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NUMERICAL ANALYSIS OF EFFECT OF POROUS MEDIA ON COMBUSTION

Nihan Elmas[1,*] and Aydın Mısırlıoglu[2]
[1] Astronautical Engineering Department
Istanbul Technical University, 34390 Istanbul, Turkey
[2] Astronautical Engineering Department
Istanbul Technical University, 34390 Istanbul, Turkey
([*] Corresponding author: elmasni@itu.edu.tr)

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.

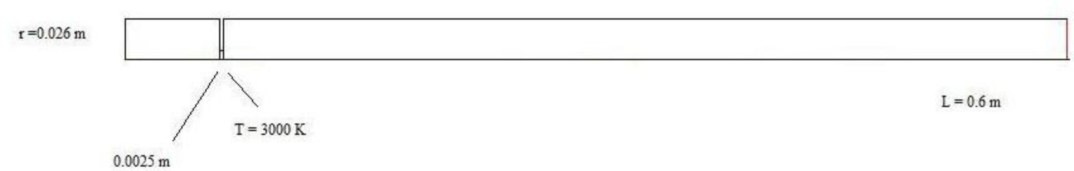

Figure1. Burner model

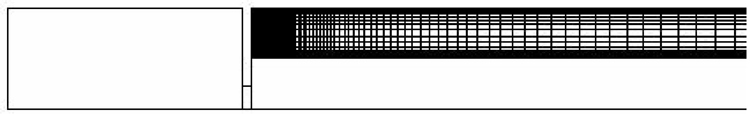

Figure 2. Part filled with porous media

Table 1

Mass Fractions

	Reactants			
	CH4	O2	H20	CO2
Inlet	0. 0228	0. 2278	-	-
Outlet	-	0.330	0.124	0.151

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:

$$\frac{1}{r}\frac{\partial}{\partial r}(rqVr)+\frac{\partial}{\partial x}(qVx)=0 \tag{1}$$

$$\frac{\partial}{\partial x}(rqv_x v_x)+\frac{\partial}{\partial r}(rqv_x v_r)=\frac{\partial}{\partial r}\left(r\tau_{rx}\right)+r\frac{\partial \tau_{xx}}{\partial x}-r\frac{\partial P}{\partial x}+\rho g_x r \tag{2}$$

$$\frac{\partial}{\partial x}(rqv_r v_x)+\frac{\partial}{\partial r}(rqv_r v_r)=\frac{\partial}{\partial r}\left(r\tau_{rr}\right)+r\frac{\partial \tau_{rx}}{\partial x}-r\frac{\partial P}{\partial r} \tag{3}$$

$$\frac{1}{r}\frac{\partial}{\partial x}(rqv_x\int c_p dT)-\frac{1}{r}\frac{\partial}{\partial r}(rqv_r\int c_p dT)-\frac{1}{r}\frac{\partial}{\partial r}\left(rqD\frac{\partial\int c_p dT}{\partial r}\right)=\Sigma h_{f,i}^0\,\dot{m}''' \tag{4}$$

$$\frac{1}{r}\frac{\partial}{\partial r}(rqv_r Y_A)+\frac{1}{r}\frac{\partial}{\partial x}\left(rqv_x Y_A\right)-\frac{1}{r}\frac{\partial}{\partial r}\left[r\rho D_{AB}\frac{\partial Y_A}{\partial r}\right]=\dot{m}_A''' \tag{5}$$

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.vs,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.

$$\frac{\mathrm{d}p}{\mathrm{d}x_i} = -\frac{\mu}{k_{1,ij}} \boldsymbol{v}_{s,j} - \frac{\rho}{k_{2,ij}} |\boldsymbol{v}_{s,j}| \boldsymbol{v}_{s,j} \qquad (6)$$

Energy equation :

$$\frac{\partial}{\partial t}(\gamma \rho_f E_f + (1-\gamma)\rho_s E_s) + \nabla\cdot(\vec{v}(\rho_f E_f + p)) = \nabla\cdot\left[k_{eff}\nabla T - \left(\sum_i h_i J_i\right) + (\bar{\bar{\tau}}\cdot\vec{v})\right] + S_f^h \qquad (7)$$

CONCLUSION

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

REFERENCES

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Turns, S. [1996], *An Introduction to Combustion*, McGraw-Hill Book Co. Ed. , Singapore