Modeling of Gasoline Hollow Cone Spray Using OpenFOAM

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Abstract

An accurate prediction of gasoline hollow cone sprays is the basis for understanding combustion process in gasoline direct injection engines. Several modifications were made to OpenFOAM 1.4.1-dev in order to correctly model gasoline hollow cone sprays.

First, the real gasoline properties, such as surface tension, dynamic viscosity, heat of vaporization, etc, were implemented into the liquid library. The detailed description of the implementation can be found at www.tfd.chalmers.se/~hani/kurser/OS_CFD_2009/ChenHuang/OFProject0122.pdf.

Second, the Rosin-Rammler distribution [1], see equation 1, was implemented in order to simulate the probability density function (PDF) for droplet diameters.

$$f(D) = \frac{n}{\delta}\left(\frac{D}{\delta}\right)^{n-1} e^{-\left(\frac{D}{\delta}\right)^{n}} \quad (1)$$

Although a PDF called Rosin-Rammler distribution had already been implemented into the original code, the latter PDF

$$f(D) = \left(\frac{D}{\delta}\right)^{n} e^{-\left(\frac{D}{\delta}\right)^{n}} \quad (2)$$

was not the Rosin-Rammler PDF. In order to show the difference between the two PDFs, a statistical analysis was made based on all the droplet diameters, around 5000 samples, generated by the original and modified OpenFOAM. Figure 1 compares the results of the statistical analysis (red rectangulars) with the Rosin-Rammler PDF given by equation 1 (solid lines). The PDF generated by the modified code agrees with equation 1, but this is not so for the original OpenFOAM.

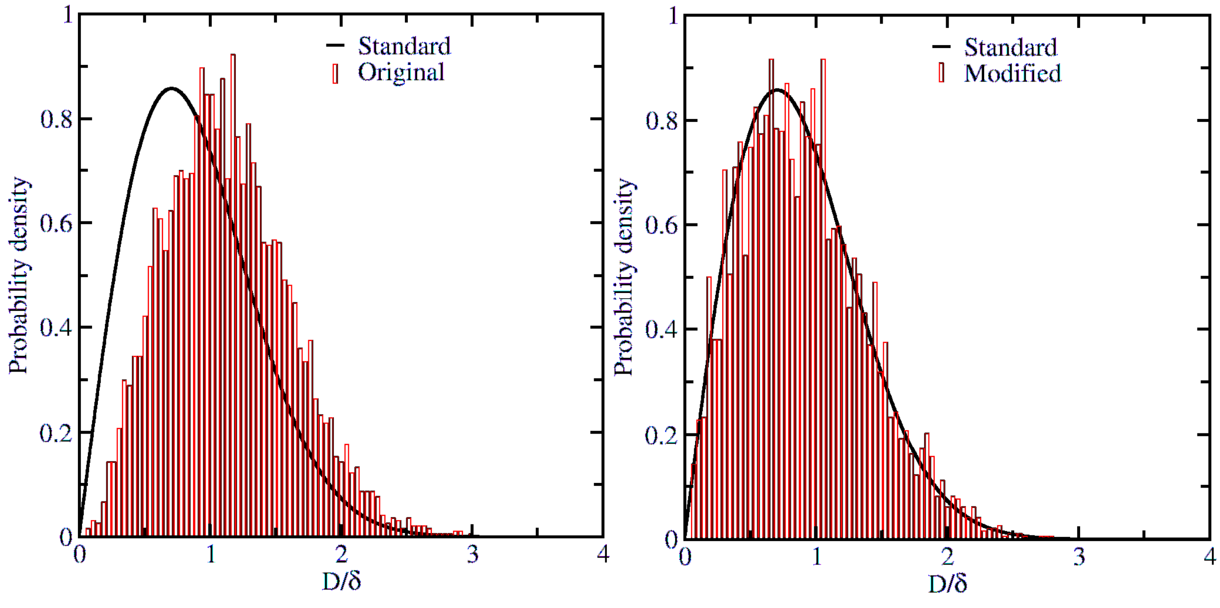

Figure 1 Comparison of droplet-size PDFs generated by the original (left) and modified (right) OpenFOAM with the Rosin-Rammler PDF given by equation 1.

