

## A Fictitious Domain Method for Combustion Problems

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In this work we had extended and implemented a fictitious domain method (FDM) for time dependent combustion problems in non-regular domains. Such a method allows working in regular domains using regular meshes independently of the geometry of the actual domain [1]. We are considering the case when 2D flame propagates in a rectangular tube with obstacles and we focus our attention on its numerical solution by FDM approach. The study is based on the assumption of a low Mach number flow and uses a one-step global chemistry model of the methane-air laminar flame. The physical model assumes a flow in the rectangular vessel with length  $L$  and cross section of  $2h \times 2h$  and with obstacles is planar. The combustible gas is a stoichiometric methane-air mixture. Sound wave propagation is neglected. The ideal gas law is valid. With these assumptions and using FDM approach, the governing conservation equations of energy, species, state, mass and momentum in the low Mach number limit can be written as follows

$$\begin{aligned}\rho \frac{\partial H}{\partial t} + \vec{V} \cdot \text{grad } H &= \frac{dP_t}{dt} + \text{div} \left( \frac{\lambda^\varepsilon}{c_p} \text{grad } H \right), \\ \rho \frac{\partial Y}{\partial t} + \vec{V} \cdot \text{grad } Y &= \dot{w}_{CH_4} + \text{div}(\rho D^\varepsilon \text{grad } Y), \\ P_t(t) &= \frac{\rho R T}{W}, \quad H = c_p(T)T + QY, \\ \frac{dP_t(t)}{dt} &= \frac{k_f - 1}{\nu} \left( \int_S \lambda \frac{\partial T}{\partial n} dS + Q \int_V \dot{w}_{CH_4} dv \right), \\ \text{div } \vec{V} &= -\frac{\partial \rho}{\partial t}, \quad \vec{V} = \rho \vec{v}, \\ \frac{\partial \vec{V}}{\partial t} + \text{Div}(\vec{v} \vec{V}) &= -\text{grad} \left( p_d + \frac{2}{3} \mu \text{div } \vec{v} \right) + \text{Div}(2\mu \dot{S}) - \xi^\varepsilon \vec{V},\end{aligned}$$

where  $P_t$  is the average pressure,  $p_d$  is dynamic pressure. The fictitious coefficients are:

$$\lambda^\varepsilon(x) = \begin{cases} \lambda, & \text{if } x \in \Omega \\ \varepsilon, & \text{if } x \in \Omega_f \end{cases}, \quad D^\varepsilon(x) = \begin{cases} D, & \text{if } x \in \Omega \\ \varepsilon, & \text{if } x \in \Omega_f \end{cases}, \quad \xi^\varepsilon(x) = \begin{cases} \xi, & \text{if } x \in \Omega \\ \varepsilon^{-1}, & \text{if } x \in \Omega_f \end{cases},$$

where  $\Omega$  is the actual flow domain,  $\Omega_f$  is the fictitious domain (obstacle domain),  $\varepsilon$  is small positive parameter.

Boundary conditions are non-slip and heat- and mass isolated. At initial time the gas mixture is at rest at a temperature of 300 K and pressure of  $P_t(0)=P_0=10^5 \text{ Pa}$ ,  $p_d=0$ . The transport coefficients, thermodynamic data, kinetic coefficients and numerical algorithm are given elsewhere [2]. The computational cost is almost the same as in the case of tube without obstacle.

1. A.Kaltayev, Zh. Ualiev, Sh. Smagulov. A Fictitious Domain Method for Combustion Problems in a Non-Regular Domains. Proceedings of Ninth International Conference on Numerical Combustion April 7-10, 2002, Sorrento, ITALY, 249-250pp., <http://www.ing.unisannio.it/icnc2002>
2. A.Kaltayev, U.R.Riedel, and J.Warnatz. The Hydrodynamic Structure of a Methane-Air Tulip Flame. Combust. Sci. and Tech., 2000, Vol.158, pp.53-69.