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Investigation of the temperature field induced in the process of friction of a composite pad and a homogeneous disc ☆

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ABSTRACT

The analytical model for the determination of transient temperature field and heat fluxes in friction elements of brakes (pad/disc) is presented. It is assumed that one friction element is composed of a multi-layer composite strip, and the second element is a homogeneous semi-space. The solution to a non-stationary thermal problem of friction is obtained for a tribosystem with heat generation on a surface of contact and convective heat exchange with an environment on outer surface of a strip. The influences of composite parameters, for example, reinforcement fraction in the cross-section of periodic cells and the ratio of the conductivities of matrix and fibers, on the maximal temperature are studied.

1. Introduction

Composite materials are widely used in the design of friction elements in modern brake systems [1–5]. Thermophysical properties of the components (fiber and matrix) of composite materials are different, and their influence on the temperature generated due to friction must be predictable. Therefore, the development of effective analytical and numerical methods of determination of temperature in a pad/disc tribosystem is the current problem.

The mean temperature on the contact surface during braking is often given by solving the one-dimensional boundary-value problem of heat conduction for two bodies: the plane-parallel strip (the pad) and semi-infinite foundation (the disc). Usually it is assumed that materials of both bodies are homogeneous [6–8].

By applying a homogenization model with the use of microlocal parameters [9,10], a transient heat conduction equation of parabolic type (for multi-layer composite strip consisting of finite periodically repeated cells of rectangular shape each) was derived in papers [11,12]. The solution to this equation in the case of a thermal problem of friction for a composite strip deposited on a homogeneous foundation under uniform or time-dependent heating of free surface of the strip was obtained in articles [13,14]. The special case of such composite, i.e., two-periodic layered semi-space, was considered in article [15]. An inverse algorithm based on the conjugate gradient method and the discrepancy principle was applied in article [16] to estimate the unknown time-dependent heat flux for the system composed of a multi-layer composite strip and the semi-infinite foundation, while the temperature history at some measurement locations was known.

The heat problems of friction refer to problems of heat conductivity and the calculation of the temperatures in friction couples during braking. The statement of such problems is considered in two approaches. In the first variant the elements of friction pair are divided in thoughts and then on each of friction surfaces the intensity of heat fluxes are set in such a way that their sum equals the specific power of friction [13,14]. The second variant consists of the simultaneous solution to the heat conduction equations for both pad and disc with the subsequent determination of the temperature and heat flux intensities on the surface of friction. Within the framework of the second approach we have analyzed a distribution of transient temperature in the composite pad (the strip) and the homogeneous disc (the foundation) using the solution of a corresponding contact boundary-value heat conduction problem.

2. Problem formulation

Let us apply to the upper surface of the strip of thickness d and at infinity in semi-space the constant pressure p_0 perpendicular to the contact plane (Fig. 1). In the beginning, for $t=0$ the strip starts moving over the semi-space surface with constant speed V_0 in the direction of the y-axis. As a result of friction, on the contact surface $z=0$ heat is generated, which causes heating of friction pair elements. It is assumed that

1) The thermal resistance on the contact surface is negligible and the temperatures of the strip and the foundation on this surface are identical.
2) The sum of heat flow intensities directed from friction surface to interior of each elements equals the power of friction $q_0=fV_0p_0$.

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