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Effective Model and Method for simulation Burning Flows

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ABSTRACT

Simulating of non-stationary viscous chemical-reacting flows through channel with curved walls is important for many scientific and applied problems. Numerical investigations of 2D and 3D equations while accounting tens different chemical species and hundred chemical reactions is very hard and labor-consuming. In such cases quasi-one-dimensional approaches are useful and widespread. Known quasi-one-dimensional ones are based on averaging of governing equations along cross section of the channel. These models do not take into account the curvature of channels wall. We use the new quasi-one-dimensional model valid for smooth channels. It is based on averaging of governing equations written in the curvilinear orthogonal coordinate system adapted to the walls shape:

$$\frac{y'_w(x)}{y_w(x)}\frac{\partial\xi}{\partial x}\frac{1}{y}\frac{\partial\xi}{\partial y}=0, \qquad \eta=\frac{y}{y_w(x)}, \qquad \zeta=\alpha$$

where (x, y, α) is cylindrical one and the smooth function $f_w(x)$ is the walls shape. The new quasi-one-dimensional model allows taking into account curvature of channels wall, viscosity, various chemical-physical processes in volume and on surface and so on. As it is one- dimensional, even the consideration a large number of chemical reactions does not result in substantial increase of labor input. This model allows simulation flows in channels with great value of inclination angle. Known quasi-one- dimensional have error about tens percents in this case. The system of a chemical kinetics is the stiff one and requires special methods for solution. We use the stiff method of lines and the Rosenbrock-Wanner scheme. This method provides the accuracy $O(\tau^2)$ without the processes splitting. The convergence of presented method was tested on exact solution investigated by authors. Test on embedded grids shows that our method has the consistency $O(h^2)$. We simulated non-stationary combustion of hydrogen-oxygen mixture with 9 species and 24 reactions in a nozzle. The influence of walls curvature on combustion was shown. Numerical results show the preference of new quasi-one- dimensional model and the efficiency of developed numerical method.

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