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Optimization of constructal economics for volume-to-point transport

Shengbing Zhou, Lingen Chen *, Fengrui Sun

Postgraduate School, Naval University of Engineering, Wuhan 430033, PR China

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Abstract

The constructal economic optimization for a given area is carried out in this paper with minimum transport cost objective by using a triangular elemental area. A number of triangular elements are assembled to form a new larger rectangular area and optimized by relaxing the angle constraint. The results obtained herein are discussed and compared with those in recent references.

Keywords: Constructal theory; Volume-point transport; Economics; Generalized thermodynamic optimization

1. Introduction

Constructal theory [1–10] advocates that various shapes and structures of the matter in nature possess the tendency for their performances tend to their optima. The optimal performance (such as minimal heat-resistance [11], minimal entropy-generation [12], minimal cost [13–15], maximum revenue [13–15], etc) and the corresponding shape and structure for the given optimization objectives and constraint conditions have been investigated using constructal theory when two or more various velocity flows (such as heat flows, fluid flows, people and vehicle flows, goods flows, etc) exist.

Thermoeconomics [16], whose task is to solve cost and efficiency problems of thermal and related engineering systems, has been a useful branch of engineering thermodynamics.

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* Corresponding author. Tel.: +86 27 836 150 46; fax: +86 27 836 387 09.
E-mail addresses: lgchenna@yahoo.com, lingenchen@hotmail.com (L. Chen).

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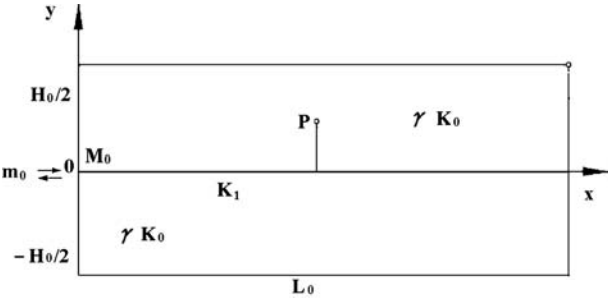

Fig. 1. Rectangular-elemental area.

Chen et al. [17–19] developed the finite-time exergoeconomic analysis method by combining finite-time thermodynamics with thermoeconomics in 1990s. The finite-time exergoeconomic performance bounds, optimization relations and parameter optimization criteria were considered. De Vos [20–22] also researched endoreversible thermoeconomics.

According to thermoeconomics, economics was combined with constructal theory. Bejan et al. [13,14] researched economic optimization for a given area with the minimum transport-cost objective. First, a rectangular elemental area with height H_0, length L_0 and area size A_0 was optimized, as shown in Fig. 1. The uniform flow-rate is denoted as γ [kg/(m^{2}s)], so the total flow of the goods in the element is $m_0 = \gamma A_0$. The goods flow to point M_0 using the most expensive-cost factor K_0 along the Y-direction and a less expensive-cost factor K_1 along the X-direction. The minimum cost and the corresponding elemental shape and structure were obtained. Then, a relatively larger volume was designed and optimized by introducing a new link of higher velocity. A number (n_1) of optimized elemental-volumes were assembled on the upper and lower sides of the new link. There exists an optimal number n_1 corresponding to the minimum transport cost of the assembled volume (i.e., the first-order construct). The analogous work was continued until the control volume was covered by the assembly. Ghodoossi and Egrican [15] researched constructal economic optimization for the given area made up of an assembly of rectangles in a rectangle, rectangles in a triangle, triangles in a triangle and triangles in a rectangle.

In the studies of Refs. [13–15], the angles of the link paths were assumed to be perpendicular to each other. Based on Ref. [15], this paper will carry out the constructal economic optimization for the given area made up of an assembly of triangles in a rectangle with the minimum transport cost objective by relaxing the angle constraint. The link paths are no longer perpendicular to each other. The minimum transport cost for the elemental area is obtained. Then, a number (n_1) of elements are assembled into the first-order construct and optimized. The complete analytical results are obtained by continuing with an analogous process. The results obtained herein are compared with those in recent references.

2. ‘Volume-point’ transport model

The mathematical description of the question considered in this paper is:

Consider a given region (‘volume’) with area A, in which all ‘points’ (representing consumers or producers) are distributed as average values. A stream of goods flows from one