Shock Tube Studies of Soot Formation in Heptane-Air and Heptane-DME-Air Mixtures

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Motivation

Diesel engines are high in efficiency; however relatively high soot emission limits the use of diesel engines. Previous researchers have been demonstrated that addition of oxygenates in diesel fuel reduces soot emissions, but the key question is how do oxygenate additives in fuel reduce engine soot emission? An improved understanding of the mechanism that describes how oxygenates reduce soot will enable intelligent design of optimized fuel composition and potential additives.

Overview

A real diesel engine with real diesel fuel, however, is not a good choice for investigating very fundamental soot formation since combustion in a real engine includes many different effects coupled together. Different strategies are needed. Consider first the fuel itself, real diesel fuel is a complicated mixture of many components can vary widely and from barrel to barrel; a simpler surrogate fuel formulation is needed. Heptane can be used instead as a single-component diesel surrogate fuel since it has a cetane value typical for diesel. Dimethyl ether (DME) was chosen as a representative of an oxygenate since it has been widely shown to suppress soot formation. More importantly, detailed kinetic models are available for both heptane and DME, so that it is possible to build soot formation model upon existing chemical kinetic models.

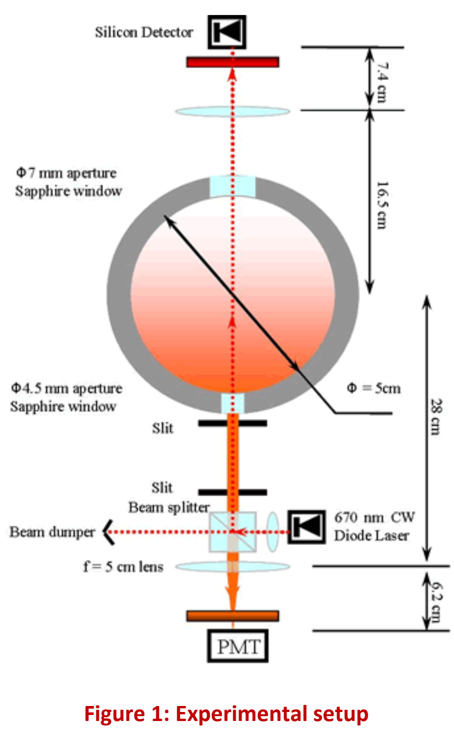

Figure 1: Experimental setup

Secondly, a simple reaction vessel is needed. Here, a shock tube is an ideal facility. A shock tube can produce controlled shock waves and shock wave compression allows wide range of pressures and temperatures with fluid transport effects.

The third strategy adopted is to make sooting tests at high pressures, say larger than 20 bars, at conditions similar to those that occur in real diesel engines. Experimental soot data at these high pressures are rare and are needed to validate the models.

There are two key parameters describing soot formation tendency: soot formation induction time and soot yield, which is the conversion rate of fuel carbon into soot. By using optical methods, such as laser induced extinction and soot thermal emission, we can determine the two parameters without disturbing the test sample. With soot formation induction time and soot yield for various experimental conditions we can determine the dependencies of heptane soot formation on several key parameters: dimethyl ether (DME) concentration, temperature, pressure, fuel partial pressure and equivalence ratio.

With this comprehensive experimental data base for soot formation, soot kinetic models can be tested and refined.

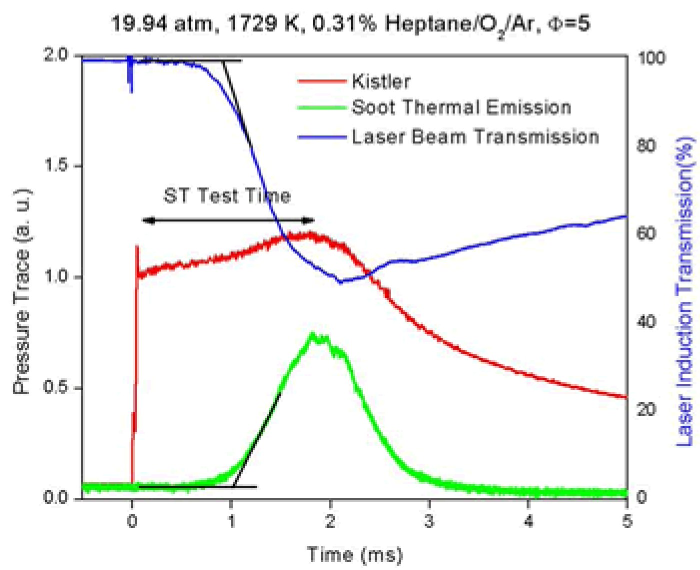

Figure 2: Sample data