FUEL DROPLETS HEATING AND EVAPORATION

Nawar Al-Esawi, Mansour al Qubeissi
Centre for Mobility and Transport, Faculty of Engineering, Environment and Computing, Coventry University, CV1 2JH, UK

Aims and Objectives

This work aims at introducing a new mathematical model for heating and evaporation of blended fuel droplets. The model is anticipated to be applicable to multicomponent blended fuel (bio-fossil fuel) used in direct internal combustion engines

The learning objectives are:

- Introducing a CPU efficient approach.
- The generalisation of the previously developed models (DC and MDQD) for the analysis of blended bio-fossil fuel droplet heating and evaporation.

Introduction

- The heating and evaporation of automotive fuel droplets are crucial to the design of internal combustion engines and to ensuring their good performance.
- The interest in bio-fossil fuel blends has been mainly stimulated by depletion of fossil fuels and the need to reduce carbon dioxide emissions that contribute towards climate change.
- Biodiesel and ethanol are renewable fuels and more friendly to the environment than fossil fuel.

Types of Biodiesel

There are several types of biodiesel. Some examples of these types are: Tallow Methyl Ester **(TME)**, Lard Methyl Ester **(LME)**, Butter Methyl Ester **(BME)**, Coconut Methyl Ester **(CME)**, Palm Kernel Methyl Ester **(PMK)**, Palm Methyl Ester **(PME)**, Safflower Methyl Ester **(SFE)**, Peanut Methyl Ester **(PTE)**, Cottonseed Methyl Ester **(CSE)**, Corn Methyl Ester **(CNE)**, Sunflower Methyl Ester **(SNE)**, Soybean Methyl Ester **(SME)**, Rapeseed Methyl Ester **(RME)**, Linseed Methyl Ester **(LNE)**, Tung Methyl Ester **(TGE)**, Hemp-oil Methyl Ester, produced from Hemp seed oil in Ukraine **(HME1)**, Hemp-oil Methyl Ester, produced in European Union **(HME2)**, Canola seed Methyl Ester **(CAN)**,Waste cooking-oil Methyl Ester **(WCO)**, Camelina Methyl Ester **(CML)**, Jatropha Methyl Ester **(JTR)** and Yellow Grease Methyl Ester **(YGR)** .

Basic Equations

The heating and evaporation processes are described by the heat and mass transfer equations. The heat conduction equation for the temperature $T=T(t,R)$ in the liquid phase in a spherical droplet can be presented as [1,2]:

$$\frac{\partial T}{\partial t} = \kappa\left(\frac{\partial^2 T}{\partial R^2} + \frac{2}{R}\frac{\partial T}{\partial R}\right)$$

The diffusion of mass fractions (Y_{li}) of liquid species i in a spherical droplet is described by the following equation:

$$\frac{\partial Y_{li}}{\partial t} = D_{\text{eff}}\left(\frac{\partial^2 Y_{li}}{\partial R^2} + \frac{2}{R}\frac{\partial Y_{li}}{\partial R}\right)$$

Results (Diesel-Biodiesel Fuel Blends)

The time evolution of surface temperature and radii of various biodiesel-diesel droplets predicted by these equations are shown in Figure 1.

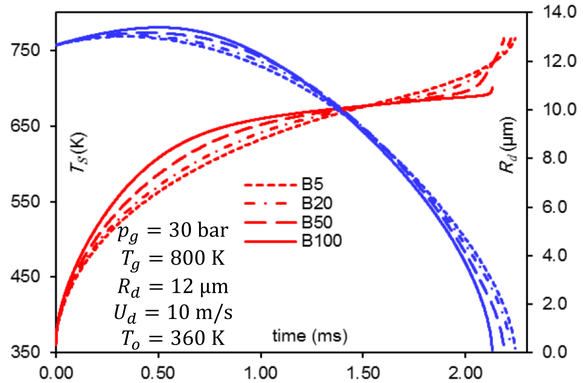

Fig.1: Droplet surface temperatures (Ts) and radii (Rd) versus time for four fractions of RME biodiesel fuel in diesel: B5, B20, B50 and B100

Table 1 shows the droplet lifetimes of selected types of biodiesel fuels mixtures with pure diesel fuel and their deviations from the one predicted for PD fuel (2.25ms).

Table 1. Estimation of diesel-biodiesel and pure biodiesel fuel droplets lifetimes and their deviations compared with those of PD fuel.

Biodiesel fuels	B100		B5	
	Lifetime (ms)	Diff (%)	Lifetime (ms)	Diff (%)
CME	1.765	21.56	2.229	0.93
PMK	1.846	17.96	2.230	0.89
SME	1.981	11.96	2.236	0.62
RME	2.131	5.29	2.242	0.36
HME1	2.022	10.13	2.237	0.58
HME2	1.994	11.38	2.238	0.53
WCO	2.002	11.02	2.235	0.67

A typical example of time evolutions of mass fractions at the surface of droplets (Y_{li}) of selected nine species of B50 fuel mixture of diesel with RME is shown in Figure 2.

