Flame Front Modeling Regarded as Surface of Discontinuity

Abstract

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In the proposed paper flame front is assumed to lie on a surface of discontinuity, separating burnt from un-burnt gases and it is described by the G-equation [1].

$$\frac{\partial G}{\partial t} + \vec{u}.\nabla G = S_L \left|\nabla G\right| \qquad (1)$$

The G-equation is derived from the equality G(x,y,t)=C, which represents different iso-levels that give the location of the reaction zone (flame front). A particular iso-level is advected with external velocity $\vec{u}$ while propagating normally to itself with laminar burning velocity S_L.

Taking into account the kinematics on the surface of discontinuity, we arrive at the following formula for the G-equations*:

$$\frac{\partial f}{\partial t} + (\vec{u}.\vec{n} - S_L)\left|\nabla f\right| = 0, \qquad (2)$$

Here $\vec{n}$ is the unit normal vector to the surface, equal to $\nabla f / \left|\nabla f\right|$. The equation (2) represents the fact that moving an element of the surface in a normal direction has to be done at velocity $V_F = \vec{u}.\vec{n} - S_L$.

In [2] the external flow field was taken to be a flow of periodic vortices, which was obtained as perturbation to a steady stagnation point flow. Other possibility is to consider convective flow field in non-reactive mixture as it was described in [3].

Here is how to implement this: the flow-velocity field results need to be placed into the G-equation, where $\vec{u}$ resides. Next, is to solve the G-equation by numerical methods, s.a upwind finite differences already used in [2,4],. Additional efforts are required to produce the “flow field” according to mass and momentum conservation laws. Therefore the flow field will be a numerical solution to the Navier-Stockes equations, which is a challenge of its own reign.

To accomplish the task to following steps are required:

1) Solve and store velocity field for convection due to a “hot spot” or alternately -due to “hot wall”.
2) Insert the velocity field into the G-equation solution algorithm

3) Save and visualize the output for G(x,y,t) at various time moments to track down the front surface.

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References:

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* Here and when appropriate in the paper, the notation G is replaced with f.