International Journal of Thermal Sciences 50 (2011) 1782–1789

Contents lists available at ScienceDirect

International Journal of Thermal Sciences

journal homepage: www.elsevier.com/locate/ijts

Multiobjective constructal optimization of an insulating wall combining heat flow, strength and weight

Lingen Chen*, Zhihui Xie, Fengrui Sun

College of Naval Architecture and Power, Naval University of Engineering, Wuhan 430033, China

A R T I C L E I N F O

Article history:
Received 1 September 2010
Received in revised form
28 January 2011
Accepted 28 March 2011
Available online 6 May 2011

Keywords:
Constructal theory
Insulating wall
Heat insulation
Mechanical strength
Multidiscipline
Generalized thermodynamic optimization

A B S T R A C T

For a vertical insulating wall, it is pursued in engineering design that taking the three requirements of heat insulation, mechanical strength and weight into account simultaneously, so we further develop the pioneer study of multidisciplinary constructal optimization presented in the previous paper [S. Lorente, A. Bejan, Combined 'flow and strength' geometric optimization: internal structure in a vertical insulating wall with air cavities and prescribed strength, Int. J. Heat Mass Transfer, 2002, 45(16): 3313–3320]. In this paper, thermal resistance per unit mass is introduced as the optimization objective, and a multidisciplinary and multiobjective constructal optimization is carried out based on the maximization of thermal resistance per unit mass with the global constraints, i.e. fixed external dimensions and prescribed mechanical strength. The results show that, the thermal resistance per unit mass of the insulating wall can approach its maximum with the corresponding optimal number of cavity under specified environmental condition (i.e. with specified natural convection effect). The bigger the strength is, the smaller the thermal resistance per unit mass is. For specified strength, the maximum thermal resistance per unit mass is insensitive to the change of the overall Rayleigh number group when the overall Rayleigh number group is much small; and then decreases monotonically with the increase of the overall Rayleigh number group when the overall Rayleigh number group is big, however, its decreasing amplitude decreases gradually. When heat flow, strength and weight are all taken into account, the 3-way optimization and selection (the maximization of thermal resistance per unit mass) of wall architecture requires higher degree of accuracy compared with the 2-way optimization and selection (the maximization of overall thermal resistance). This paper gives out an alternative scheme for the practical design of insulating wall, especially for the application case in which the weight of wall is limited strictly.

1. Introduction

Constructal theory has bloomed since it was put forward by Bejan [1] in 1996 and become one of the most active fields of thermal science [2–18]. Constructal law, which is the new development of the first and second laws of thermodynamics and the mentality core of constructal theory, indicates that a system can approach its maximal global performance by the freely evolving of its external shape and internal structure with some global constraints. It has been widely employed to study the constructal problems in many subject fields such as engineering [3,7,8], sociology [9], economics [19,20], material science [21], geophysics [22], biology [23] and medicine [24], etc.

Until now, single-objective optimization has been the main body of the research of constructal optimization, and includes time minimization [1,25], profit rate maximization [19], cost minimization [19,20], maximum temperature difference minimization [16,26–30], heat transfer rate maximization [31], fluid flow resistance minimization [32], heat flux maximization [33,34], path length minimization [35], exergy loss minimization [36], electrical resistance minimization [37], power maximization [38], entransy dissipation rate minimization [39–48], maximum thermal resistance minimization [49], etc. The research of multiobjective optimization includes the optimization of convective heat transfer for low fluid flow resistance and low thermal resistance [50,51] and various tree-shaped heat exchangers [34,52,53], the optimization of pipe network for hot water for low pumping power and low heat loss [54], the optimization of solid–gas chemical reactor for high density of chemical reaction and low pumping power [55,56], etc. Especially, Lorente and Bejan [57] exploited a new direction called multidisciplinary constructal optimization and studied the constructal optimization of an insulating wall by combining heat transfer and strength. After this, Gosselin et al. [58] studied the constructal optimization of a beam under thermal attack by

* Corresponding author. Tel.: +86 27 83615046; fax: +86 27 83638709.
E-mail addresses: lgchenna@yahoo.com, lingenchen@hotmail.com (L. Chen).

1290-0729/$ – see front matter © 2011 Elsevier Masson SAS. All rights reserved.
doi:10.1016/j.ijthermalsci.2011.03.022