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Three-element model of frictional heating during braking with contact thermal resistance and time-dependent pressure

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ABSTRACT

The solution to a thermal problem of friction during braking for a three-element tribosystem disc/pad/caliper with time-dependent specific power of friction and heat transfer through a contact surface has been obtained. The influence of duration of increase in pressure (from zero at the initial moment of time to nominal value at the moment of a stop) and the Biot number on the temperature for such materials as cast iron disc/metal–ceramic pad/steel caliper has been studied.

1. Introduction

Basic elements of disc brakes are a cast-iron disc which rotates with the wheel, friction material (brake pads) and a caliper fixed to the steering knuckle (Fig. 1). When the braking process occurs, the hydraulic pressure forces the piston, and, therefore, pads and disc brake are in sliding contact. Set up force resists the movement and the vehicle slows down or eventually stops. Friction between disc and pads always opposes motion and the heat is generated due to conversion of the kinetic energy. However, friction surface is exposed to the enlarged air flow during drag braking and the heat is dissipated.

The knowledge of a temperature regime of these elements is important to estimate efficiency and reliability of work of frictional materials of brakes in the given conditions of operation. The temperature appreciably determines the friction and wear characteristics of materials of brakes [1–3], the structural transformations within them [4], the intensity of the processes of physical and chemical mechanics on frictional contact [5]. Experimental determination of temperature of a surface of contact concerning authentic objects in most cases causes significant technical difficulties and is connected with essential material and time expenses [6,7]. Therefore, theoretical (analytical or numerical) definition of a temperature regime of elements of friction couple obtained by the solution of a corresponding thermal problem of friction during braking attracts the great interest.

The problem of heat conductivity at friction is formulated as follows: to find distribution of temperatures in elements of friction pair when a contact surface is heated by heat flux and on the free surfaces the heat transfer to the environment takes place.

Mathematically, this problem can be formulated as a boundary-value problem for one or several heat conductivity equations of parabolic type. Usually, on the contact surface two boundary conditions are set. The first equates the sum of intensities of heat fluxes directed inside the body to specific power of friction [8]. In the second – boundary condition affirms, that the difference in the intensity of heat flux on the surface of contact is proportional to the difference of contact temperatures. The coefficient of proportionality is the contact heat transfer coefficient (the value, inversely proportional to the thermal resistance of contact). The thermal contact of bodies, taking into account the jump of their temperatures on the surface of contact, is called incomplete or imperfect [9,10]. In the special case when the heat transfer coefficient tends to infinity (or the contact thermal resistance tends to zero), the second of these conditions is reduced to the condition of equality of temperatures on the contact surface. Together with the first boundary condition this condition of equality of contact temperatures constitute a system of boundary conditions of perfect thermal contact [11].

In the case of inhomogeneous bodies, at the presence of the thermal resistance on the contact, depending on the pressure

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