coefficient of friction on the angular speed, braking time and the temperature fields of the pad and the disc. First the thermal problem of friction during braking was formulated. It consisted of the non-linear boundary-value problem of heat conduction as well as the equation of motion. Such coupling allowed to take into account relationship between the temperature and the change of the speed during braking. The numerical solution of the problem in 2D and 3D arrangements of the models was obtained using FEM. The calculations were performed using COMSOL Multiphysics 4.4 software. Both in the axisymmetric and the three-dimensional model perfect contact conditions were applied, however in the latter relative rotational motion of the disc over the stationary pad was set. Two materials of the pad (cermet FC-16L, FMC-11) and one material of the disc (cast iron ChNMKh) were examined. The experimental dependencies of the coefficient of friction on the temperature and the contact pressure were adopted and applied to the FE computational models. The dimensions of the disc brake components were adopted from article [2].

The calculated axisymmetric temperature fields $T(r, z)$ of the pad and the disc (FC-16L/ChNMKh) at the end of braking process (p = 1.47 MPa) are shown in Fig. 1a. As can be seen the disc is heated within the entire volume, whereas the temperature of the pad increases only in the near vicinity from the contact surface (z = 0). The corresponding temperature on the mean radius of the friction surface and deceleration changes during braking for two different values of the contact pressure are presented in Fig. 1b. An increase in the contact pressure from p = 0.39 MPa to p = 1.47 MPa significantly shortens the braking time from

t = 33.15 s to t = 11.89 s. The maximum temperature for these two contact pressures equals T = 523.5°C (t = 25.2 s) and T = 635°C (t = 9.53 s), respectively (maximum radius).

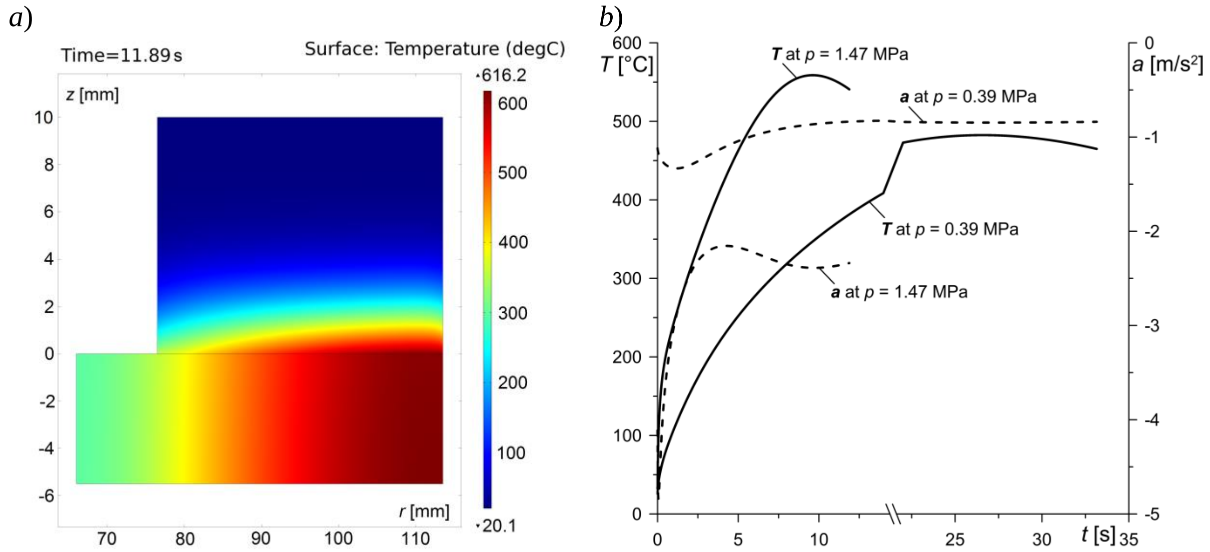

Fig. 1. Temperature distributions in the pad and the disc at the end of braking process (a), and evolutions of temperature on the contact surface (mean radius r = 95 mm) and deceleration of the vehicle during single braking process (b) for FC-16L/ChNMKh

Based on the obtained results for both the 2D and 3D disc brake FE models it was concluded that relatively insignificant change in the coefficient of friction due to temperature variation has an impact on the braking time and in turn the temperature field of the disc and the pad. Therefore omission of the coupling between the coefficient of friction and the vehicle speed may falsify the outcomes. The developed FE models of the brakes will be further extended to analyse both an effect of the temperature-dependent coefficient of friction the thermosensitive materials and wear.

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