(2-08) Effects of Swirl Turbulent Flow Field and Inhomogeneous Concentration Field on Combustion of Fuel-Air Mixture in a Constant Volume Vessel

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Abstract

Direct injection spark ignition (DISI) engines, which are able to achieve better thermal efficiency and higher output power simultaneously, have been developed. The DISI engine is operated unthrottled in an ultra-lean condition by distinctively stratifying the charge and by preparing a fuel-rich mixture around the spark plug. However, the effects of mixture inhomogeneity and simultaneous details of the flow field at the time of the spark on the combustion have not yet been clarified.

In this research, the fundamental flame propagation and combustion characteristics of a stratified fuel-air mixture, similar to mixtures used in direct injection spark ignition (DISI) engines, were investigated. A swirling fuel-air mixture was produced in a disc-type combustion chamber by accelerating the mixture tangentially. Propane was injected into the center of the combustion chamber at an injection pressure of 0.3 MPa. The strong swirl combined with the gas injection created an axisymmetric fuel-rich mixture near the spark location and a lean mixture near the wall. The swirl, gas injection and spark timing changed the flow field, turbulence intensity, and inhomogeneity of the fuel-air mixture. The mixture was ignited at the center of the vessel. The fuel concentration distribution and the swirling flow field at the time of the spark were measured using LIF and LDV, respectively. Experimental tests were performed for various fuel distributions and different swirl flow at the ignition timing. Flame propagation and the combustion characteristics of an inhomogeneous fuel-air mixture are discussed using instantaneous flame images obtained from a high-speed video and the pressure history.

Three main conclusions are drawn from this work. First, strongly swirling flow with gas injection at the center generates successive inhomogeneous fuel concentrations. By changing the period between gas injection and ignition, various gradients of inhomogeneous mixture concentrations and equivalence ratios can be obtained in the vicinity of the spark location. A stratified charge with an appropriate mixture near the spark location allows the flame to propagate and combustion to occur, even when an ultra-lean fuel-air mixture is used. Second, the stratified stoichiometric mixture in the vicinity of the spark location propagates more rapidly than in the homogeneous case with the same overall equivalence ratio, resulting in a higher rate of pressure increase and a shorter ignition delay time. Third, when stratified mixtures with the same pattern of fuel concentration but different turbulence intensities are considered, the main combustion period decreases with turbulence intensity at an overall equivalence ratio of 0.30, since the burning velocity also increases.