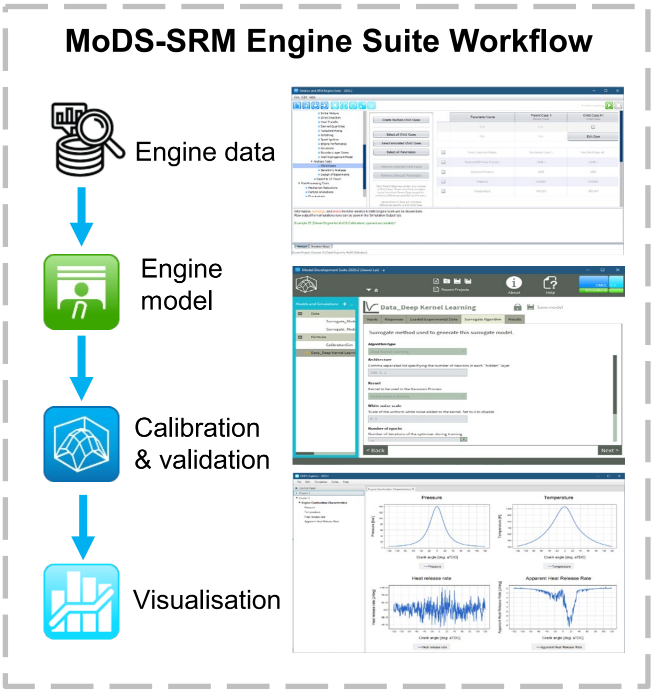
User Story

Lean Burn Spark Ignition Engine Simulations



OVERVIEW

Lean burn technology is one of the leading approaches in improving the fuel economy by running the engine at lean/low (fuel-to-air) equivalence ratio, ϕ. At the same power output, lean burn engines also produce less hydrocarbons (HCs) due of their enhanced combustion.

This use-case studies the effects of lean burn on the engine power output and gas phase emissions such as CO, HCs and NO_x from a gasoline fuelled spark ignition (SI) engine using the SRM Engine Suite; a detailed physico-chemical stochastic reactor model. The engine variables such as the EGR and spark timing are calibrated using MoDS (Model Development Suite) software that applies advanced statistical algorithms to achieve the target BMEP level while running the engine with lean fuel mixture.

CASE DESCRIPTION

A physico-chemical model is set up in the SRM Engine Suite to simulate a gasoline SI engine with operating equivalence ratios ranging from 0.45 to 1.

Subsequently, the MoDS-SRM workflow is applied to optimise the engine variables such as the external EGR mass fraction and spark timing to achieve the target BMEP while running at lean fuel conditions. In this example, the target BMEP is defined as that obtained with a stoichiometric equivalence ratio.

The simulation results before and after the calibration of engine variables are compared to study the effects of lean burn technology.

THE CHALLENGE

To study the effects of lean burn combustion on the power output and gas phase emissions in a gasoline fuelled spark ignition engine

THE SOLUTION

- Use CMCL's SRM Engine Suite software to model the spark ignition engine, specifying a lean fuel mixture
- Use CMCL's MoDS to calibrate the engine variables at lean burn conditions to achieve the target engine power output

THE RESULTS

- Quick and detailed simulations of a gasoline fuelled spark ignition engine running on stoichiometric or lean fuel mixtures
- The engine variables at lean burn conditions calibrated to achieve target engine power output where possible
- Simulation results and predicted trends for power and gas phase emissions agree well with measurements results published by Ye and Li (2010) [1]

