SOME ASPECTS OF FLAME LOCALIZATION INSIDE AXIS-SYMMETRIC CYLINDRICAL POROUS MEDIA BURNERS

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Two factors intrinsic to cylindrical axis-symmetrical Porous Media Burners (PMB): 1- radial change of gas filtration speed, 2 - heat losses from the surface - provides natural stabilization of combustion front inside the carcass due to filtration speed decrease with the radius growth and leads to some peculiarities in flame localization.

In the work we have analyzed flame localization by using one-temperature analytical model and performed one-dimensional two-temperature numerical simulation of combustion front localization.

One-temperature formulation of the problem (temperatures of gas Tg and solid phase T are assumed equal) in the case of stationary situation and instantaneous reaction, yields

$$(c\rho)_g u_g \frac{\partial T}{\partial r} = 1/r \frac{\partial}{\partial r} \lambda r \frac{\partial T}{\partial r} + Q\rho_g u_g \delta(T - T_1)$$

(1)

together with boundary conditions (B.C.)

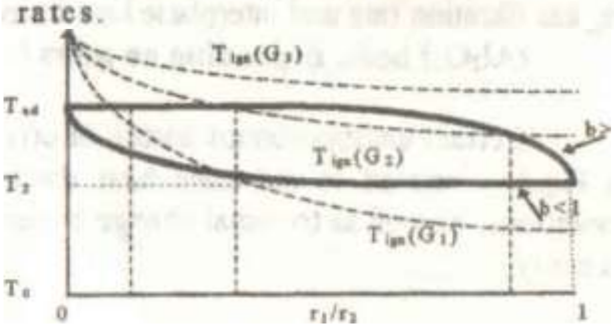
$$T(0) = T_o\ ,\ T(r_1) = T_1\ ,\ -\lambda \frac{\partial T}{\partial r}\bigg|_{r_2} = \sigma(T_2^4 - T_o^4).$$

(2)

All the nomenclature is conventional.

Analytical solution doesn't define combustion temperature T_1 and flame location r_1. Use of additional equation for the ignition temperature T_{ign} [1] let us find these parameters, see Fig. 1.

Fig.1. Illustration to flame localization. ▬ - analytical solution (1),(2), ------ - ignition temterature [1] dependence. G_1, G_2 and G_3 - flow rates.



Solutions for the analytically formulated problem for packed bed of d_0 = 5.6 mm Al_2O_3 balls are presented with lines at the Fig.2. Inter-phase heat transfer coefficient a calculated according to [2], heat conductivity of the carcass was estimated as a sum $\lambda = \lambda_{cr} + \frac{32\sigma d_0 m\varepsilon}{9(1-m)} T_{ad}^3$, where λ=15 W m k. The carcass porosity m=0.4, surface emissivity ε=0.6.

Analytical solution shows that there are may be one, two roots or no solutions for flame localization, depending on the fuel flow rate External ignition is possible in limited interval of flow rates, when there is only one root for localization.

Numerical simulation of combustion localization

Numerical simulation was performed within non-stationary problem statement We used two- temperature model with overall Arrhenius reaction rate. Supply of fresh mixture having ambient temperature T_o to the burner inlet (at r = r_2) and irradiation from PMC outer surface (at r = r_2) were simulated with boundary conditions (B.C.)

$$T_g\Big|_{r_0} = T_0, \qquad \frac{\partial T_g}{\partial r}\Big|_{r_2} = 0; \qquad \frac{\partial T}{\partial r}\Big|_{r_0} = 0, \qquad -\lambda_s \frac{\partial T}{\partial r}\Big|_{r_2} = \varepsilon\sigma\left(T_2^4 - T_0^4\right),$$

for gas and solid phase correspondingly. Contrary to analytical problem statement, where B.C. were taken as zero, during numerical simulation inner radius r_0 has finite value of 1 cm

We simulated series of non-stationary flame position trajectories with different radii of combustion ignition. Ignition was simulated by giving high-temperature step (T= 1200 K) in the porous body at the initial instant of time. Major series of computations were performed for methane- air combustion kinetics modeled with overall reaction rate $-\partial y/\partial t = y\mathbf{z}exp(-E/RT)$, (where $\mathbf{z}$ = $2.6e^8$ 1/s, E=$13e^4$ J/mol [1]) and adiabatic combustion temperatures dT_{ad}=1200, dT_{ad}=1500 and dT_{ad} =2000 K. Mass mixture flow rate G varied in a wide range 0.001 - 2.5 kg/sec. Other parameters were as in the analytical calculations Computations confirmed the possibility of existence of two roots and localization radii for the systems under consideration Fig. 2

