Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 52(6) (2020) 423-426
DOI: 10.22060/mej.2018.14525.5875

The Solution of the Transient Diffusion-Radiation Binary Gas mixture Problem in Low Pressure Values between Two Flat Plates at a Gray Medium

S. Mohammadpour, S. Payan*

Department of Mechanical Engineering, University of Sistan and Baluchestan, Zahedan, Iran

ABSTRACT: In this research, a transient two-component radiation-penetration problem is solved numerically. This study aims at investigating the effect of the radiated absorbing gas density in low pressure values on the distribution of the medium temperature in terms of the time, position, and the amount of heat transferred from the radiation environment in terms of the time in two modes of radiation equilibrium and constant temperature of the medium. The modified discrete ordinates method was used to solve the radiation problem; while, the implicit finite volume method was used to solve the transient time penetration problem. The results were observed that the time effect of density led to the time effects on the ambient temperature distribution with a radiated balance and the effects cannot be neglected in states with 1 and 10 mass absorption coefficients. The problem analysis shows that although the radiation equation can be solved in a steady manner for the time interval of interest, one cannot neglect its time effects due to changes in the density of adsorbing gas even at low pressures. By analyzing the problem, it was determined that the temperature effect on density during the radiation equilibrium is rather than the penetration coefficient. This effect is not negligible in 1 and 10 mass absorbing coefficients; therefore this subject emphasizes the importance of considering the penetration coefficient in terms of temperature.

Review History:

Received: 30 May 2018
Revised: 13 Nov. 2018
Accepted: 3 Dec. 2018
Available Online: 19 Dec. 2018

Keywords:

Transient radiation-two-component diffusion
Radiation equilibrium
Discrete ordinates method
Gray medium
Temperature-varying penetration coefficient

1- Introduction

In fact, in a mixture of gases, a gas may penetrate into another gas, liquid, or solid substance. The penetration of vapors into organic particles or cloud components and/or the vapor penetration into atmosphere are an important research field in the transfer of atmospheric components. The penetrating material may be radiation absorbent, emitting, and scattering; this influences the amount of radiation in the environment. Some of these organic and airborne components are toxic and harmful because these components are deposited once they enter into the lungs. It is essential to know the concentration, distribution of other components, and chemical compositions of the mixture of particles to have an appropriate assessment of the collision of evaporative vapors, harmful oxides, and organic particles impact on general health [1-4]. Ahmad et al. [5] examined the thermal penetration coefficient and thermal diffusion coefficient in the MagnetoHydroDynamic (MHD) stream surrounded by a parallel wave wall. They have applied an induction magnetic field perpendicular to the vertical plane. The solution was divided into two stationary and turbulent parts; the latter was considered due to wall motion and waving. It was concluded that temperature decreases with the increase in several parameters such as radiation, thermal penetration coefficient, and thermal diffusion coefficient. The thickness of the boundary layer increases with the influence of thermal diffusion coefficient, thermal penetration coefficient, and thermal radiation. Thermal penetration, thermal diffusion and thermal radiation play a crucial role in flow transfer and transmission parameters.

The effect of binary diffusion with varied diffusion coefficient of pressure and temperature on the distribution of the radiation layer temperature with the radiative equilibrium and distribution of the radiation source in terms of time, and the impact on the layer stability time have not been addressed. The suggestion of this topic demonstrates that consideration of the feature temperature in radiation problems is of particular importance for the purpose of investigating the heat transfer from radiative environments. And although this property may be negligible, its variations might change the amount of radiation heat transfer. As a result, it has higher impacts on the growth of the boundary layer in more complex cases such as combination of radiative heat transfer with other heat transfer types, including displacement, and thus, the total amount of heat transfer is affected.

2- Governing Equations

In this paper, two transient two-component diffusion-radiation problems have been considered along with the corresponding problem solving algorithms. Assume a combined transient two-component diffusion-radiation heat transfer between two flat plates in a gray environment radiation equilibrium and constant temperature modes as shown in Figs. 1-a and 1-b. The surfaces of the black are at a specified temperature. In the radiation equilibrium mode, the purpose of the problem solving is to calculate the density distribution of the absorber as a gray gas using the concentration equation at low pressures considering a variable diffusion coefficient with the temperature at each

*Corresponding author's email: s_payan_usb@eng.usb.ac.ir

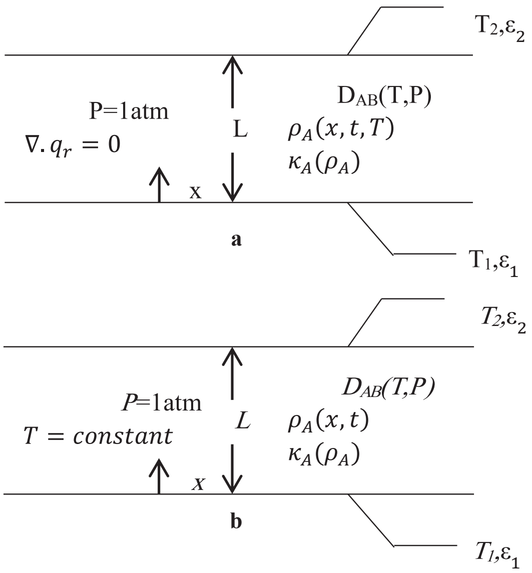

Fig. 1. Geometry of the Transient Diffusion-Radiation mixture heat transfer problem between two flat plates in a gray medium with varying diffusion coefficient with temperature a) The medium in the radiation equilibrium b) medium at constant temperature

