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Experimental disc heat flux identification on a reduced scale braking system using the inverse heat conduction method

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ABSTRACT

This work focuses on the local heat fluxes on a disc during braking conditions. The generated heat and the temperature field are identified using an inverse heat conduction method coupled to temperature measurements inside the disc. Function specification is used to estimate the boundary conditions in the model without any prior information on the flux intensity and the evolution regarding the time and the position on the sliding surface. Disc heat flux identifications are performed for different braking conditions (sliding speed and normal pressure) on a High-Speed Tribometer. The temperature values are obtained using a telemetry system that allows inductive data transfer. The influence of the braking conditions on the heat repartition and the surface temperature is discussed.

1. Introduction

In automotive brake linings, the friction materials are used to rapidly dissipate the kinetic energy on small surfaces. The pads and the disc are then subjected to severe thermal and mechanical stresses. The tribological and wear behaviours are affected by the temperature elevation in the contact zone [1]. A loss of braking efficiency is observed for organic brake pads with this temperature elevation. This loss of efficiency is caused by phenolic resin degradation above 300 °C [2], which varies with the chemical formulation. Efforts are aimed at finding some way to cool the disc [3–5] and limit the temperature elevation. The thermal conditions are essential for better understanding the physical phenomena occurring at the interface. The heat partition is generally defined by the parameter α, that defines the part of the heat dissipated on the disc side. Due to contact zone asperities and the dynamic effects, differences between the disc and pad surface temperatures have been observed. It is also necessary to define a contact thermal resistance R_c [6] depending on the sliding speed, materials, and wear debris.

Some particular temperature fields have been observed using thermography on the disc contact surface. Anderson has named and classified them as hot spots [7]. The temperature can locally achieve values greater than 1200 °C on asperities. This phenomenon is defined by Blok [8] as the flash temperature, and Greenwood has suggested a way to evaluate their values [9]. Macroscopic spots originate in thermoelastic instabilities [10]. These spots preferentially appear in cases of severe braking conditions [11]. Dufrenoy [12] has highlighted that this heat localisation is responsible for disc damage because the thermal gradients induce mechanical stresses.

Unfortunately, the emissivity of the disc changes with the temperature and surface roughness during braking. To accurately measure the surface temperature, emissivity cartography is needed, as identified in a previous work [13]. Thevenet [14] has developed a specific two-colour pyrometer to simultaneously measure the emissivity and surface temperature below 200 °C. This is possible by assuming that the emissivity value does not vary with the wavelength and that the disc can be considered as a grey body in the wavelength range. The two-colour pyrometer was then used by Kasem [15] to obtain corrected surface temperature values by coupling it with an infrared camera. Additionally, Siroux [16] has measured the local disc–pin interface temperature through a calcium fluoride window embedded at the pin side.

At the same time, analytical and numerical models have been developed to estimate the heat repartition in the antagonist parts and to predict the temperatures fields. Siroux has identified the temperature field in a disc subject to periodic sliding contact using a model based on the Fourier transform algorithm [17]. Laraqi has

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