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Estimation of viscous and inertial resistance coefficients for various heat sink configurations

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Abstract

In the presented paper a simple method was applied to calculate a viscous and inertial resistant coefficient of a porous material substituting a flared fin heat sink geometry. Based on the performed calculations plots showing the variation of the resistant coefficients with heat sink height and distance between fins were made. In addition, empirical relations that can be applied for a calculation of required resistant coefficients were proposed. Finally a comparison of a flow characteristic both for the real heat sink and its porous representation for selected cases was shown. In the analysis an air flow in room temperature was investigated. Analyses were performed for a range of Reynolds number: $8.3 \cdot 10^3 – 1.7\ 10^4$. All the necessary numerical calculations were made in ANSYS Fluent commercial code, Microsoft Excel and Matlab.

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1. Introduction

The modeling of the heat transfer around the various types of heat sinks is a well-known and widely studied problem. There are many papers that consider the problem of heat and mass transfer in heat sinks of varying shape and geometry. For example Y. T. Yang and H.S. Peng [1] studied the thermal performance of a non-uniform pin fin heat sink for various cooling medium velocities. At the same time B.L. Chan Byon [2] studied, both experimentally and numerically, the influence of the design of a radial heat sink on cooling efficiency in natural convection flow.

Because of the increasing computational power available in CPUs it is now possible to provide very detailed information about the heat transfer characteristics of an individual heat sink. However, if a heat sink only forms part of a larger system and, as is also common, there is more than one heat sink in overall system, it is becomes more

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difficult to include the resultant complex geometry in the numerical model. Primarily this difficulty relates to the significant increase in the number of mesh elements required to represent the heat sink geometry properly. In practice this can results in a mesh with tens of millions of elements. It is unfeasible to obtain a solution to a model with such a large mesh in a reasonable time.

To overcome this issue, it is possible to include a heat sink in a model as a porous material. Such a model is often referred to as a compact model of a heat sink. By representing a heat sink as a simple porous element, the number of mesh elements may be significantly reduced as the complex heat sink geometry is often replaced by a simple body (for example: cylinder, box etc.). An example of such an approach was given by Narasimhan S. and Majdalani J. [3] where a fin heat sink was replaced by a porous block. The calculations performed showed a satisfying accuracy of a porous heat sink model both in the natural and forced convection case. A similar approach was given by a Jeng T.M. et al. [4,5] for a pin fin heat sink. Another successful application of a porous model for simulation of a pin fin heat sink was presented by Yu E. and Joshi Y. [6] who performed both numerical and experimental investigations of the efficiency of a pin fin heat sink subjected to natural convection cooling.

Whilst the substitution of the real heat sink by a simple porous body often brings benefits in terms of shorter calculation time, in order to have a good approximation of the real heat sink it is necessary to fulfill two main requirements. Firstly, it is necessary to maintain a similar pressure drop along the coolant flow to properly approximate heat sink dynamic behavior. Another aspect is its thermal performance, which is often described by a heat sink thermal resistance characteristic curve. When substituting for a complex heat sink geometry, it is also necessary to maintain its thermal characteristic. In practice this can be done for example by applying existing thermal resistance vs heat flux curve of a real heat sink to calculate an effective thermal conductivity of a porous material to keep a proper temperature drop along heat sink [3]. If the thermal resistance curve is not accessible an original heat sink geometry can be used to find the required thermal resistance values.

In this paper the primary focus is on the flow similarities between the heat sink geometry and its porous representation. The thermal performance of a group of heat sinks will not be studied.

As previously stated, in order to maintain a similar coolant flow behavior in a porous model of a heat sink, a proper pressure drop along the porous material must be retained. To fulfill this requirement it is necessary to determine precise values of viscous and inertial resistances for a porous material. A semi empirical model that allows these coefficients to be calculated for fin and pin fin heat sinks was proposed by Jeng T.M and Tzeng S.C. [7].

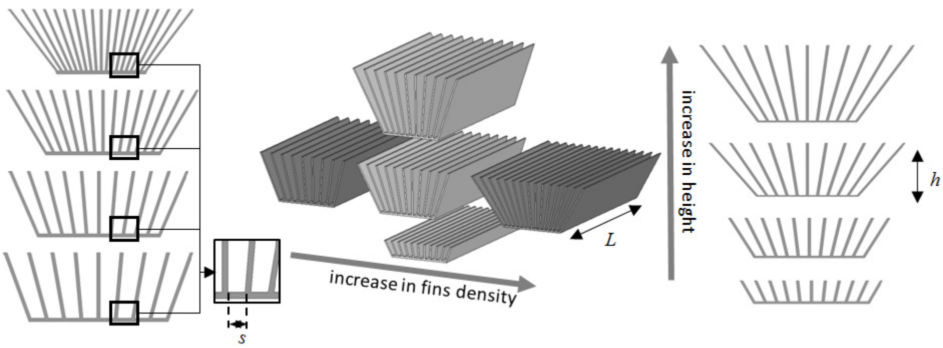

Fig. 1. Example of heat sinks geometry under investigations.

In this paper a similar approach will be performed to identify resistance coefficients for a group of flared fins heat sinks. Additionally, a sensitivity study of the influence of heat sink dimension on the resistance coefficient values is also performed.

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