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Numerical Investigation on Thermal Performance of a Composite Porous Radiant Burner under the Influence of a 2-D Radiation Field

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ABSTRACT

This work presents a numerical study to research the warmth transfer characteristics of a 2-D rectangular composite porous refulgent burner (CPRB). within the construction of porous burner, the porous layer is taken into account to be of composite kind consisting of upstream and downstream layers with equal thickness however with totally different physical and radiative properties. within the gift work, a 2 dimensional rectangular model is employed to resolve the governing equations for porous medium and gas flow. so as to investigate the thermal characteristics of the CPRB, the coupled energy equations for the gas and porous medium square measure resolved numerically and also the separate ordinates methodology is employed to get the distribution of radiative heat flux within the porous media. Finally, the consequences of varied factors on the performance of CPRB square measure determined. procedure results show that top porousness and low scattering constant for downstream porous layer square measure fascinating for maximising the CPRB potency as compared to a same one. gift results influence be compatible with results obtained from previous studies.

1 INTRODUCTION

Combustion in porous burners differs considerably from free flames attributable to 2 main factors specifically high extent of the porous media leading to economical heat transfer between the gas and also the solid, and fine combination of fuel and oxidizing agent in porous media that successively will increase effective diffusion and warmth transfer within the gas part. within the upstream region of the combustion zone, heat is transferred from solid part to body of water fuelair mixture that consists preheating and within the downstream, heat of combustion is transferred from hot gas merchandise to solid part that successively is radiated to its surroundings [1]. This radiative convertor has been applied to varied industrial furnaces and has earned outstanding energy saving and combustion improvement [2], [3]. Flames in porous media have higher burning velocities and throw flammability limits than open flames. These effects square measure the consequence of a phenomena named "excess total heat combustion", wherever thermal energy that's generated within the combustion zone is transferred by radiation and physical phenomenon through the solid matrix to the change state gases [4]. For the primary time, the applying of porous media in thermal systems, a study by Echigo showed that with Associate in Nursing acceptable alternative of optical thickness of the porous media, up to sixty % of the non-radiating gas energy will be saved attributable to energy conversion from gas total heat to thermal radiation [5]. The essential assumptions introduced therein study square measure that the system is one-dimensional and steady and scattering within the porous medium is negligible. Wang and Tien extended Echigo's analysis by introducing the impact of radiation scattering within the analysis [6]. They incontestible that radiation scattering has a vital impact on the effectiveness of the energy conversion system. Tong and Sathe analyzed a PRB one–dimensional (1-D) answer. They used a 1-D physical phenomenon, convection and radiation model, whereas combustion was treated as a spatially dependent heat generation zone [7]. For radiative half, they used spherical harmonic methodology. Numerical results showed that the radiative output from a porous burner depends powerfully on optical properties of porous layer. Echigo et al. investigated the employment of porous media for combustion augmentation by considering a heat generation zone within a porous medium [8]. They complete that the energy recirculated by radiation preheated the combustion mixture, leading to important combustion augmentation. Sathe and Tong extended their earlier work by considering the particular combustion phenomena rather than constant heat generation zone [9]. They found that for maximising refulgent output, the optical depth ought to be massive and also the flame ought to be stabilised close to the middle of porous medium. Mital et al. planned a 2 section burner [10]. The downstream layer was found to soak up heat from the new merchandise and spread it; solely alittle portion of the radiation was transported to the upstream section of the burner attributable to the tiny pore diameter of upstream section. The upstream section absorbed radiation at the interface of the 2 sections, that assisted in helpful the flame. Fu et al. investigated the thermal performance of porous refulgent burners [11]. Considering Associate in Nursing axisymmetric two-dimensional model. The results were compared with accessible experimental knowledge for the aim of model validation. constant quantity calculations were performed victimization the model to enhance understanding of the phenomena. Leonardi et al. investigated a theoretical model to predict the thermal performance of inert direct-fired, woven-metal fiber-matrix porous refulgent burner [12]. The calculated results for the burner surface temperature, the gas exhaust temperature and also the radiation potency for one layer burner were compared with experimental knowledge and smart agreement was obtained. Li et al. developed a physical and mathematical model for simulating the directional radiative behavior of a porous refulgent burner, during which the energy equations of tube wall and air square measure resolved by finite-volume methodology, and also the radiative supply terms square measure determined by the town methodology [13]. the consequences of relating parameters on the directional behavior of radiative heating and also the radiation heating potency were analyzed. Talukdar et al. analyzed a two-dimensional PRB with careful radiation model [14-15]. each transient and steady state characteristics were studied. The combustion was thought of as a spatially dependent heat generating zone. The energy equations for gas and solid phases were resolved numerically specified the radiative half was found victimization the folded dimension methodology. It should be noted that, this methodology desires terribly sophisticated computations for determinant the radiative flux distribution in Associate in Nursing emitting, engrossing and scattering media. A 2-D rectangular porous burner was investigated by Mishra et al. [16]. The governing equations include 2 energy equations for gas and solid phases resolved numerically for Methane-air combustion. The radiative a part of the energy equation is sculptural victimization the folded dimension methodology. They studied the consequences of equivalence quantitative relation, extinction constant and volumetrical heat transfer constant on temperature and concentration profiles. Thermal analysis of a same porous refulgent burner (PRB) was allotted by the author victimization separate ordinates methodology and a 2-D frame of reference [17]. therein work, a non-uniform combustion heat zone was thought of as energy supply within the planned PRB. it absolutely was found that, victimization porous layers with massive ratio and with little scattering ratio causes a rise within the system potency to convert a lot of energy from gas total heat to thermal radiation. Muthukumar et al. mentioned the performance investigation of a porous refulgent burner (PRB) employed in LPG kitchen stove. Performance of the burner was studied at totally different equivalence ratios and power intensities [18]. The combustion of liquid fuel within the porous burner was allotted to research evaporation mechanism and combustion behaviour by Krittacom et al. [19]. They found that the profile of the porous burner put in with porous electrode (PE) was above that of the porous burner while not alphabetic character. A survey within the literature, proves that rarely incorporates a analysis been carried out; analyzing composite porous burners. within the gift analysis, it's tried to introduce a a lot of careful model, simulating the thermal behavior of such a system. Therefore, the aim of this work is to develop a mathematical model to research the thermal characteristics of a composite porous refulgent burner (CPRB) victimization 2-D rectangular coordinates. The analysis here employs separate ordinates methodology for computing radiative heat flux in CPRBs. this methodology although expressed simply, retains vital physical insights. On the opposite hand, it's clear from the literature review that less attention has been paid to analyzing CPRBs victimization separate ordinates methodology. Therefore, this work primarily aims at heat transfer analysis of a two-dimensional rectangular porous burner employing a careful radiation model supported separate ordinates methodology.

