Simulation of laminar flame propagation in a multicomponent droplet stream

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Abstract

To predict alternative fuels performances at ignition, a multicomponent evaporation model [1] was implemented into the lagrangian solver of ONERA's CFD code CEDRE. Several chemical components are now considered in the droplets, and the vaporisation process is sequential. The present study aims at testing the droplet composition effect on spray combustion.

The academic case of a 1D laminar flame propagating along a droplet stream is investigated. The first parametric study deals with monocomponent n-decane droplets and the results are compared to the equivalent gaseous flame configuration in order to understand vaporisation effects [2][3][4]. A reduced chemical scheme is considered for which Arrhenius preexponential factor is calculated from the equivalence ratio [6]. The evolution of the flame speed versus the total equivalence ratio is well reproduced, even if the flame speed value is slightly overestimated due to the simple chemistry used in the present study. The droplet diameter strongly affects the flame speed for a fixed total equivalence ratio (the flame speed is slower when the diameter is larger) [5].

Then 1D laminar flame computations are performed for multicomponent droplets. Droplets are composed with n-decane and n-hexadecane in order to underline how component volatilities alter flame behaviour. As both components are n-alkanes, n-decane and n-hexadecane are supposed to have the same chemistry mechanism, in order to only study the sequential vaporisation effect on flame propagation. Two reduced chemical schemes adapted to multicomponent combustion are compared [7][8].

The modified parameters are the droplets composition, the droplets initial diameter, and the total equivalence ratio. Results on the flame velocity, its temperature and its thickness are analysed. The flame structure depends on the droplet composition and the global behaviour of the 1D laminar flame for bicomponent droplet is halfway between results obtained for each monocomponent droplet (pure n-decane, and pure-n-hexadecane). The composition of burnt gases in rich combustion strongly depends on the total equivalence ratio, the diameter and composition of the droplets. The next step will be to consider different chemical kinetics. The final objective is to caracterize separately each effect of the droplet composition.
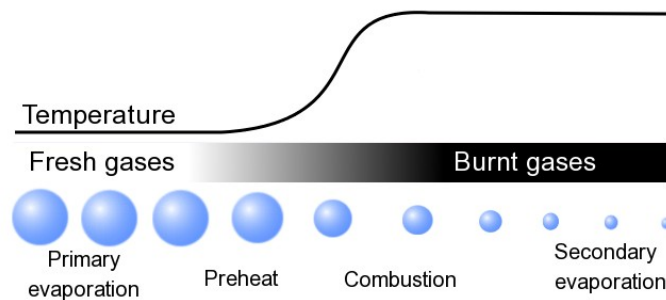
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