

# Optical investigation of soot evolution in spray combustion influence of fuel composition and injection parameters

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# Optical Investigation of Soot Evolution in Spray Combustion
# Influence of Fuel Composition and Injection Parameters

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# Abstract

The effect of fuel composition and injection pressure on the particulate matter (PM) component of exhaust in diesel engine combustion is experimentally examined in this dissertation. Two different types of fuel composition are investigated as thermo-chemical means of reducing the PM emission. The first type involves the use of fuel emulsions to effectively cool the flame temperature and provide active radicals for soot oxidation. The fuel-water emulsions of 13% and 25% mass of water are examined. The second type employs a high cetane number admixture to enhance the auto-ignition of the fuel and high availability of oxygen in the butylal molecule. Two diesel: butylal blends having 75:25 and 50:50 mass percentages are used. The effect on PM emissions of these four blends are compared to that of the baseline fuel, diesel. Furthermore, as the oxygen content of 50:50 diesel butylal blend is similar to that of 13% mass water-fuel-water emulsion, a comparison of these two allows the effects of chemical composition to be distinguished. The effect of injection pressure on PM emissions is also examined for the baseline and diesel blends. In order to assure a constant base for comparison among the test cases, the energy content of the injected fuel is kept constant for all test cases.

The experiments are conducted in a high temperature – high pressure constant volume, combustion cell (HTDZ). The range of operation in HTDZ covers that typically found in a diesel engine. Thus, an extensive study of the effects of the aforementioned thermo-chemical and fluid mechanical parameter is possible. Using the optical access to the cell, two line-of-sight optical techniques, two-color pyrometery and the back-diffused laser (BDL)

method, are simultaneously applied. The trends in the mean KL-factor and its temporal integral after start of injection are qualitatively similar with the two measurement techniques, and in particular the results from the two-color pyrometery are in good agreement with trends recorded in literature. Weak laser extinction is thought to be the reason for the quantitative discrepancy of BDL compared as to two-color pyrometry.

The measurements with two-color pyrometry show that relative to the baseline fuel, diesel, both the fuel-water emulsions and diesel-butylal blends have substantially reduced PM emissions. The fuel-water emulsions can yield up to 58% percent reduction in PM and the diesel-butylal blends up to 25% reduction, for the compositions examined in the present work. The effectiveness in PM emission reduction increases as the water mass percentage is increased for the fuel-water emulsion, and the butylal additive is increased for the diesel-butylal blend. In the case of diesel: butylal the reduction of the PM emission is a direct consequence of the increased $O_2$ amount in the fuel that is directly available for soot oxidation. On the other hand, for the fuel-water emulsions, the readily available OH radicals are more effective in attacking soot precursors or for oxidation after the soot is created. A comparison of 13% water-diesel emulsion and 50:50 diesel butylal, which have similar $O_2$ (and C) content shown that their PM emissions are reduced to roughly the same extent compared to the baseline diesel. The PM emissions for all test fuels are observed to reduce as the injection pressure is increased. This reduction is also accompanied by a reduction in the soot temperature. A phenomenological two-step, two-zone model is used to simulate the effect of injection pressure in the baseline fuel. The model yields results that are in good agreement with the experimental data. The predicted soot mass fraction lies within the standard deviation of the experimental measurements for the most of the combustion period. At the end of the combustion period the soot model over-predicts the soot mass fraction. Furthermore, interrogation of the simulated data shows that the reduced PM emissions are a consequence of a shorter diffusion combustion phase.

Overall, the present work clarifies the physical mechanisms by which fuel-water emulsions and oxygenated additives are effective in reducing PM emissions of diesel combustion. These findings thus contribute to the advancement of emission control technologies for diesel engines that is necessary in order to meet future EU emission regulations.