Prediction of Evaporation Time of Biodiesel Spray Generated from Small Industrial Burner

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Abstract

The Maximum Entropy Formalism (MEF) has been used to model dimensionless mass-based drop-diameter distribution data at local position within a spray generated from a small industrial burner. The function is in turn used to predict evaporation time of the group of drops employing the dimensionless D2-law. Three different fluids: water, diesel and biodiesel have been used in this study. The Model’s parameters for the dimensionless mass-based drop-diameter distributions are found to possess same values. This means that the shape of the drop-size distributions in the same. This work illustrates that the mean diameters of the diesel and biodiesel drop-size distributions are of the same order, but their evaporation times differ significantly, which indicates that care should be taken on the injection conditions of the nozzle when biodiesel is used in the burner that has originally been designed for diesel fuel.

Key words: Bio-fuel, Evaporating, Mass distribution, Dimensionless, Maximum entropy formalism(MEF)

Introduction

In the study, the maximum entropy formalism (1) has been used to model the measured drop-size distributions. The mathematical formula obtained from this model is the solution to the problem satisfying a set of physical constraints and is possessed of the maximal entropy. When evaporation is considered, the drop-size distributions are transformed into the dimensionless mass-based drop-diameter distributions. (2) Section 2 explains the transformed process in detail. The classical D2-law (3) in an appropriate dimensionless form will then be used to determine the evaporation time of the distributions. Section 3 illustrates how evaporation time for diesel and biodiesel distributions are calculated and compared.

Methodology

Local Distribution Data

Measurement data used in this work are local drop-size distribution within liquid sprays. The data were taken from three cross-sectional planes: at 3-, 5- and 7-cm from the nozzle exit (Figure 1(a)). (4-5) The volume-based local drop-size distributions, \( \Delta Q/Q \) (or mass fraction, \( \Delta w/w \)) of the spray at the centre core from the three planes are superimposed in the same plot and shown in the upper graph of Figure 2. The right shift of the distribution as the vertical distance from the nozzle increasing is more likely to be due to small drop deceleration. The lower graph of Figure 2 shows the mass fraction distributions along the radius of the 7th cm plane. It is shown that the mean diameters of the drops are larger toward the outer edge of the spray.

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are changed to the dimensionless mass distributions using the below equation

\[ F(\xi_i) = \frac{\Delta n_i}{\Delta n_i} = f_i D_{43} \]

(1)

where \( \xi_i \) is \( D_i / D_{43} \) and \( D_{43} \) is average diameter. Figure 3 plots the experimental mass distribution in the dimensionless form. It can be seen from Figure 3(a) that the dimensionless mass distributions at the centre core, taking data from different planes, are in similar shape distribution. Similar results are also obtained when series of the dimensionless distributions along the radius are superimposed (see Figure 3(b)). The shape of dimensionless mass distribution of the particular spray used in this study, therefore, does not sensitive much to the location.

**Figure 1.** (a) Side view of axisymmetrical spray and (b) Cross-section of 7-cm plane of the spray consisting of on the concentric rings.

**Figure 2.** Axisymmetrical planes(left), mass fraction distribution (right).

**Dimensionless Mass-Based Drop-Size Distribution**

The mass fraction drop-size distribution data for both at the centre core and the outer region

**Fitting the Drop-Size Distribution by MEF Model**

The model used in this study is based on Maximum Entropy Formulism (MEF) which is a three parameters model: \( q_1, \alpha \) and \( D_{43} \). In this
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When group of drops evaporate, the numbers of drops within the same class does not change with time

\[ \Delta N_i = \Delta N_0 \]  

(3)

The volume of the drops, however, reduces during the evaporation process according to the dimensionless \( D^2 \)-law. The remaining mass-based drop-diameter distribution as a function of time can then be calculated accordingly:

\[
\left( \frac{dw_{i=0}}{w_{i=0}} \right) = \frac{\left( \xi^i - \tau \right)^2}{\xi^i} \left( \frac{dw_{i=0}}{w_{i=0}} \right) \]  

(4)

The mass evaporated at different dimensionless time, \( \tau \), can then be evaluated using equation 5.

\[
\frac{w_i}{w_c} = \frac{w_i - w_c}{w_c} = 1 - \int_{\xi=0}^{\xi=\infty} \left( \frac{w_i}{w_c} \right) \]  

(5)

The last term of equation (5) integrates the remaining mass-based drop-diameter distribution at the evolution time \( \tau \).

The real evaporation time of the drop-size distribution, however, depends on evaporation rate of the liquid and the mean diameter of the distribution\(^{(2)}\)

\[ t = \frac{(D_0)^2 \tau}{\lambda} \quad \text{sec} \]  

(6)

where \( \lambda \) is the evaporation constant of the liquid drop. The evaporation constants for a single drop of diesel and biodiesel at 200°C were experimental found to be 9.6x10\(^{-9}\) and 3.75x10\(^{-9}\) m\(^2\)/s respectively.\(^{(6)}\) At the center of the 7th cm-plane, the mean diameters of diesel and biodiesel are 9.2 and 10.3 \( \mu \)m respectively.\(^{(5)}\) Figure 4 shows that the evaporation time of group of drops of the diesel and biodiesel at the center core differ significantly from 16 and 42.9 ms.