Third, unit injector model was modified to consider varied discharge coefficient, C_d. With this varied C_d the needle movements, opening and closing, can be considered, while the injection pressure can be kept constant.

Finally, the modified code was tested against experimental data obtained in Chalmers spray chamber [2]. Figure 2 shows spatial droplet distributions measured (top row) and computed using original (middle row) and modified (the last row) code. In the both simulations, the setups for evaporation, heat transfer, dispersion, and drag models were kept the same. Reitz-Diwakar model was used to compute secondary break-up and the constant C_s for stripping break-up lifetime was tuned to be 40 in order to get good agreement with measured liquid penetration. The results simulated with the modified code show less droplets left at the upstream of the hollow cone spray, in line with the measurements, see Fig 2.

Figure 3 compares measured and computed liquid penetration and average Sauter Mean Diameter (SMD). The results obtained using both the original code and the modified OpenFOAM are close to the measurements, but with correct Rosin-Rammler distribution, the liquid penetration is shorter and SMD is smaller, see blue lines in Fig. 3 . The use of varied C_d results in increasing liquid penetration in the beginning of injection (cf. red and blue lines in Fig 3).

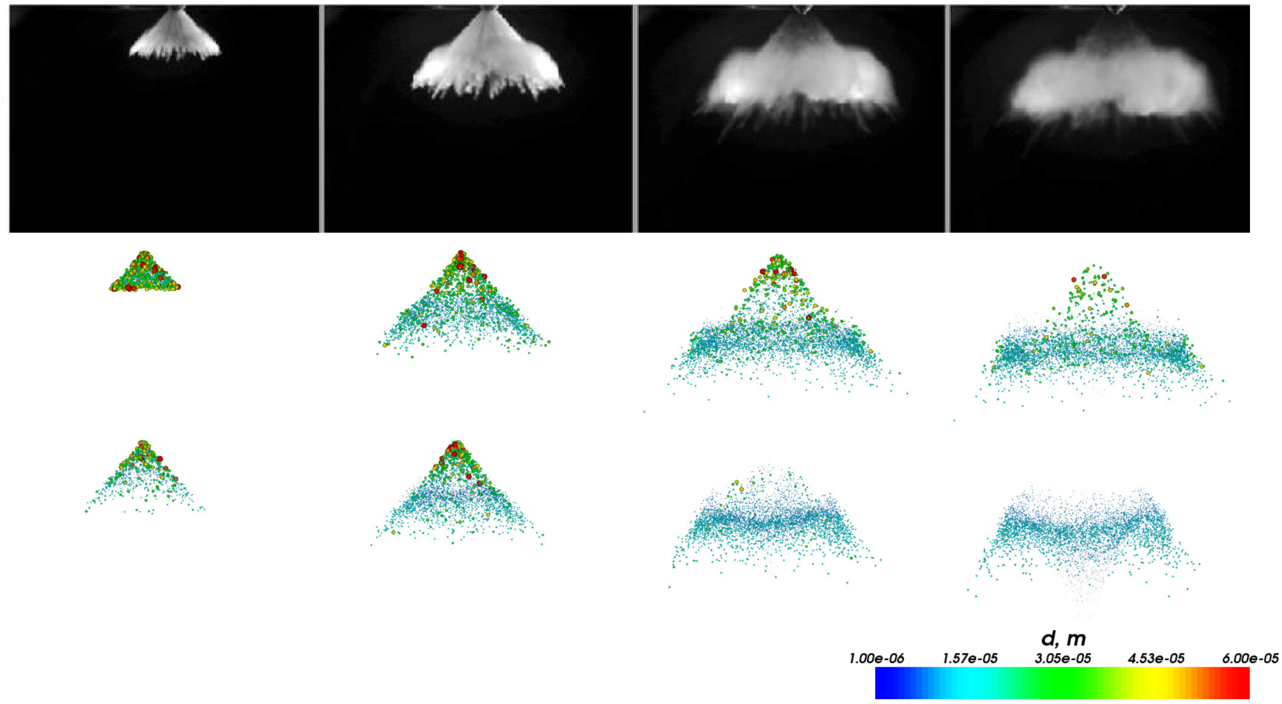

Figure 2 Comparison of gasoline droplet distributions measured [2] (top row) and computed using the original (middle row) and modified (last row) code. $T_{gasoline}$=243 K, T_{air}=350 K, p_{inj}=200 bar. The parameters of the Rosin-Rammler PDF were set as follows: δ=30µm, n=2, 1µm≤D≤120µm. The time from left to right is 0.18, 0.36, 0.64, and 0.82 ms aSOI.

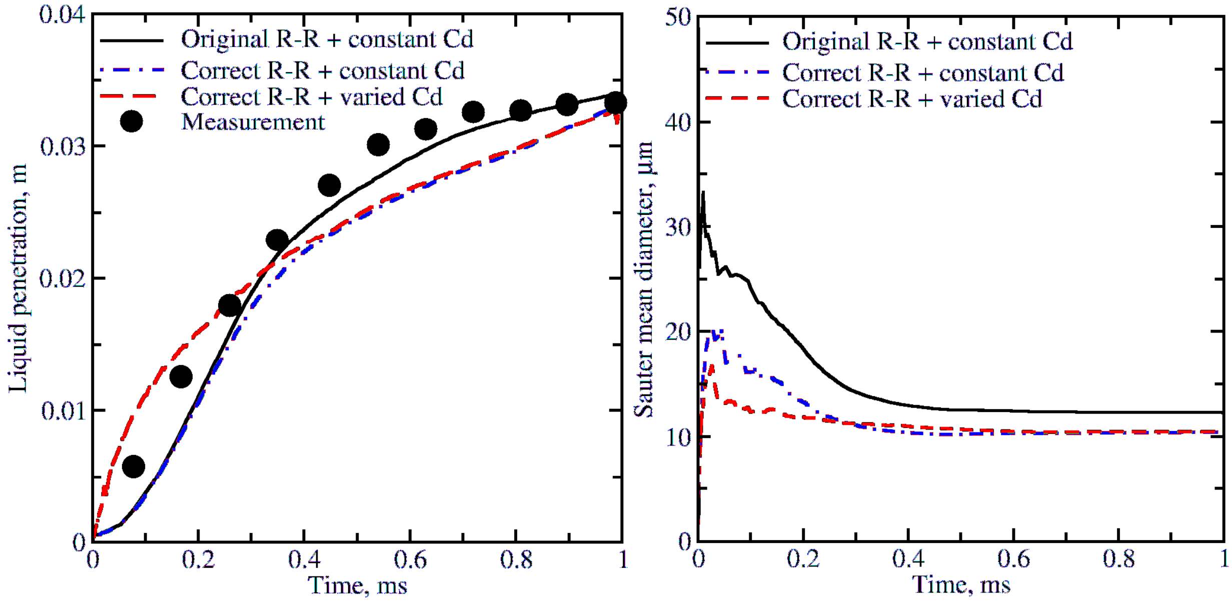

Figure 3 Liquid penetration (left) and SMD (right) vs. time. Symbols show the measured data [2] Black curves have been computed using the original Open FOAM. Red and blue curves have been obtained running the modified code.

Key words: gasoline, hollow cone spray, Rosin-Rammler distribution, OpenFOAM.

References

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[2] S Hemdal, J Warnberg, I Denbratt,P Dahlander: *Stratified coldsStart sprays of gasoline-ethanol blends*, SAE 2009-01-1496.