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CMCL Innovations

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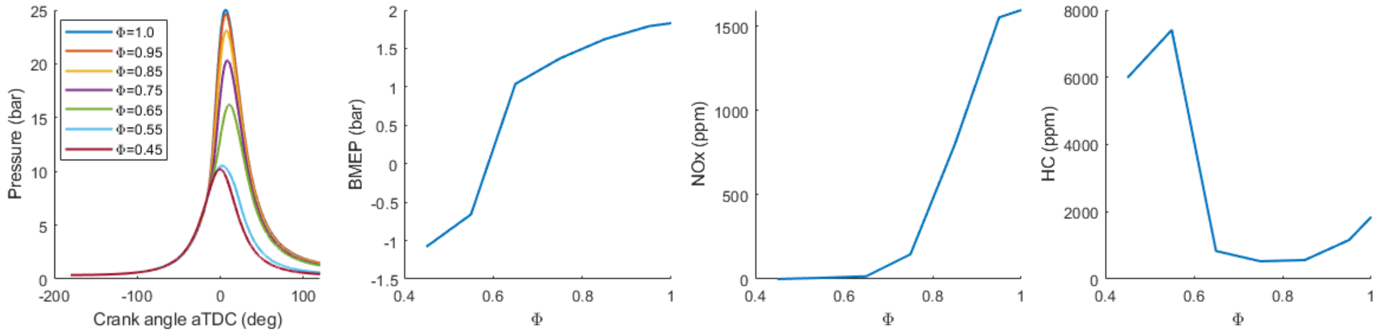
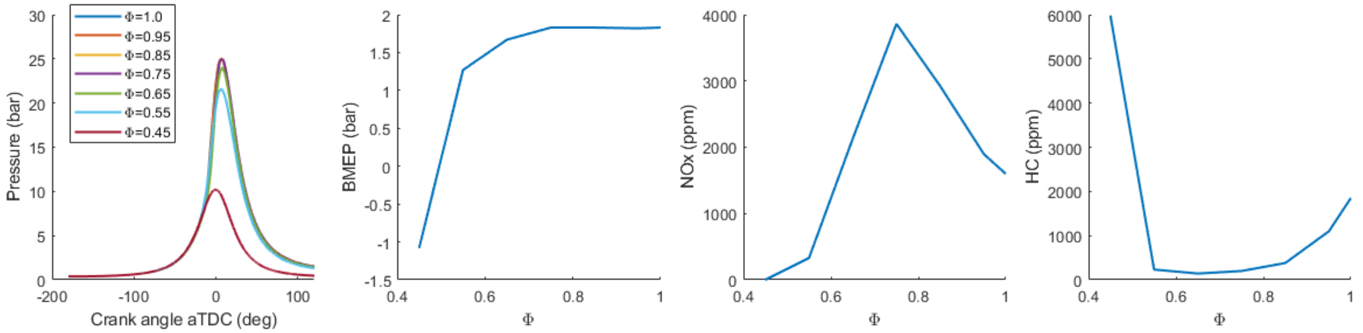


In-cylinder pressure profile and engine output before calibration



In-cylinder pressure profile and engine output after calibration

RESULTS

At the same engine set up, running the engine with leaner conditions led to a reduction in BMEP, in-cylinder maximum pressure and temperature. Correspondingly, reduction in temperature-sensitive NO_x emissions.

After EGR and spark timing calibration, the target BMEP is achieved while running leaner fuel mixture with equivalence ratios ranging from 0.75 to 0.95. By maintaining the same power output at lean conditions, it is observed that the amount of HC is reduced as the combustion efficiency improves at leaner conditions. However, one of the trade-offs of running at leaner conditions is the increase in NO_x emissions that is caused by the increase in in-cylinder temperature. Target BMEP cannot be achieved below equivalence ratio 0.75 indicating the fuel mixture is too lean under the given operating conditions.

The simulation results and predicted trends agree well with measurements results published by Ye and Li (2010) [1].

APPLICATION AREAS

- Spark ignition lean burn engines

PRODUCTS USED

- SRM Engine Suite
- MoDS

[1] Ye, Z-M., & Li, Z-J. (2010). Impact of lean-burn control technology on the fuel economy and NOx emission of gasoline engines. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 224(8), 1041-1058. https://doi.org/10.1243/09544070JAUTO1409