

Modeling of Spray Behavior of a Diesel Fuel Surrogate

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ABSTRACT

As emission legislations are becoming increasingly more stringent, fundamental knowledge about fuel spray behavior in compression ignition (*i.e.* diesel) engines is needed. Once introduced to the combustion chamber, a proper dispersion and subsequent expedient evaporation of diesel fuel is critical for achieving low emissions of, in particular, soot and unburnt hydrocarbons. As experimental data is extremely costly, engine designers favor the utilization of models, which can predict the spray behavior of a fuel.

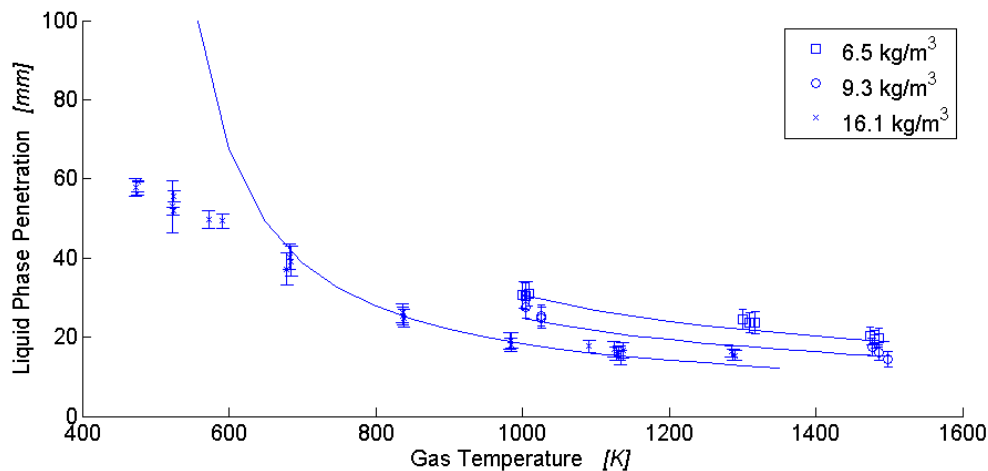
Once such model, frequently cited in literature, was developed by Siebers et al. [1, 2]. This model is based on the assumption that, at high gas temperatures and densities, droplet evaporation is governed primarily by the entrainment (rate) of hot gas, rather than interphase transport (*e.g.* liquid-to-vapor). By solving the mass, momentum and energy balance, this semi-empirical quasi-1D model is capable of computing the quasi-steady penetration distance L (*e.g.* from the injector nozzle) of the liquid phase of the spray. At L , the vaporized fuel is assumed to be at a saturated condition in thermodynamic equilibrium with the hot gas, at a temperature between that of the injected fuel and the hot cylinder contents.

For diesel engines, L is of particular importance, as it is a good indicator of the occurrence of a phenomenon known as wall-wetting (*i.e.* collision of liquid fuel with the cylinder liner or piston). This is an issue to be addressed when new combustion concepts like Homogeneous Charge Compression Ignition (HCCI) are used in unmodified direct-injected diesel engines. Short and long term effects of wall-wetting are hydrocarbon emissions and engine damage (*e.g.* via oil dilution) respectively.

As diesel fuel is a mixture of more than 10^4 different chemical compounds, so-called surrogate fuels are used in the modeling process to capture generic physical behavior of a multi component fuel with a single component fuel. From literature [3] is known that n-heptadecane (n-C₁₇H₃₆) has a boiling behavior that approximates that of commercial diesel fuel. Requisite physical properties for n-C₁₇H₃₆ were determined [4] utilizing estimation methods based on extended Corresponding States Theory.

Model results for L were compared to experimental data retrieved from the Eindhoven High Pressure Cell [5]. This optically accessible constant volume cell is capable of

producing and withstanding the high gas temperatures and pressures present in diesel engines at the time of fuel injection. The liquid phase of the fuel spray was visualized by applying Mie-scattering and recorded at high speed (e.g. 100 kHz). Results of this comparison are plotted for a wide range of gas temperatures and densities (although densities are still limited to non-turbocharged diesel engine conditions) in the figure below. Here, the solid lines and points represent the modeled and experimental data respectively.



It can be deduced from this figure that at the conditions for which the spray model was developed (i.e. high gas temperatures and densities) the model results fall neatly within the error bars of the measured data. To achieve this, the parameter b in the Siebers model was set to its original theoretical value of 0.25 [2]. In [2], however, the fitted value of 0.41 is used in order to obtain better agreement with the measurements. At relatively low temperatures (e.g. in the boiling range of diesel fuel) the model tends to overestimate L . It is believed that as the temperature of the gas gradually approaches that of the liquid fuel, the assumption of mixing-limited vaporization no longer holds as interphase transport is likely to become more dominant. This is currently under investigation.

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