Soot Characteristics of Mode transition between Low Temperature Combustion and Conventional Combustion

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Abstract. The nanostructure, morphology and oxidative reactivity of the soot produced in both conventional and low temperature combustion (LTC) modes are studied in a single-cylinder heavy-duty diesel engine. Comparison of the diesel soot produced in two aforementioned combustion modes shows that the LTC soot is consist of smaller primary particles, agglomerated in clumps of carbonaceous materials with irregular shapes. LTC soot also exhibits lower carbon to hydrogen ratio and higher oxidative reactivity compared to conventional mode soot. The soot produced during mode transition from LTC to conventional mode is also studies by use of Raman micro-spectroscopy. Results indicate that soot produced during mode transition has a larger graphitic portion compared to both conventional and LTC regimes which in turn suggests lower oxidative reactivity of the mode transition soot. It is shown that through implementation of proper injection strategy during mode transition, soot nanostructure can be altered toward less graphitized and more reactive structure.

Background and objectives

Low temperature combustion (LTC) regime has been widely researched in few past decades due to its benefits in terms of soot and NOx emissions. However, because of load limitation LTC mode can only be applied in dual-mode operation where engine operation mode switches back and forth from LTC mode in lower loads to conventional mode in higher loads. In order to understand after-treatment requirements of such dual-mode operating engines, the characteristics of the soot generated in LTC mode, conventional mode, as well as mode transition period, should be investigated.

Experiments

Research was performed in a single-cylinder naturally-aspirated research engine with commercial diesel as fuel. The collected soot was analyzed using a variety of technics including Scanning Mobility Particle Sizer (SMPS), Transmission Electron Microscopy (TEM), Thermo-gravimetric Analysis (TGA). Elemental analysis and Raman micro-spectroscopy.

Results

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The soot produced in LTC and conventional modes and well as the soot produced in mode transition condition show distinctive differences in nanostructure, morphology and oxidative reactivity. The average size of primary particles is found to be 17 nm for LTC mode and 32 nm for conventional mode. Results of elemental analysis shows that LTC soot has lower carbon to hydrogen ration which indicates more immature state of the soot. As observe in TEM images, the LTC soot is in form of clumps of carbonaceous materials with irregular shapes while the conventional soot morphology is in form of distinctive primary particles agglomerated in chain like structures [1].

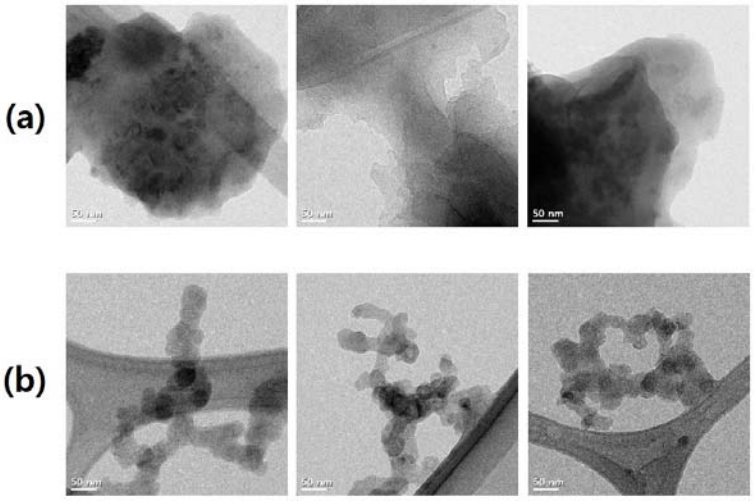

Figure 1. Morphology of diesel soot generated in *a)* low temperature combustion mode and *b)* conventional diesel combustion mode

Results of Raman micro-spectroscopy analysis on the soot generated during mode transition shows that mode transition soot has a different nanostructure compared to both LTC and conventional soot. The mode transition soot is found to poses a larger of graphitic portion which indicated lower reactivity of the soot which is deemed to be due to delay in evacuation of EGR as well as retarded phasing during the mode transition, which suppresses in-cylinder oxidation of the soot. However, applying a proper injection strategy [2] could reduce the graphitic portion of the soot through reduction of the equivalence ratio and regulating combustion phasing during mode transition.

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