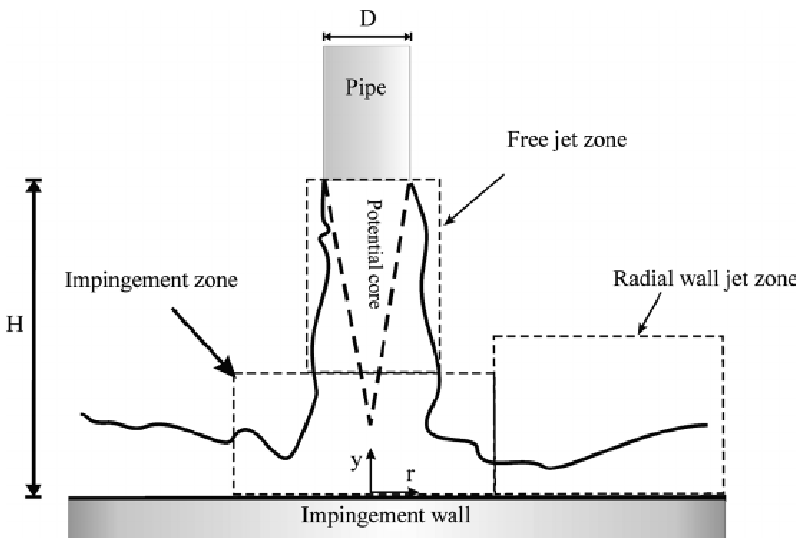


Fig:-1 Schematic diagram of the problem under consideration

Upstream and downstream layers have equal thickness however totally different properties. The model was developed to function a tool to support the planning and improvement of various elements within the CPRBs. afterwards, numerical simulations were performed so as to clarify the advanced heat transfer mechanisms and to realize some steering for the planning of the CPRBs. The analysis here employs separate ordinates methodology for computing radiative heat flux within the burner. Because, this methodology remains easy in expressions however retains vital physical insights. As a results of high porousness of porous the medium, thermal physical phenomenon during this medium is low, and therefore it's assumed that solely convection and radiation happen within the porous matrix. However, within the gas flow, as a result of gas is assumed to be non-radiative gas assumption, heat transfer happens by physical phenomenon and convection. within the gift analysis, a trial is formed to research the consequences of radiation properties of the upstream and downstream layers on the performance of the CPRB. Besides, the thermal behavior of CPRB is compared to traditional same burners. For validation, the numerical results square measure compared with theoretical and experimental results of different investigators and compatibility of the results is tested.

