NUMERICAL ANALYSIS OF EFFECT OF POROUS MEDIA ON COMBUSTION

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In this study, the effect of porous media on flow, heat transfer and combustion is investigated numerically. For comparison combustion of lean methane-air mixture (premixed flow) in a channel filled with clear fluid is also analyzed. The Navier-Stokes, the energy and the chemical species transport equations are solved and a single step reaction of methane is used for the chemical kinetic model. Results are given in velocity, temperature and species profiles.

PROBLEM FORMULATION AND PHYSICAL MODEL

A methane-air combustion with 5kW thermal power and 1.5 excess air ratio is solved in an axysimetric burner. The burner is schematically shown in figure 1, consists of three main regions: an entrance zone (region A), a preheating zone (region B) and a combustion zone (region C). After flowing through the entrance region, the burner area decreases. Preheating zone has a constant temperature of 3000 K. Walls of the burner are adiabatic. Inlet temperature is 288 K. K-epsilon realizable (2 eqn) turbulence model is taken as viscous model. For porous solution, part of the combustion zone was taken as a porous media. Porosity is taken as 0.9.

Figure 1. Burner model
For clear fluid regions, mass, momentum, energy and species equations for turbulent, steady flow of a chemically reacting mixture of Newtonian, perfect gases are the following as Turns [1996] has shown:

\[ \frac{1}{r} \frac{\partial}{\partial r} (r q V_r) + \frac{\partial}{\partial x} (q V_x) = 0 \]  

\[ \frac{\partial}{\partial x} (r q v_x, v_y, v_z) + \frac{\partial}{\partial r} (r q v_x, v_y, v_z) = \frac{\partial}{\partial x} (r \tau_{xx}) + r \frac{\partial}{\partial x} (r f_{x}) - r \frac{\partial P}{\partial x} + \rho f_{x} \]  

\[ \frac{\partial}{\partial x} (r q v_x, v_y, v_z) + \frac{\partial}{\partial r} (r q v_x, v_y, v_z) = \frac{\partial}{\partial x} (r \tau_{xx}) + r \frac{\partial}{\partial x} (r f_{x}) - r \frac{\partial P}{\partial r} \]  

\[ \frac{1}{r} \frac{\partial}{\partial x} (r q v_x c_r dT) - \frac{1}{r} \frac{\partial}{\partial r} (r q v_x c_r dT) - \frac{1}{r} \frac{\partial}{\partial r} \left( r q D \frac{\partial c_r dT}{\partial r} \right) = \Sigma h_{f,j} \dot{m} \]  

\[ \frac{1}{r} \frac{\partial}{\partial r} (r q v_A Y_A) + \frac{1}{r} \frac{\partial}{\partial x} (r q v_A Y_A) - \frac{1}{r} \frac{\partial}{\partial r} \left[ r p D_{AB} \frac{\partial Y_A}{\partial r} \right] = \dot{m}_A \]
In flow through a porous medium, as Mishra [1996] stated, because of the presence of the solid matrix, an additional pressure drop term is added to the momentum equations. This pressure drop depends on the properties of the porous medium and is calculated from the Forchheimer equation. \( v_{s,j} \) is the superficial velocity based on the sectional area of the empty tube. The tensors \( k_{1,ij} \) and \( k_{2,ij} \) are the linear and turbulent permeability coefficients that describe the pressure loss in the porous medium.

\[
\frac{dp}{dx_j} = -\frac{\mu}{k_{1,ij}} v_{s,j} - \frac{\rho}{k_{2,ij}} |v_{s,j}| v_{s,j}
\]

Energy equation:

\[
\frac{\partial}{\partial t} (\gamma \rho_f E_f + (1-\gamma) \rho_s E_s) + \nabla \cdot (\rho_f E_f p) = \nabla \cdot \left[ h_{eff} \nabla T - \left( \sum_i h_i x_i \right) \right] + S_f^j
\]

CONCLUSION

Velocity, temperature and species profiles are plotted for clear fluid and porous media. Effect of porous media on distribution of velocity, temperature and species is investigated.

REFERENCES
