ELSEVIER

Journal of Quantitative Spectroscopy & Radiative Transfer 96 (2005) 439–450

Journal of Quantitative Spectroscopy & Radiative Transfer

www.elsevier.com/locate/jqsrt

Numerical heat transfer study in a scattering, absorbing and emitting semi-transparent porous medium in a cylindrical enclosure

M. Timoumi, B. Chérif*, M.S. Sifaoui

Unité de Rayonnement Thermique, Département de Physique, Faculté des Sciences de Tunis, Campus Universitaire, 1060 Tunis, Tunisia

Received 29 October 2003; accepted 29 December 2004

Abstract

In this paper, heat transfer problem through a semi-transparent porous medium in a cylindrical enclosure is investigated. The governing equations for this problem and the boundary conditions are non-linear differential equations depending on the dimensionless radial coordinate, Planck number N, scattering albedo ω, walls emissivity and thermal conductivity ratio k_r. The set of differential equations are solved by a numerical technique taken from the IMSL MATH/LIBRARY. Various results are obtained for the dimensionless temperature profiles in the solid and fluid phases and the radiative heat flux. The effects of some radiative properties of the medium on the heat transfer rate are examined.

Keywords: Porous medium; Semi-transparent; Radiation; Conduction; Convection; Cylindrical geometry

1. Introduction

Heat transfer in heterogeneous media has attracted considerable attention of several researches, because of its important application in many high-temperature phenomena such as solar energy collector, catalytic reactors and heat exchangers. However, only a few approximations have been

*Corresponding author. Tel.: +216 98 52 51 64.
E-mail addresses: bechir.cherif@ipein.rnu.tn, bechir_cherif@yahoo.com (B. Chérif).

0022-4073/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jqsrt.2004.12.003

developed in order to deal with the role played by radiation in the heat transfer rate in such media [1–3]. The radiative transfer equation (RTE) was solved in an infinite isotropic [4,5] as in anisotropic scattering steady-state porous medium using the discrete ordinates method (DOM) combined with an asymptotic analysis [6,7]. Recently, Cherif et al. have studied the problem in a transient rectangular semi-transparent porous medium [8] and in a cylindrical optically thick porous medium [9].

The current study examines the heat transfer by simultaneous radiation, conduction and convection in a scattering, absorbing and emitting porous medium in a cylindrical enclosure. We resolve the radiative transfer equation and introduce explicitly the radiative heat flux expression in the conservative energy equation. We extend the DOM to study heat transfer in the medium; we evaluate the derivative term appearing in the RTE, with recourse to a classical difference schema [10,11].

2. Formulation

The considered medium here consists of a pile of homogeneous spheres contained between two isothermal cylinders. The inner cylinder has a radius R_1 and is at a temperature T_{s1} subject simultaneously to a radial fluid flow at a temperature T_{f1} and a diffusely incident radiation q. The outer cylinder has a radius R_2. A schematic diagram of the physical system is shown in Fig. 1.

For the mathematical analysis, the following basic assumptions are made: steady state; (b) the fluid flow and heat transfer are one dimensional; (c) all the thermo-physical properties are constant; (d) the solid is absorbent, participating, scattering and it behaves as a grey body for radiation; (e) the temperature gradients in the solid particles are negligible; (f) the fluid phase is incompressible and the mass flow rate at every cross-section of the medium is constant.

In addition to these assumptions, we consider the case of a non-radiating gas, the mathematical formulation of the problem is based in sufficiently general conservation form of the energy equation of the fluid and solid phases and which one of the radiative transfer for cylindrical symmetry. We, therefore, normalise the problem by introducing the reference temperature $T_r = T_{s1}$.

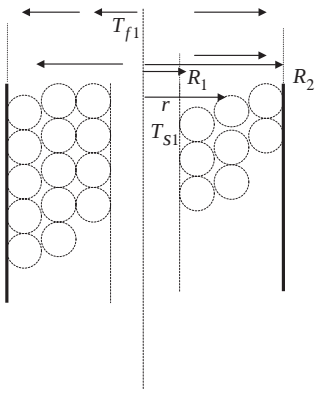

Fig. 1. Coaxial cylinders separated by a semi-transparent porous medium.