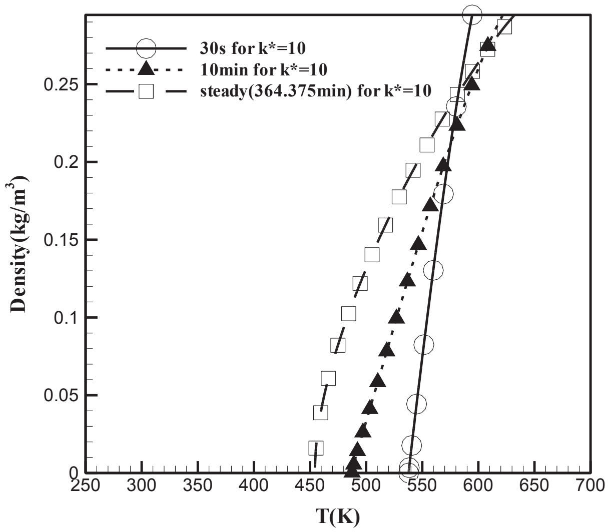

Fig. 2. Density changes based on temperature in the radiative equilibrium of medium

instant. Once it is substituted in the absorption coefficient equation, and the radiation equation is solved at that instant, the ambient temperature distribution and surface heat fluxes are achieved. In the constant temperature mode, solving this problem results in the calculation of the radiation source at each instant and the surface radiation flux. The distribution of the diffusion coefficient is calculated by Eq. (3). In this paper, the pressure is constant and equal to 1 bar. The concentration of adsorbent on the boundaries is specified; and the distance between the plates is 1 meter.

The transient concentration is obtained by Eq. (1); and this equation is used to calculate the density of the radiation absorbent A. The boundary and initial conditions for the solution of Eq. (1) are given in Eqs. (2-a) and (2-b), respectively.

$$\frac{d\rho_A}{dt} + \frac{d}{dx}\left(D_{AB}(T,P)\frac{d\rho_A}{dx}\right) = 0 \tag{1}$$

$$x=0 \qquad T=673\text{K} \qquad \rho_A = 0.3\,\text{kg}/\text{m}^3$$

$$x=L \qquad T=273\text{K} \qquad \rho_A = 0.0\,\text{kg}/\text{m}^3 \tag{2-a}$$

$$t=0 \qquad T=273\text{K} \qquad \rho_A = 0.0\,\text{kg}/\text{m}^3 \tag{2-b}$$

In Eq. (1), DAB is the diffusion coefficient that follows the Eq. (3) for low pressure gases.

$$D_{AB}(T,P) = aP\left(\frac{T}{\sqrt{T_{C-A}T_{C-B}}}\right)^b \times \left(P_{C-A}P_{C-B}\right)^{1/3} \times \left(T_{C-A}T_{C-B}\right)^{5/12} \times \left(\frac{1}{M_A}+\frac{1}{M_B}\right)^{0.5} \tag{3}$$

The radiative heat transfer equation in an effective environment is Eq. (4). The intensity of radiation on the given surfaces and the emission factor is 1.

$$\frac{dI}{ds} = -(\kappa_a+\sigma_s)I(\Omega)+\kappa_a I_b+\frac{\sigma_s}{4\pi}\int_{\Omega'=4\pi} I(\Omega')\phi(\Omega',\Omega)d\Omega' \tag{4}$$

3- Results and Discussion

To analyze the two-component radiation-diffusion problem, several changes have been used in the radiation equilibrium and constant temperature modes. Here, in brief, the density variations in radiation balance mode are analyzed with the mass absorption coefficient $\kappa_a^* = 10.0$.

As shown in Fig. 2, due to significant difference in surface temperature and near gas, the density of the layer has also severe changes or jumps near the boundaries. By increasing the mass absorption coefficient, the influence of the layer density has been increased in terms of temperature. Of course, the temperature jump is still visible due to low optical thickness and the effect of temperature on the density, especially on the cold border, but this jump decreases with the increase in mass absorption coefficient.

4- Conclusions

The main results of the present research are as follows:

(1)In the case of radiant equilibrium mode, the penetration coefficient depends on both temperature and the properties of the absorbent. Thus, in low pressure gases, the penetration coefficient is small. Temperature dependency of penetration coefficient influences the density and changes the shape of the density variations in terms of temperature.

(2)In the case of radiation equilibrium mode, due to extreme temperature difference at the surface and its near gas as a result of low optical thickness, the density of the layer has also severe changes or jumps near the boundaries. By increasing the mass absorption coefficient, the amount of layer density variations increases in terms of temperature.

References

[1] M. Tang, M. Shiraiwa, U. Pöschl, R. Cox, M. Kalberer, Compilation and evaluation of gas phase diffusion coefficients of reactive trace gases in the atmosphere: Volume 2. Diffusivities of organic compounds, pressure-normalised mean free paths, and average Knudsen numbers for gas uptake calculations, Atmospheric Chemistry and Physics, 15(10) (2015) 5585-5598.

[2] J.H. Kroll, J.H. Seinfeld, Chemistry of secondary organic aerosol: Formation and evolution of low-volatility organics in the atmosphere, Atmospheric Environment, 42(16) (2008) 3593-3624.

[3] A.L. Robinson, N.M. Donahue, M.K. Shrivastava, E.A. Weitkamp, A.M. Sage, A.P. Grieshop, T.E. Lane, J.R. Pierce, S.N. Pandis, Rethinking organic aerosols: Semivolatile emissions and photochemical aging, Science, 315(5816) (2007) 1259-1262.

[4] J. Han, Diffusion Law of Air Pollution in Chemical Enterprises, Chemical Engineering Transactions, 59 (2017) 1153-1158.

[5] N. Ahmed, D. Bhaattacharya, D. Barua, Radiation, Soret and Dufour Effects in MHD Channel Flow Bounded by a Long Wavy Wall and a Uniformly Moving Parallel at Wall, Journal of Applied Mathematics and Fluid Mechanics, 6 (2014) 1-19.