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Heat-conduction optimization based on constructal theory

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Abstract

An analysis of the "tree-like network" construct method is presented. The high effective-conduction channel distribution has been optimized, without the premise that the new-order assembly construct must be assembled by the optimized last-order construct. The "tree-like network" construct method is faultiness. A more optimal construct is obtained, and when the thermal conductivities and the proportion of the two heat-conduction materials are constants, the limit of the minimum-heat resistance is derived. These conclusions can be used as a guide for engineering applications.

Keywords: Constructal theory; "Tree-like network" construct method; High effective-conduction channel distribution; Generalized thermodynamic optimization

1. Introduction

As a result of the rapid development of electronics, more and more components have been integrated in the circuits, while the sizes of components become smaller and smaller, so the problem of cooling becomes more important. One way of cooling the components is by using high-conductivity material. For this problem, Bejan put forward the "tree-like network" construct method based on the constructal theory [1–19], which derived the optimal high effective-conduction channel distribution with the premise that

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the heat generation is uniform and the ratio of conductivity of high conductive material to conductivity of the electronic material is high.

The "tree-like network" construct method started the optimization with a rectangular area which is very small. Optimizing this area, the optimal shape is deduced. Then, assembling the first-order assembly construct with the optimal area and optimizing this construct with respect to the rectangular area and the distribution of high-conductivity material. In this way, a higher-order assembly construct can also be assembled. It ends when the area covers the whole given area. However, there are some doubts about the "tree-like network" construct method. This method assembled the new construct with the optimized last construct. However, whether this optimization process is the best has not been proved. Having compared the thermal resistance of each order construct, Ghodoossi [20] found that the thermal resistance does not decrease with the increase of the construct complex, which is against the claim of the construct theory. In this paper, the high effective conduction channel distribution is optimized again without the premise that the new order construct is assembled by the optimized last one. It is proved that the "tree-like network" construct method is faultless. A more optimal construct is obtained, and when the thermal conductivity and the proportion of the two heat-conduction materials are constant, minimum heat-resistance can be derived. All these conclusions can be used as a guide in engineering applications.

2. Rectangular elemental-area

As shown in Fig. 1 [20], the rectangular area ($H_0 \times L_0 \times 1$) generates heat at a constant rate q. The heat generation rate per unit area is constant [$q''' = q/(H_0 \times L_0)$]. The area size A_0 is constant, but the aspect-ratio H_0/L_0 is free to vary. The heat generated in the rectangular area is first directed to a relatively highly conductive link of width D_0, which is located on the longer axes of the rectangular elemental area. Then it is conducted to a heat sink located at point M_0 by the D_0 link. The boundary of the rectangular elemental area is adiabatic, except for the heat-sink point M_0. It is assumed that the thermal conductivity of a highly conductive link (k_p) is much higher than the thermal conductivity of electronic material (k_0) and the area occupied by highly conductive material is much smaller than the area of electronic material. It is also assumed that the rectangular elemental area is slender enough to assume one-dimensional (y-direction) heat conduction through the heat generating area.

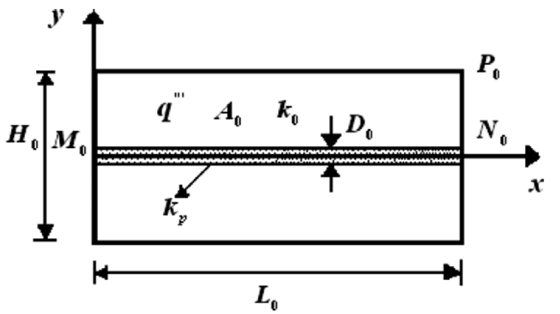

Fig. 1. Rectangular elemental-area.