TWO LAGRANGIAN PROPERTIES OF TURBULENT DIFFUSION WITH A KEY ROLE IN PREMIXED COMBUSTION MODELLING

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The aim of the present work is to highlight the key role to model premixed combustion processes of two Lagrangian features of turbulence. The features under consideration are i) the growing in time of the turbulent diffusion coefficient for short elapsed times, which strongly influences the formation of the developed flame during the initial stage of combustion (for example, in the spark ignition engines), and ii) the existence of a front of turbulent diffusion whose speed strongly controls the velocity of the steady state flame.

Even if the Lagrangian properties of turbulent diffusion are generally ignored in models of, for example, gas turbine premixed combustion, here we discuss the practical fallout in engineering design of the two cited Lagrangian aspects as well as the theoretical justification of a generalized TFC model [1], which is aimed to the description of both the initial and the final stages of premixed flame, where the mentioned Lagrangian effects of turbulent transfer are described in the context of the Eulerian model equations.

In the idealized case with constant density and homogeneous and stationary turbulence, the considered two Lagrangian effects can be exactly mathematically managed [2] and the main results are the following:

1. The arbitrary chemical transformation of Lagrangian particles does not influence the turbulent diffusion coefficient that remains the same as in nonreacting systems during both the nonequilibrium and the equilibrium regimes. Actually, this result generalizes the classical Taylor theory [3] to the case of chemically reacting flows.
2. The velocity of the turbulent steady state flame with the constant flamelet speed S_L emerges to be equal to $U_t = (u'^2 + S_L^2)^{1/2}$, and not $U_t = u' + S_L$ as it is sometimes assumed. Hence in weak turbulence a 40% percentage error, that cannot be neglected in applications, can be corrected by using the new formula and in strong turbulence, $u' >> S_L$, $U_t \cong u'$ it confirms and better quantifies the classical Damköhler intuitive estimation $U_t \sim u'$ [4].

References

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