LES and Experimental investigation of Diesel sprays

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Abstract

In this paper, a Diesel spray has been investigated experimentally and numerically in order to improve the understanding of transient processes of short injection typically used in multi-injection strategies of internal combustion engine. The spray was observed experimentally in a high pressure high temperature cell that reproduces the thermodynamic conditions which exist in the combustion chamber of a Diesel engine during injection using a pre-combustion technique. A single-hole injector was mounted within the top face of the cell and the spray was injected at the following operating conditions: P_{inj} = 120 MPa, T_{gas} = 900 K and P_{gas} = 6.7 MPa. Planar Laser-induced Fluorescence (PLIF) was used to obtain two dimensional fields of fuel mass concentration. A normalization method based on the determination of the total injected mass was used to derive quantitative information from the fluorescence imaging. Also, 50 single-shot images of the vapor jet were acquired for each timing in order to allow statistical analysis.

Large Eddy Simulation (LES) numerical approach has been used in order to investigate single-shot transient processes and averaged results. Different LES simulations have been carried out using a Lagrangian approach including recently developed models in the AVBP code, for instance, the DVI model for initial formation of dense sprays and the SAB model for the droplets breakup. The injected fuel was a mixture of 70%vol n-decane and 30% vol 1-methylnaphtalène representative of a standard diesel. Five test cases were defined and are presented in Table 1. Since the injection boundary conditions are not fully known, the calculation methodology consisted in adjusting the numerical jet using the experimental results. Case 1 is the result of this adjustment and will be considered as the reference case, subsequently referred to as T9P12. Particularly, an experimental flow rate and α_l = 0.85 were used. The case 2 uses a modified flat flow rate during the full opening period. Then, the case 3 uses a value of α_l equal to 0.80 to study the effects of cavitation in the orifice on the jet. Finally, the case 4 employs the SGS dynamic Smagorinsky model instead of the standard Smagorinski model used in the first 3 cases. For each case, a series of 15 or 30 LES was calculated by setting different seeds for random sampling of the injected blobs.

The LES computations have been carried out with a well refined mesh in the injection zone. The characteristic size of the tetrahedral cells is of the order of 80 microns over a distance of about 100 diameters from the nozzle exit. This mesh correctly resolves the Gaussian profiles of liquid volume fraction and velocity specified by the DVI model. The full paper will includes the discussion of all the cases presented in Table 1.In particular, it has been shown that more than 30 LES simulations are needed in order to obtain converged numerically results. In this case, a satisfactory quantitative agreement has been obtained between the numerical results and the experiments, in terms of mass density, both in the averaged images and for the axial and radial profiles (see Figure 1 and Figure 2).

Table 1 Definition of the LES parameters for the T9P12 case : Pinj = 120 MPa, Tgas = 900 K and Pgas = 6.7 MPa.

Case	Label	Injection rate	Liquid volume fraction, α_l	SGS models	Total number of LES computations
1(15) 1(30)	A85	Experimental	0.85	Smagorinski model	15 30
2(15)	TXE	Experimental, modified	0.85	Smagorinski model	15
3(15)	TXN	Experimental	0.8	Smagorinski model	15
4(30)	DYN	Experimental	0.85	Dynamic Smagorinski model	30

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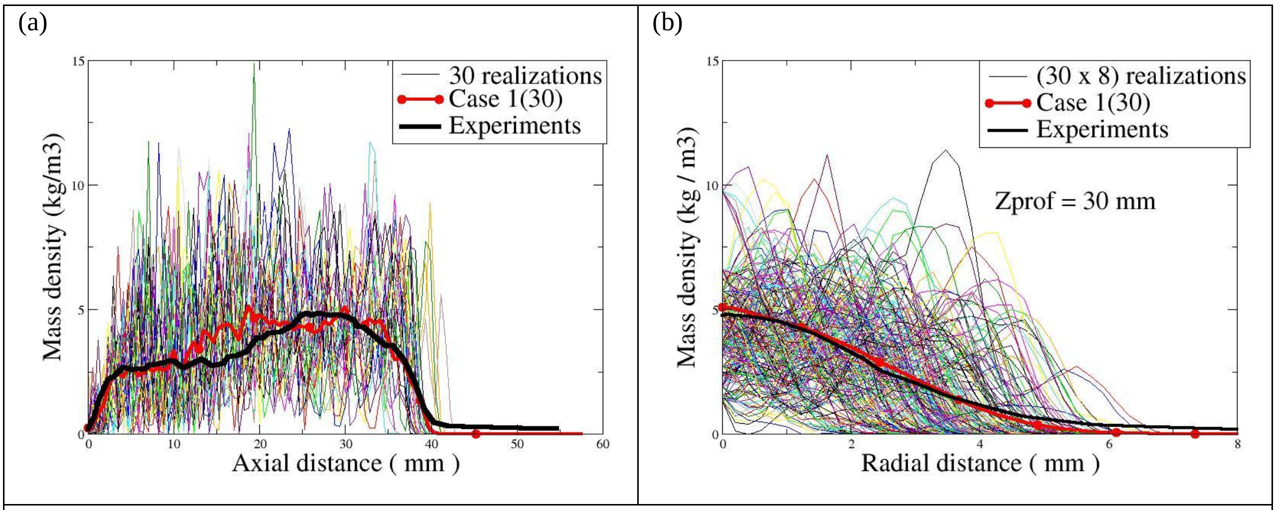

