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Factorial Analysis on Partial Oxidation Phenomena of Post Injected Fuel in Diesel Engines

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Post fuel is injected for the regeneration of diesel particulate filter (DPF). In early post injection, the fuel is partially oxidized, and it is a cause of deterioration in fuel consumption, however the factors and the mechanism of the partial oxidation phenomena are not investigated yet.

To analyze them, engine experiments were conducted on an inline 4-cylinder diesel engine with compression ratio of 15.8 and displacement volume of 1998 cm^3. The engine was customized to be operated by HCCI operation with the port-fuel injection of n-hexane, and a dual fuel operation by diesel fuel and n-hexane is possible.

First, the engine was operated by conventional diesel operation (pilot, pre, and main injections) in DPF regeneration mode in Test 1. Post fuel injection timing (θ_{post}) was a parameter of the experiments and the oxidation ratio calculated by rate of heat release and THC and CO emissions were measured by emission analyzer. In Test 1, when the post fuel is injected in 40-52.5 °CA ATDC, the post fuel is partially oxidized, and the oxidation ratio of post fuel becomes lower as the post fuel injection timing is retarded.

In Test 2, partial oxidation phenomena in homogeneous circumstances were analyzed by the dual fuel operation of HCCI with n-hexane and post diesel injection. The partial oxidation of post fuel occurs when the post fuel is injected in 32-34 °CA ATDC, and the results suggests that the main reasons of partial oxidation of post fuel are the heterogeneities of temperature and equivalent ratio distributions in cylinder. This indicates that premixed diesel combustion as the main combustion is effective for exhausting post fuel as THC without partial oxidation.

In Test 3, the effects of heterogeneities of temperature and equivalent ratio distributions in cylinder on partial oxidation of post fuel were investigated by adding the small fuel quantity of after-injection (1.0-3.0 mm^3/cycle). The test results show the similar tendencies like those of conventional diesel operation in DPF regeneration mode in Test 1, and the heterogeneities were analyzed by 3D-CFD code, AVL FIRE. The data of fuel mass, carbon monoxide (CO) mass and temperature in each cell volume were calculated in each crank angle timing, and the distributions of fuel mass and CO mass were arranged by the temperature, as shown in Figures 1 and 2. Under the condition of a post injection timing (θ_{post}) of 25 °CA ATDC, when all the fuel is oxidized, there is no fuel in the temperature range below 1000 K at 5 °CA after the start of injection, and the oxidation reaction proceeds quickly. On the other hand, when the post-injection timing θpost is delayed from 47.5 °CA ATDC, the oxidation reaction is suppressed in the fuel that exists in the low temperature range of 400-900 K below the auto-ignition temperature. For example, when the post injection timing (θ_{post}) is 47.5 °CA ATDC, the fuel presence area shifts to the lower temperature side as the piston descends, and the fuel mass also decreases, confirming partial oxidation of the post-injected fuel, but when the post injection timing (θ_{post}) is 60 °CA ATDC, the fuel presence area shifts to the lower temperature side as the piston descends. However, in the case of the post injection timing (θ_{post}) at 60 °CA ATDC, the fuel mass does not decrease, and the oxidation reaction of the fuel does not progress. The results show that the fuel in 400-900 K, lower than auto ignition temperature, stops the reactions in the expansion stroke, and the ratio of partial oxidation of fuel decreases as the retard in post injection timing (θ_{post}), because the fuel mass in 400-900 K increases.

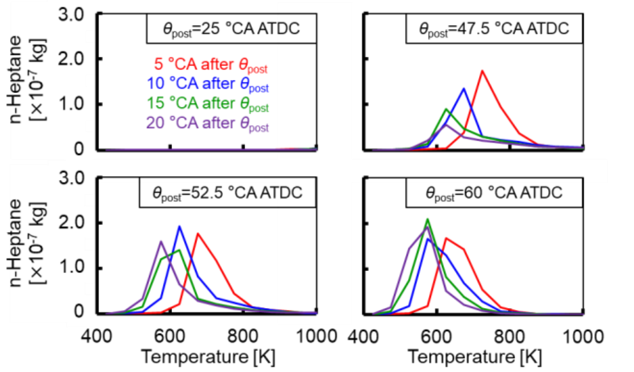

Fig.1 Mass distribution of fuel existing in each temperature range

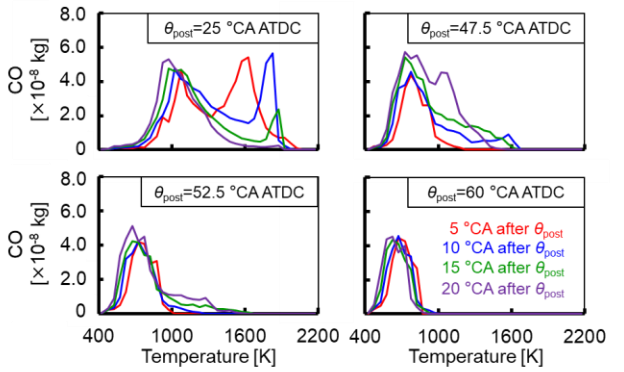

Fig.2 Mass distribution of CO existing in each temperature range