Abstract

Diesel fuel is composed of a complex mixture of hundreds of hydrocarbons that vary globally depending on crude oil sources, refining processes, legislative requirements and other factors. In order to simplify the study of this fuel, researchers create surrogate fuels with a much simpler composition, in an attempt to mimic and control the physical and chemical properties of Diesel fuel. The first surrogates were single-component fuels such as n-heptane and n-dodecane. Recent advancements have provided researchers the ability to develop multi-component surrogate fuels and apply them to both analytical and experimental studies. The systematic application of precisely controlled surrogate fuels promises to further enhance our understanding of Diesel combustion, efficiency, emissions and particulates and provide tools for investigating new and alternative engine combustion systems.

This thesis employed analytical and experimental methods to develop, validate and study a library of multi-component surrogate Diesel fuels. The first step was to design a surrogate fuel to precisely match the physical and chemical properties of a full-range petroleum Diesel fuel with 50 cetane number and a typical threshold soot index value of 31. The next step was to create a Surrogate Fuel Library with 18 fuels that independently varied two key fuel properties: cetane number and threshold soot index. Within the fuel library cetane number ranged from 35 to 60 at three threshold soot index levels of 17, 31 and 48 (low, mid-range and high). Extensive ASTM fuel property tests showed that good agreement with important physical and chemical properties of petroleum Diesel fuel such as density, viscosity, heating value and distillation curve.

An experimental investigation was conducted to evaluate the combustion, emissions, soot and exhaust particles from the petroleum Diesel fuel and the matching surrogate fuel. A fully-instrumented single-cylinder Diesel engine was operated with combustion strategies including Premixed Charge Compression Ignition (PCCI), Low-Temperature Combustion (LTC) and Conventional Diesel Combustion (CDC). For combustion, the ignition delay, low-temperature (first stage) and high temperature (second stage) heat-release matched very well. Gaseous emissions, soot and exhaust particles maintained good agreement as exhaust gas recirculation and combustion phasing were varied.

This thesis demonstrated that fully representative Diesel surrogate fuels could be tailored with the proper blending of the following hydrocarbon components: n-hexadecane, 2,2,4,4,6,8,8-heptamethylnonane, decahydronaphthalene and 1-methylnaphthalene. It was also established that the volumetric blending fractions of these four components could be varied to independently control the fuel cetane number and threshold soot index while retaining the combustion, physical and chemical properties of full-range petroleum Diesel fuel. The Surrogate Fuel Library provided by this thesis supplies Diesel engine researchers and designers the ability to analytically and experimentally vary fuel cetane number and threshold soot index. This new capability to independently vary two key fuel properties provides a means to further enhance the understanding of Diesel combustion and design future combustion systems that improve efficiency and emissions.