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Combustion Characteristics and Pollutant Emissions in Gasoline/Ethanol Mixed Fuels

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Abstract : The recent development of biofuel production technology facilitates the use of bioethanol and biodiesel on automobile. Bioethanol, especially, can be used as a fuel for gasoline vehicles because the addition of ethanol has been known to increase octane number and reduce soot emissions. However, the wide application of biofuel has been still limited because of lack of detailed combustion properties such as auto-ignition temperature and pollutant emissions such as NOx and soot, which has been concerned mainly on the vehicle fire safety and environmental safety. In this study, the combustion characteristics of gasoline/ethanol fuel were investigated both numerically and experimentally. For auto-ignition temperature and NOx emission, the numerical simulation was performed on the well-stirred reactor (WSR) to simulate the homogeneous gasoline engine and to clarify the effect of ethanol addition in the gasoline fuel. Also, the response surface method (RSM) was introduced as a design of experiment (DOE), which enables the various combustion properties to be predicted and optimized systematically with respect to three independent variables, i.e., ethanol mole fraction, equivalence ratio and residence time. The results of stoichiometric gasoline surrogate show that the auto-ignition temperature increases but NOx yields decrease with increasing ethanol mole fraction. This implies that the bioethanol added gasoline is an eco-friendly fuel on engine running condition. However, unburned hydrocarbon is increased dramatically with increasing ethanol content, which results from the incomplete combustion and hence needs to adjust combustion itself rather than an after-treatment system. RSM results analyzed with three independent variables predict the auto-ignition temperature accurately. However, NOx emission had a big difference between the calculated values and the predicted values using conventional RSM because NOx emission varies very steeply and hence the obtained second order polynomial cannot follow the rates. To relax the increasing rate of dependent variable, NOx emission is taken as common logarithms and worked again with RSM. NOx emission predicted through logarithm transformation is in a fairly good agreement with the experimental results. For more tangible understanding of gasoline/ethanol fuel on pollutant emissions, experimental measurements of combustion products were performed in gasoline/ethanol pool fires, which is widely used as a fire source of laboratory scale experiments. Three measurement methods were introduced to clarify the pollutant emissions, i.e., various gas concentrations including NOx, gravimetric soot filter sampling for elements analysis and pyrolysis, thermophoretic soot sampling with transmission electron microscopy (TEM). Soot yield by gravimetric sampling was decreased dramatically as ethanol was added, but NOx emission was almost comparable regardless of ethanol mole fraction. The morphology of the soot particle was investigated to address the degree of soot maturing. The incipient soot such as a liquid like PAHs was observed clearly on the soot of higher ethanol containing gasoline, and the soot might be matured under the undiluted gasoline fuel.

Keywords : gasoline/ethanol fuel, NOx, pool fire, soot, well-stirred reactor (WSR)
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