International Communications in Heat and Mass Transfer 38 (2011) 1322–1329

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

The thermal problem of friction during braking for a three-element tribosystem with a composite pad ☆

Michal Kuciej

Faculty of Mechanical Engineering, Bialystok University of Technology, 45C Wiejska Street, Bialystok, 15-351, Poland

ARTICLE INFO

Available online 16 August 2011

Keywords:
Frictional heating
Braking
Temperature
Composite
Heat transfer

ABSTRACT

The analytical solution to a thermal problem of friction during braking with constant retardation for a three-element system (a foundation/strip/semi-space) is obtained. The solution allows to find the evolution and distribution of transient temperature in the caliper/pad/disk tribosystem. Unlike known solutions for three-element tribosystem, this one is obtained on the assumption that material of the pad (strip) is the periodic composite. The every unit cell of the composite contains four sub-cells with rectangular cross-section and with different thermo-physical properties. It is assumed, that intensity of the heat generation on the contact surface is equal to power of friction and through this surface the heat transfer takes place. The influence of the geometrical dimensions and thermo-physical properties of composite sub-cells on the maximum temperature in the system has been investigated.

1. Introduction

The majority of disk brake systems consist of three basic elements: a rotating disk and motionless pads fixed in a caliper (Fig. 1). Mathematically, the thermal problem of friction for such tribosystem can be formulated as a one-dimensional boundary-value problem of heat conductivity with time-dependent frictional heating on a contact surface of a top semi-space (the disk) and a strip (the pad). The strip is connected with the semi-infinite foundation (the caliper). The analytical solution to a thermal problem of friction has been obtained in Refs. [1–3] using the Laplace integral transform method. The solution simulates the process of frictional heating in the above mentioned three-element tribosystem at constant pressure and linearly-decreasing sliding speed. The corresponding solution for the same tribosystem with pressure monotonically increasing in time from zero to nominal value, has been studied in Ref. [4]. Influence of pressure increase with fluctuations on temperature has been investigated in Ref. [5].

The solutions in Refs. [1–5] have been obtained in case of a homogeneous material of the strip. However, the modern pads are more often made from composite materials [6–10]. Therefore, the aim of this article is to investigate a transient temperature field in three-element tribosystem, on the assumption that one of its elements – the strip – is made from a composite material, which consists of n periodically repeated cells of rectangular shape each. The region of middle cross-section of unit cell is $\Delta = \{(x,z) \in R^2, 0 \le x \le a \cup 0 \le z \le b\}$. Each unit cell Δ contains four different rectangular sub-cells $\Delta_1 = (0, a_1) \times (0, b_1)$, $\Delta_2 = (a_1, a) \times (0, b_1)$, $\Delta_3 = (a_1, a) \times (b_1, b)$ and $\Delta_4 = (0, a_1) \times (b_1, b)$ with the heat conductivities K_i and diffusivities k_i, $i = 1, 2, 3, 4$, respectively (Fig. 2). The perfect thermal contact at the interfaces is assumed.

The transient heat conduction equation of parabolic type and the effective thermal-physical constants for such structure of composite have been obtained in Refs. [11,12]. Using these results, the solution of boundary-value problems of heat conductivity has been studied in Ref. [13] for the composite coating deposited on the homogeneous foundation and heated by a thermal flux with intensity decreasing linearly in time. The solution of inverse problem – determining an unknown time-dependent heat flux for the system composed of the composite strip and semi-infinite homogeneous foundation with known distribution of the transient temperature field – has been found in Ref. [14]. The analytical solution to the thermal problem of friction during braking at constant retardation for a two-element tribosystem – the homogenous strip (the pad) or the composite strip (the pad) sliding on a surface of the homogeneous semi-space (the disk) – has been obtained in Refs. [15,16]. Review of work related to mathematical modeling or FEM modeling of thermal processes during braking can be found in Refs. [17,18]. The influence of several experimental and theoretical formulas for heat partition ratio on temperature in a pad/disk tribosystem has been studied in Ref. [19].

In this paper we work towards the solution of the same problem for the above-mentioned three-element tribosystem with the composite strip.

2. Statement of the problem

Let the constant pressure p_0 in direction of z-axis of the Cartesian system of coordinates $Oxyz$ be applied on infinity in the semi-spaces

☆ Communicated by W.J. Minkowycz.

E-mail address: m.kuciej@pb.edu.pl.

0735-1933/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2011.08.005