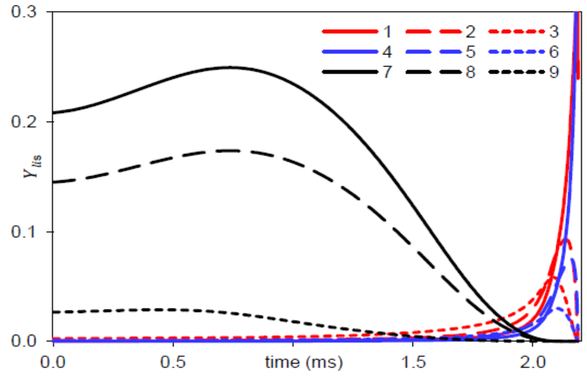

Fig. 2: The liquid mass fractions at the surface of droplet versus time.

Results (Ethanol-Gasoline Fuel Blends)

The time evolution of radii of various ethanol-gasoline fuel are shown in Figure 3.

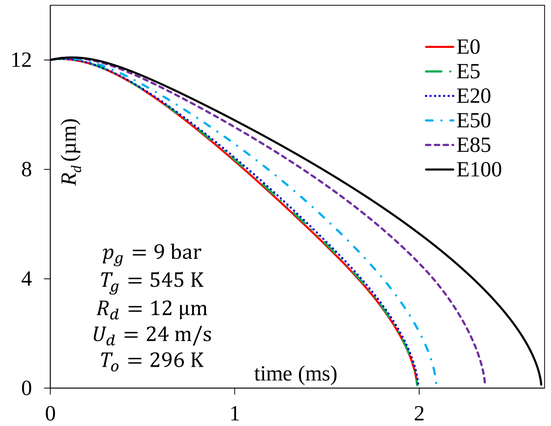

Fig.3: Droplet radii (Rd) versus time for four fractions of ethanol-gasoline fuel blend, pure gasoline and pure ethanol.

Table 2 shows the droplet lifetimes of ethanol-gasoline fuel blends and their deviations from the one predicted for pure gasoline fuel (1.988ms).

Table 2. Estimation of ethanol-gasoline fuel droplets lifetimes and their deviations compared with those of pure gasoline fuel (1.988 ms)

Blend	time (ms)	Diff %
E0	1.988	-
E5	1.989	0.050
E20	1.994	0.302
E50	2.093	5.282
E85	2.356	18.511
E100	2.662	33.903

Impact of non-ideal vapour-liquid equilibrium

The impact of the corrected activity coefficient using the UNIFAC model on the estimation of droplet lifetimes of both pure diesel and pure gasoline fuels is shown in figures 4 and 5.

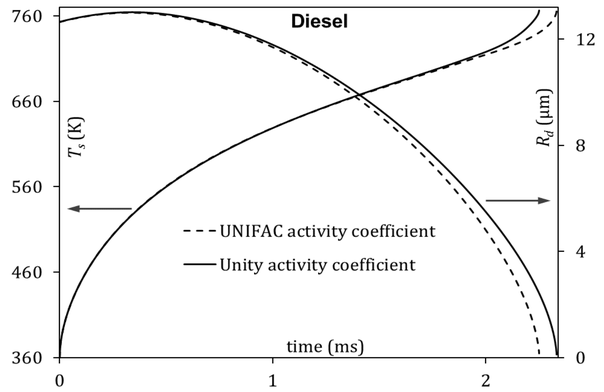

Fig.4: Droplet surface temperatures and radii versus time for diesel fuel with and without taking into account the effect of the activity coefficient.

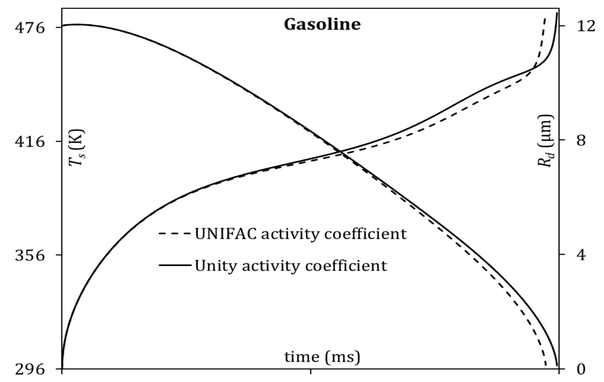

Fig.5: Droplet surface temperatures and radii versus time for gasoline fuel with and without taking into account the effect of the activity coefficient.

References

[1] Al Qubeissi, M., 2015, *Heating and Evaporation of Multi-Component Fuel Droplets*, WiSa, Stuttgart, Germany.

[2] Sazhin SS. Droplets and Sprays. London: Springer; 2014.

[3] Sazhin SS. Advanced models of fuel droplet heating and evaporation. Prog Energy Combust Sci 2006;32:162–214..

[4] Al Qubeissi M, Al-Esawi N, Sazhin SS. Droplets heating and evaporation: an application to diesel-biodiesel fuel mixtures. ILASS2017, Universitat Politècnica València; 2017.

[5] Al Qubeissi M, Sazhin SS, Turner J, Begg S, Crua C, Heikal MR. Modelling of gasoline fuel droplets heating and evaporation. Fuel 2015;159:373–84.