Figure 1 Results of T9P12 case 1: Pinj = 120 MPa, Tgas = 900 K and Pgas = 6.7 MPa.. Comparison of the experimental and LES axial (a) radial (b) profiles of the fuel mass density at axial location (Zprof=30 mm) from the nozzle exit and at time t=0.5 ms. The red curve with solid circles is the average of (30 x 8 = 240) LES profiles depicted by thin lines. The experimental profiles are the results of the averaging of 50 injections.

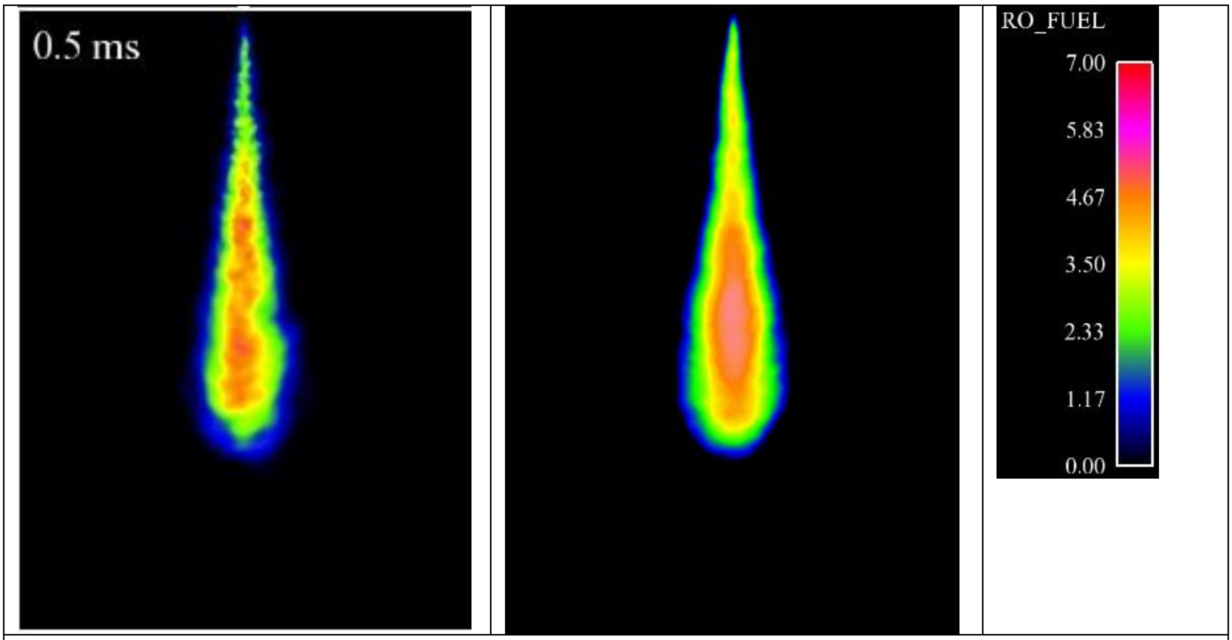

Figure 2 Averaged results of T9P12 case 1. Quantitative comparison of the experimental (right) and LES (left) averaged fuel mass density results at 0.5 ms. The same color pallet of the fuel mass density is used for the numerical and experimental results (RO_FUEL in kg/m3).