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Constructal optimization for “disc-to-point” heat conduction without the premise of optimized last-order construct

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A B S T R A C T

Based on constructal theory, branch-patterned disc with first- (or higher-) order assembly is optimized based on constructal minimization of maximum temperature difference without the premise that elemental sectors that assemble the perimeter of the branch-patterned disc are optimal. Results show that the optimal constructs without the premise and that with the premise are different obviously with the same conditions, maximum temperature difference of heat transfer without the premise decreases by 49.3%, and every optimal branch-patterned disc with higher-order assembly reduces to a branch-patterned disc with first-order assembly. The optimal construct obtained in this paper decreases the maximum thermal resistance greatly.

1. Introduction

Bejan is at the origin of the constructal theory [1,2], which had its start in 1996. He told that the idea came to him after he studied the street networks of Rome [3]. Constructal law was stated as follows: For a flow system to persist in time (to survive) it must evolve in such a way that it provides easier and easier access to the currents that flow through it. Since Bejan [1] applied constructal theory to optimization problems involving heat conduction, it has been developing rapidly [4–15] and has provided new research impetus into heat transfer problems [16–60]. The necessity to cool electronic devices grows ever higher as electronic devices become ever smaller. Cooling electronic devices can be described as a “disc-to-point” heat conduction problem; essentially, how to determine the optimal distribution of a high-conductivity material through a given disc such that the heat generated in the disc is conveyed most effectively to a single point. The optimal structure and distribution of the high-conductivity material were determined in Ref. [61] by decreasing the thermal resistance via minimizing maximum temperature differences as the optimization criterion for heat conduction problems within a disc. A disc uniformly-slotted with radially-distributed rectangular blades was studied and the blade structures made of high-conductivity materials were optimized by following the same optimization procedure in Ref. [62]. In Ref. [63] the analytic solution of Ref. [61] was further validated with numerical simulations, tree channels with loops were optimized, and heat conduction performances of radial-patterned and branch-patterned discs were compared. Based on Ref. [61], the structure and distribution of high-conductivity material of the heat-generating disc were optimized based on constructal minimization of entransy dissipation rate [64], and the obtained results in Ref. [64] were compared with those in Ref. [61].

Ref. [61] assumed that the elemental sectors that assembled into the perimeter of the branch-patterned disc were optimal, optimized the structure and distribution of high-conductivity material of the heat-generating disc based on constructal minimization of maximum temperature difference, and determined a critical point in which the high-conductivity material is distributed according to the optimized radial pattern or branch pattern that decreases the global thermal resistance of the entire disc. Based on Ref. [61], by relaxing the assumption that the elemental sectors that assemble into the perimeter of the branch-patterned disc are optimal, the structure and distribution of high-conductivity material of the disc will be optimized, and the obtained results will be compared with those obtained in Ref. [61].

2. Radial-patterned disc [61]

The radius of radial-patterned disc as shown in Fig. 1 [61] is R_0 and its thermal conductivity and heat generation rate are k_0 and q''' respectively. The heat current, $q = q'''\pi R_0^2$, which is generated uniformly in the disc flows through the high-conductivity paths (the thermal conductivity of the material is k_p and the thickness is

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