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Effect of Local Inhomogeneities on Heat Transfer through Porous Bed

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Extended Abstract

The problem of heat transfer through porous material, which of form may be continuous or particulate, can be encountered regularly in various industries. The common engineering method for calculating heat transfer in for example a catalytic bed is to use the so-called ‘Effective conductivity method’. The method is based on Fourier's law and describes the system as one continuum with effective thermal conductivity calculated using the average characteristics of the bed. To calculate this conductivity, various models have been created in the last century. From these the Zehner-Schünder model [1] is often recommended [2] with various later refinements enhancing its range of applicability. Although practical, these systems also have limitations. As they are based on the principle of local averaging and local thermal equilibrium, they require a minimal size of a system on which the effect of local inhomogeneities can be neglected [3]. However, these requirements limit its applicability to large systems, usually without an internal heat source. Moreover, as the method treats the system as one continues volume, information about local phenomena and temperature field is also lost. To explore such systems, CFD methods are often used, as they enable researchers to ‘see into the system’. However, these methods are often computationally intensive due to the complex structure of porous materials or sacrifice local precision for computation time [4–6]. A compromise between the two aforementioned methods appears to be the thermal resistance network model first proposed (to our knowledge) by Argento and Bouvard [7]. It simplifies the system to a network of nodes connected through resistances based on the local structure. Through this method, local phenomena such as conduction through solids and liquids, heat transfer between phases and particles can be captured for a comparably small amount of compute power as the number of nodes that define the system is several orders of magnitude smaller than that of CFD [8].

It is the goal of our research to improve upon this method by developing new resistance models for other heat transport phenomena such as conduction or convection through fluid or heat exchange between the two phases. These models however are not currently available in the scientific literature. In the previous year, we developed our in-house resistor network solver capable of replicating effective conductivities for structures found in the literature. In these simulations, we have observed that the local temperature field is influenced by local inhomogeneities present in the porous structure. To test whether such behaviour can also be observed in reality, we required more complete experimental datasets, hence we produced our experimental porous bed, upon which more detailed data from variously structured porous beds can be measured. Based on the preliminary results gained from these experiments, it is apparent, that the observed behaviour can be recreated experimentally as a temperature difference was observed inside the porous where a more general approach would suggest a homogenous temperature field. The extent and the influence of various bed parameters however remains a question for follow up experiments. Moreover, it was found that most resistor model are incapable of replicating the observed resistance between particles in contact as they generally overpredict the resistance values.

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