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Investigating the SI-HCCI transition

multi-cycle multi-cylinder transient simulations

THE CHALLENGE

Simulation of the SI-HCCI transition, to allow an investigation into the transient process.

THE SOLUTION

Using srm suite, coupled with commercial software, the transition was simulated and emissions were investigated.

THE RESULTS

•SI-HCCI transition was simulated with srm suite.

•The short computation times, achieved by srm suite, enabled a multi-cycle multi-cylinder simulation.

•A mixture of flame propagation and auto-ignition occurred in the first HCCI cycles.

•Emissions during the transition were investigated with srm suite

The Homogeneous Charge Compression Ignition (HCCI) operating mode offers improvements in fuel efficiency and emissions compared with conventional Spark Ignition (SI) mode.

HCCI suffers from a limited operating range, due to misfire at low loads and cold start, and high rates of pressure rise at high loads. This problem may be overcome by using a dual-mode engine that operates in HCCI at low, medium, and cruising loads and speeds, and in SI mode at start-up, idle and high loads and speeds.

The transitions between SI and HCCI must be fast and smooth, without harming drivability or vastly increasing emissions or fuel consumption. The different temperatures, pressures and compositions in SI and HCCI modes make the transition between modes complex. To transit between modes, changes in fuel mass, throttle opening and valve timing must be made.

The srm suite is coupled with commercial software, used for modelling engine breathing during the open valve portion of the engine cycle, enabling multi-cycle simulations. The model is initially calibrated in both modes, using steady state data from SI and HCCI operation. The mode change is achieved by switching the cam profiles and phasing, resulting in a Negative Valve Overlap (NVO), opening the throttle, advancing the spark timing and reducing the fuel mass, as well as utilising a pilot injection.

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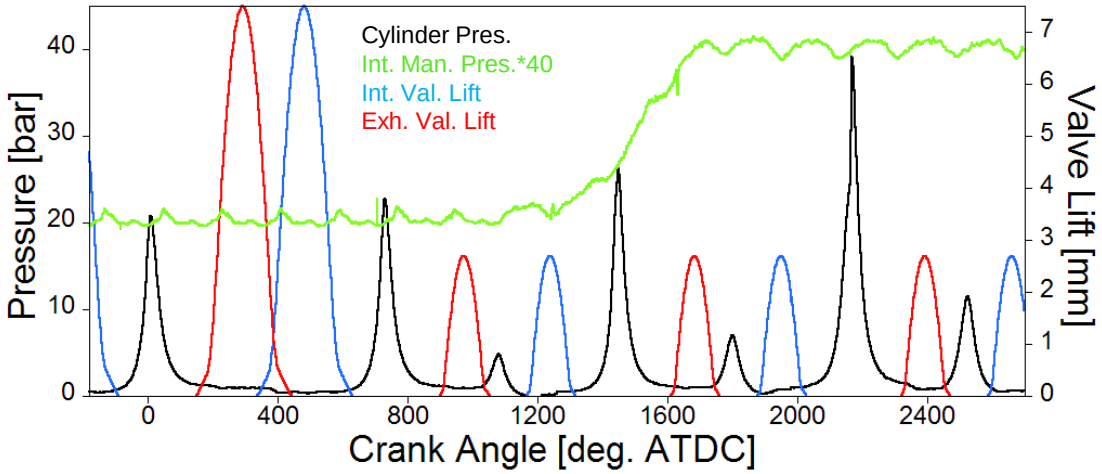
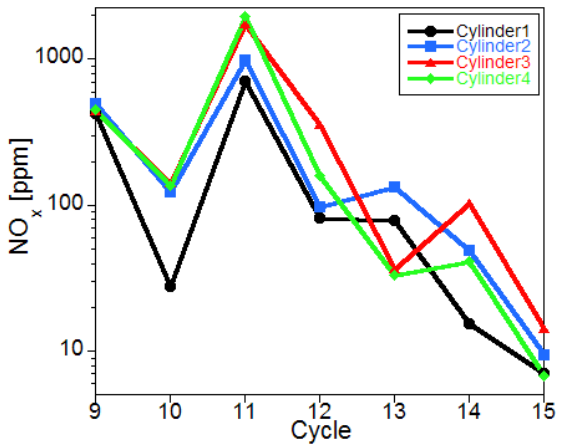


Above: In-cylinder pressure, inlet manifold pressure and valve lifts during a transition from SI to HCCI.



Above: Simulated NO_x emissions during the transition. The final SI cycle is number 10.

APPLICATION AREAS

- HCCI/PCCI
- Transient simulation
- Conventional spark ignition
- Direct injection spark ignition
- EGR
- Emissions reduction

PRODUCTS USED

- srm suite

THE RESULTS

The SRM was used to simulate the complex transition from SI to HCCI. A good agreement between the model and experimental results was obtained.

•Spark assisted HCCI

The spark was found to be crucial to ignition during the first HCCI cycles. The first HCCI cycle was found to be a combination of flame propagation and auto-ignition. Without the spark, the simulation resulted in a misfire. The ability of the model to simulate auto-ignition, at the same time as flame propagation, with a detailed chemical mechanism, resulted in a good fit to the experimental data.

•Trends follow cylinder firing order

Trends in the in-cylinder simulation results were found to follow the cylinder firing order. The simulation made it possible to investigate values that would be extremely difficult to measure.

•Emissions

The early intake valve closing in the first HCCI cycle, compared to steady state SI, caused an increase in the temperatures reached, resulting in high NO_x emissions.

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