CHARACTERIZATION OF BACKFIRE AND POSTFIRE IN A HYDROGEN FUELLED SPARK IGNITION ENGINE

Abstract

Backfire is an abnormal combustion phenomenon occurring during the suction stroke of a manifold hydrogen injection-based spark ignition engine due to mainly external ignition sources including residual gas temperature, hot spots, partially burned lubricating oil, hot engine components, misfire and postfire. Backfire results in an audible high-pitched sound with speed drop, decrease in mean effective pressure, stalling the engine operation, and damaging of engine components. This present work is aimed at investigation of backfire occurrence and its propagation in an automotive spark ignition engine fuelled with hydrogen.

A gasoline automotive four-stroke spark ignition engine (15 kW) was modified to a hydrogen engine by incorporating mainly a timed manifold hydrogen injection system. A transparent intake manifold system was developed and attached to the engine to visualize the propagation of backfire. A high-speed camera was used to capture the real-time backfire images during the engine running. The engine was run with varied speeds and torque. The experimental results indicate that backfire occurrence probability increases with the increase in torque at constant speed, the increase in speed (at constant torque), high equivalence ratio and the increase in torque with the decrease in speed (at constant brake power).

It is practically observed that the residual (exhaust) gas temperature plays a critical role in acting as one of the external ignition sources to initiate backfire when a fresh air-hydrogen mixture interacts with the residual gas inside the cylinder during the engine's suction stroke. The critical exhaust gas temperatures (EGT) identified for the backfire initiation are in the range of 765 °C to

955 °C for speeds from 2000 rpm to 4900 rpm. A dimensionless backfire occurrence number (BON) was developed using the experimental results to predict backfire occurrence, where BON greater than or equal to zero denotes backfire occurrence. Backfire occurrence is strongly linked to other abnormal combustion phenomena called misfire and postfire.

Misfire occurs during engine cranking due to too low spark duration, low in-cylinder temperature, fouled spark plug and too much advanced spark timing and the accumulation of the unburnt hydrogen during misfire burns in subsequent cycle leading to Postfire occurrence during exhaust stroke resulting in backfire. The Indicated Mean Effective Pressure based coefficient of variation during backfire, postfire and misfire was above 5% resulting in combustion instability of the engine. The CFD results indicate about 13% unburnt hydrogen as a scavenging loss leaves the exhaust manifold during the misfire cycle and the charge temperature is in the range of 1300 to 1500 K near the intake valve during backfire propagation. The pressure rise in the exhaust manifold during postfire was observed beyond 2 bar. The backfire is characterized using backfire ignition delay, expansion, convergence and termination. The average backfire propagation velocity calculated using high-speed camera images is found to be 179.3 m/s corresponding to a Mach number of 0.52 at an equivalence ratio of 0.5 and hence, backfire under varied engine speed can be characterized as deflagration (subsonic). Simultaneous acquiring of the intake manifold and in-cylinder pressure was found a reliable approach for estimating backfire propagation velocity.

The notable findings that emerged from the study are that backfire is strongly linked with misfire and postfire occurrence. The probability of backfire could be reduced by retardation of hydrogen injection timing, optimization of spark timing, high reactant velocity, and elimination of misfire and postfire.