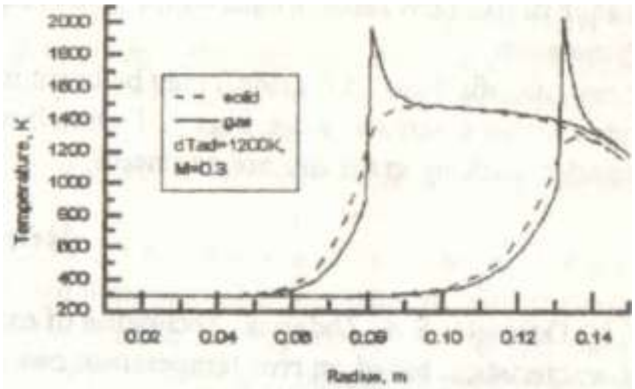


Fig 2 Temperature profiles of filtration combustion wave, corresponding to two stationary localization of the front ΔT_{ad}=1200 K, G_0=0.3 kg/sec, r_2=15cm, d_0=5 6 mm

Numerical calculation confirmed that outer localization radius r_{st2}, if it exists, is unstable (although front can stay on the radius long enough in case it initiated), if flame is ignited closer to the center from r_{st2}, the front moves towards inner stable localization radius If flame ignited outside from r_{st2} and is blown off from PMB , see Fig .3.

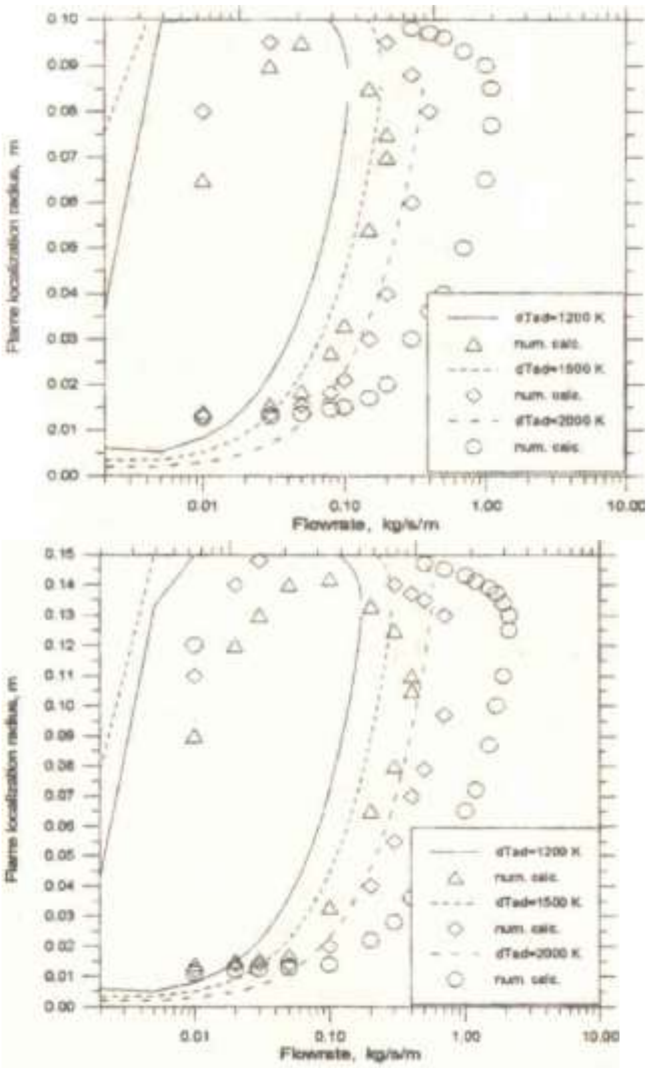


Fig. 3. Dependence of flame localization radii on flowrate. Numerical and analytical solution. Cylindrical burner outer radius r_2= 0.1 and 0 15 m, d_0=5.6 mm, methane -air mixture.

The difference between analytical and numerical calculations may be explained by the error of one-temperature approximation and assumption of constant heat conductivity λ of analytical problem consideration and also by final value of the inner PMB radius taken for numerical computation.

The computations have revealed that the wave front velocity slows down in the area of «indeterminate» localization (right extremity of the curves in Fig. 3) to such an extent that its position can be considered fixed at the initial ignition radius at times of the order of an hour

CONCLUSION

1. - There are two stationary flame localization positions inside PMB one of which is unstable
2. - If the flame is ignited or reaches the unstable radius r_{st2} (this is about 0.85-0-.9 of external radius
3. for simulated conditions), the thermal instability will develop
4. - Outside ignition of filtration combustion is possible at sufficiently calorific fuels and in a certain
5. range of gas flow rates Required (not necessarily sufficient) conditions are

delivered by above simulation

6. - Low-calorific fuels (ΔT_{ad} -900) may be burnt in a narrow area inside the carcass and at fuel flow
7. rates within a narrow range, Figs 3. To combust the leaner fuel, the bigger PMB diameter and smaller packing grain size are necessary.

References

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