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Estimation of thermal contact resistance and temperature distributions in the pad/disc tribosystem ☆

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A B S T R A C T

In this study, an inverse algorithm based on the conjugate gradient method and the discrepancy principle is applied to estimate the unknown time-dependent thermal contact resistance for the tribosystem consisting of a semi-infinite foundation (disc) and a plane-parallel strip (pad) sliding over its surface, from the knowledge of temperature measurements taken within the foundation. Subsequently, the temperature distributions in the medium can be determined as well. The temperature data obtained from the direct problem are used to simulate the temperature measurements, and the effect of the measurement errors upon the precision of the estimated results is also considered. Results show that an excellent estimation on the time-dependent thermal contact resistance can be obtained for the test case considered in this study. The current methodology can be applied to the prediction of thermal contact resistance in engineering problems involving sliding-contact elements.

1. Introduction

The ceramic–metal frictional materials are now extensively used in brake systems for their high thermal stability and wear resistance [1]. In the process of braking, the cermet patch is pressed to its counterbody (disc, brake drum, rim of the wheel, etc.). As a result of friction on the contact surface, the kinetic energy is transformed into heat. The elements of the brakes are heated and, hence, the operation conditions for the friction patches become less favorable: the friction coefficient decreases and their wear intensifies, which may lead to emergency situations. Thus, the correct calculation of temperature is one of the most important issues in the design of brakes [2]. In the past, there have been many investigations focusing on the determination of temperature in brake systems [3–5]. However, to the best of the authors' knowledge, there are few researches describing the realistic situation in the brake systems and considering the temperature drop at the interface between the pad and the disc. The accurate determination of temperature distributions in the brake systems requires considering the imperfect conditions of thermal contact at the interface.

Over the past decades, inverse analysis has become a valuable alternative when the direct measurement of data is difficult or the measuring process is very expensive, for example, the detection of contact resistance, the determination of heat transfer coefficients, the estimation of unknown thermophysical properties of new materials, the prediction of damage in the structure fields, the detection of fouling-layer profiles on the inner wall of a piping system, the optimization of geometry, the prediction of crevice and pitting in furnace wall, the determination of heat flux at the outer surface of a vehicle re-entry, and so on.

Although there have been many investigations considering the effect of contact resistance in different applications [6–9], nevertheless, the determination of thermal contact resistance at the interface has never been an easy task. The main objective of the present study is to develop an inverse analysis to estimate the thermal contact resistance for the tribosystem in Ref. [5], which consists of a sliding strip (the pad) over the surface of a semi-infinite foundation (the disc). An analysis of this kind poses significant implications on the study of the problems associated with sliding contact such as in a brake system. In this study, we present the conjugate gradient method [10–13] and the discrepancy principle [14] to estimate the time-varying thermal contact resistance by using the simulated temperature measurements. Subsequently, the distributions of temperature in the strip and foundation can be determined as well. The conjugate gradient method with an adjoint equation, also called Alifanov's iterative regularization method, belongs to a class of iterative regularization techniques, which means that the regularization procedure is performed during the iterative processes, thus the determination of optimal regularization conditions is not needed. No prior information is used in the functional form of the thermal contact resistance variation with time. On the other hand, the discrepancy principle is used to terminate the iteration process in the conjugate gradient method.

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