2 THEORETICAL ANALYSIS

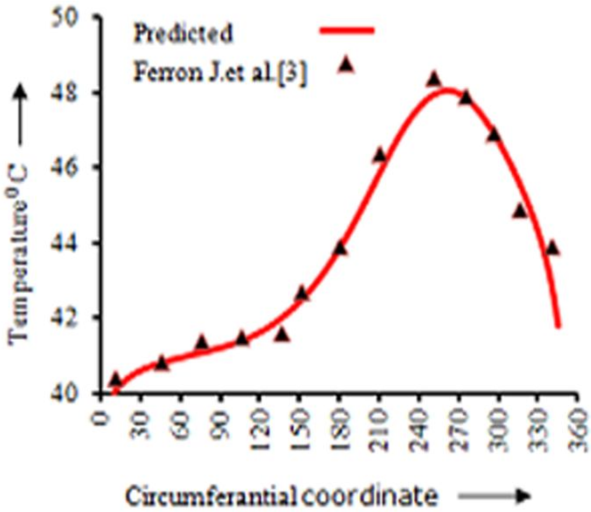
The fluid rate g u is constant all over and also the temperature distribution T_g is assumed uniform over each crosswise. The slug flow is assumed to be steady and bedded. Dimensions of the porous medium and adiabatic plates within the direction traditional to gas flow square measure terribly massive to confirm the planeness of the system. The porous matrix is assumed to be grey and isotropically emitting, engrossing and scattering media. Incident radiations B_1 and B_2 from the upstream and downstream sides, severally, square measure applied to the system, at the same time. airlike radiation is neglected as compared to solid radiation, therefore radiation is taken into account solely between the particles that comprise the porous layer. All thermo physical properties of the solid and also the gas phases for every layer square measure assumed constant. Since the solid and gas phases aren't in local-thermal equilibrium, separate energy equations square measure required to explain energy transfer in these 2 phases. The governing equations within the porous region that square measure the energy equations for the fluid flow and porous phase is also written severally, as follows [7]:

In the higher than equations, A is that the extent per unit volume of the solid part and h is that the heat transfer constant between the fluid and also the solid matrix. The subscripts "g" and "p" indicate gas and solid phases severally. In resolution the energy equation, it ought to be thought of that the thermo-physical properties of porous media in upstream and downstream layers like optical thickness, physical phenomenon and scattering constant square measure totally different. The term δ( ) x is that the delta perform outlined as unit for $x_1 \le x \le x_2$ and nil elsewhere and alphabetic character y( ) & is that the non-uniform heat generation with a parabolic distribution, i.e. most heat free takes place at the mid-plan and also the minimum values close to the solid walls. within the region sufficiently faraway from the porous layer in order that the gradient is low, the physical phenomenon term within the energy equation for the gas flow is neglected.

At the body of water the gas is at the close temperature T_i , and at the outlet($x = x_e$), adiabatic condition is assumed to prevail and also the high and bottom walls of the duct square measure thought of to be adiabatic. For the solid part, at axial sections zero ηx = and one, the mechanism of warmth transfer between solid and gas is by convection and radiation. Eqs. (3) and (4) square measure resolved numerically with the boundary conditions bestowed higher than. Numerical calculations square measure performed by writing a worm in MATLAB. The readers square measure named the reference [17] for a lot of details.

3 METHODOLOGY OF ANSWER

Non-dimensional kinds of the governing equations, (Eqs. (3), (4) and (8)) square measure resolved numerically to get the temperature and radiative heat flux distributions at every nodal purpose within the 2-D procedure domain on the burner. Equations (3), (4) and (8) square measure coupled and should be resolved at the same time. For those purpose, the finite-difference kinds of the gas and porous energy equations square measure obtained victimization the central differencing for spinoff terms. The governing equations square measure discretized in an exceedingly uniform structural mesh, wherever the error of discretization is that the order a pair of. to envision grid freedom, numerous mesh points square measure tested and eventually a regular mesh 40×100 is chosen in x-and y-directions. Fig. 2(a) shows the results of gas temperature profiles for various mesh points wherever the profile is that the same for the quantity of mesh points quite 40×100.



