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# A predictive model for the thermal contact resistance at liquid–solid interfaces: Analytical developments and validation

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ABSTRACT

An analytical model has been developed to quantify and predict the Thermal Contact Resistance (TCR) at the liquid–solid interface. Contact topography and interface characteristics are included in the model through the inclusion of solid surface roughness parameters and the mean trapped air layer at the interface. In liquid–solid contact, air is often entrapped and compressed inside the microcavities of the solid surface roughness. The mean trapped air layer is determined from the mechanisms of contact at the liquid–solid interface. The proposed models determine the radius and the density of the micro-contact points for a given set of contact conditions. The density and the radius of contact spots have been integrated into a classical thermal flux tube theory in order to calculate the TCR at a liquid–solid interface. The models have been applied to the casting–die interface in High Pressure Die Casting. The calculated TCR is found to agree with the experimentally determined results.

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## 1. Introduction

It is has been widely reported over the last two decades, that when a liquid material is brought into or dropped onto the surface of a solid substrate, an amount of air is entrapped between the liquid and the solid surfaces [1–5]. Consequently, the contact between the liquid surface and the solid surface is not perfect at a microscopic scale. If the action of contact involves the heat transfer through the interface, this poor contact results in a resistance to heat transfer known as a Thermal Contact Resistance (TCR). TCR is equivalent to the inverse of the interfacial thermal conductance or the heat transfer coefficient ($h$) at the interface.

It is well known that the occurrence of a TCR at an interface is related to the fact that the heat flux from the hot body to the cold body needs to be constricted to pass through the microcontact spots at the interface as illustrated in Fig. 1. This may be modelled at a macroscopic scale by a temperature difference at the interface that characterises the magnitude of the TCR according to Equation (1):

$$\mathrm{TCR} = \frac{\Delta T}{q} \tag{1}$$

The role of the TCR in the mechanisms of heat transfer becomes more important when the thermal properties of the contacting bodies are high [6,7]. In fact when the thermal conductivities of the contacting bodies are small, the TCR becomes very weak compared to the intrinsic thermal resistance of the bodies which depends on their thickness and their thermal conductivities. Consequently the TCR can become negligible.

The situation of contact in which TCR plays a dominant role on heat transfer is largely present in many industrial processes such as die casting [8–10], injection moulding [11–13], glass forming [14–16] and stretch blow moulding [17]. Currently the use of numerical simulation to predict various aspects of these processes such as mould filling, crystallisation, solidification and micro-structural development has become an important development focussed on improving the productivity of the process and the quality of the manufactured part along with new product developments [18]. These aspects of the process investigated by simulators depend largely on the rate of heat transfer between the

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