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Estimation of a suitable Schmidt number range in diesel sprays at high injection pressure

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ABSTRACT

The aim of this paper is to estimate a suitable range for the Schmidt number value in non-evaporative diesel sprays. For this purpose, mass distribution data obtained from X-ray absorption experiments existing in literature and a theoretical derivation for spray microscopic characteristics have been combined. Firstly, a procedure based on Gaussian concentration profiles has been proposed in order to interpret X-ray absorption results and relate them to physical parameters as local concentration or spray density. After this, information about FWHM (Full Width at Half Maximum) values has allowed to estimate spray angle in the tested conditions by the definition of Gaussian profiles for the mass radial distribution inside the spray. Following, a theoretical model dependent on momentum flux and Schmidt number has been used to simulate local mass concentration evolution along the spray axis and compare it with the values obtained from the experiments. The combination of the experimental and the theoretical data has allowed to estimate a suitable range for the Schmidt number value in such conditions as those existing in diesel sprays.

1. Introduction

High pressure sprays have been widely used in many different applications (combustion processes, internal combustion engines, etc.). Despite having been studied over decades, this kind of sprays involves many complex physical phenomena, such as atomization, coalescence, mass and momentum transfer and evaporation, and there are important questions related with these processes that still remain unclear [1–3]. One of the important aspects that have to be taken into account in the design process of pressure atomizers and injectors is the distribution of mass and velocity over the entire spray. This is especially relevant in applications such as diesel spray combustion, since the flame location and characteristics are a result of the air-fuel mixing process.

In this sense, both spray macroscopic characteristics, as spray tip penetration or cone angle [4–8], and microscopic features like droplet size, velocity or local concentration [9–13] have been measured with the help of different experimental techniques. Additionally, several theoretical models have been developed to understand and predict spray behavior [14–18]. As a result of most of these studies it can be seen that momentum flux at the nozzle exit can be considered as one of the most important parameters for the characterization of sprays [15,17,19–22]. For this reason, several experimental techniques have been developed for measuring momentum flux [23,24].

Some studies have revealed that Schmidt number has a significant influence on spray characteristics, especially in the near-nozzle field (axial positions lower than $50D_o$), where primary and secondary atomization take place [17]. Nevertheless, most of the experimental data available in the literature is restricted to positions far from the nozzle exit, where the spray concentration values are small enough to use optical techniques as PLIF (Planar Laser Induced Fluorescence) [25,26] or PDPA (Phase Doppler Particle Analyzer) [9–11,16,17]. In fact, typical ranges of study for these techniques are 20–50 millimeters, which implies axial positions higher than $200D_o$. For this reason, there are still few contributions that give accurate estimations for Schmidt number in diesel sprays. Only Prasad and Kar [27] gave a range of value of 0.7–0.8 using an injection pressure of 10–20 MPa and nozzle diameters between 0.4 and 0.57 mm. Nevertheless, injection parameters were quite far from current diesel injection conditions, both in terms of injection pressures and nozzle diameters.

In the last years, several researchers have made an effort to characterize diesel spray behavior in the near-nozzle field [28–30]. In this sense, Argonne National Laboratories have developed a technique for quantifying projected density distribution inside

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