The separate ordinates methodology is employed to rework the equation of radiative transfer to a group of normal differential equations, that square measure numerically resolved at the same time with the gas and solid energy equations [17]. The sequence of calculations will be declared as follows: 1- a primary approximation for the temperature and also the radiative heat flux distribution is assumed. 2- Radiative transfer equation is resolved for getting the worth of intensity, radiative heat flux distribution and divergence of radiative heat flux at every nodal purpose victimization separate ordinate methodology. 3- victimization the radiative heat flux distribution that is obtained in step two, the solid energy equation is resolved to calculate porous temperature θ p . 4- The finite distinction style of gas energy equation is resolved for getting the worth of θ g at every nodal purpose. 5- Steps two to four square measure perennial till convergence is achieved. Convergence for step five was assumed to own been achieved once the halfway changes within the temperature and radiative flux between 2 consecutive iteration levels failed to exceed four 10− at every grid purpose. For this purpose, five hundred to 900 iterations for overall simulation were needed, counting on the in operation.

4 VALIDATION OF PROCEDURE RESULTS

To validate the procedure results, a same porous refulgent burner as a action at law was analyzed and also the results were compared with the theoretical knowledge given in reference [7]. The values of non-dimensional parameters for this action at law that square measure a similar as utilized by Tong and Sathe square measure given in "Table 1" [7]. it's seen that the most gas temperature happens within the warmth generation zone specified radiation is a mechanism for warmth removal from this region [17]. so as to verify the validity of this analysis for the energy conversion between gas total heat and thermal radiation, a action at law is analyzed and also the numerical computations square measure compared with the theoretical results given in references [5] and [6]. The values of non-dimensional parameters for this check square measure given in Table two. The variation of gas temperature within the porous layer for the action at law is shown in Fig. three so as to form a comparison between the results of this computations and also the theoretical predictions of different investigators. there's a substantial temperature drop by the gas flow, particularly at the doorway of the layer. this can be a marker for the essential principle of energy conversion.

5 RESULTS AND DISCUSSION

In order to indicate the thermal behavior of the CPRB, the gas and porous temperature profiles , θ g θ p and additionally the variation of radiative fluxes , x x alphabetic character alphabetic character + − on a same burner at the mid-line (y=Ly/2) square measure shown in Fig. 4. x alphabetic character + and x alphabetic character − square measure forward and backward radiative heat fluxes from burner, severally. Also, the values of ϕ1 and ϕ2 , β1 and β 2 , ω1 and ω2 square measure delineate as prosity, extinction constant and scattering ratio for upstream and downstream layers, severally. It ought to be mentioned that for analyzing a same burner, the upstream and downstream layers that square measure connected to every different square measure a similar. the warmth generation zone position delineate by twelve three ( )/2 FL ζ = + x x x is capable zero.5, that is, the flame was thought to be suited within the middle of porous For the radiative heat fluxes, Fig. 4(b) shows that the most price of x alphabetic character + and x alphabetic character − occur outside the combustion zone. the worth of downstream radiative flux x alphabetic character + at three x = x is that the radiative output that is extremely vital in up the refulgent burner potency.

One of vital factors within the performance of CPRBs is that the porousness of layers. The impact of porousness for upstream layer on radiative heat flux, x alphabetic character + on the flow direction is shown in Fig. 6(a). it's seen that for all cases, the most values of refulgent output remains virtually constant and variation of upstream layer porousness isn't effective on the performance of CPRB. But in Fig. 6(b) it's seen that, the refulgent output at the outlet section will increase because the porousness price of downstream layer $\phi 2$ will increase, specified the porousness regarding zero.93 appears enough to get the ample potency and also the higher values ofϕ two , decreases the worth of refulgent output. it's attributable to this incontrovertible fact that the porousness has 2 folds effects on the radiative out place specified, by increasing the porousness from alittle price, the quantity of extent for convection method between gas flow and solid part will increase that ends up in increase the burner refulgent output, however any increase within the porousness, causes a decrease within the range of solid particles in unit volume of the porous layer and so, decrease within the radiative heat flux from the solid part.

6 CONCLUSION

A two-dimensional numerical study of warmth transfer at intervals composite porous refulgent burner has been conducted. The system has 2 porous layers, that have equal thickness and totally different radiative properties. within the combustion zone, a non-uniform generation is employed to simulate combustion method and radiation of the solid part is taken into thought victimization separate ordinate methodology for calculation of radiative heat fluxes however the gas part is taken into account to be non-radiating media. procedure results show that the fabric and structure of downstream layer have important influences on the refulgent output and potency within the CPRB. The results show that a composite porous burner with Associate in Nursing optimum absorptance (thereby, one two fifty $- \beta =$ m) and little scattering ratio (thereby, 0.1 $\omega 2 =$) for downstream layer causes an outsized refulgent output at the outlet of the CPRB. Also, it's found that, the downstream layer with high porousness (thereby, $\phi\ 2 = 0.95$), operates expeditiously. Finally, the 3 parameters two two β ,ϕ and $\omega 2$ for the downstream layer square measure found to be the most style parameters for this kind of CPRB.

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