FINAL REPORT

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Schnelle Vorhersage von klopfenden Verbrennungen in Ottomotoren

Fast Knocking Prediction for Gasoline Engines

Schnelles und robustes Simulationswerkzeug zur Vorhersage von klopfenden Verbrennungen für Ottomotoren

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Fast and Robust Simulation Tool for Knocking Prediction of Gasoline Engines

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Project no. 1370

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Abstract:

To derive a novel knock control approach from a state-of-the-art 0D knock model, first various thermodynamic investigations were performed to gain further insights into the knock phenomenon. Besides the evaluation of temperature and mixture inhomogeneities using 3D-CFD simulation results and their relation to the occurrence of knock, the application of the detonation diagram to 0D simulations was investigated, with the aim of evaluating auto-ignitions and identifying knock-relevant conditions. No direct correlation between inhomogeneities and knocking conditions was observed and limited suitability of the detonation diagram, regarding a precise prediction of knock-relevant conditions, was identified. Major progress was achieved by including cycle-to-cycle variations in the investigation. Based on the distribution of the auto-ignition onsets of simulated single working cycles, the knock frequency could be predicted with high accuracy.

Concerning a knock control application, the knock frequency calculation was reduced to increase performance and enable a simulative investigation of the new control concept in a 0D simulation environment. Comparison to conventional knock control revealed a fuel-saving and CO_2 emission reduction potential of up to 1 %. Moreover, the simulation model provides a comprehensive bases for further development of the controller and application to an engine.

Supporting 3D-CFD studies have been carried out to generate probability density functions for the temperature distribution and mixture homogeneity as well as a database with respect to the evaluation of auto-ignition locations (hotspot sizes). To allow for a high number of simulated working cycles (important for statistical evaluation), an alternative combustion model was applied and validated for Large-Eddy Simulation. With the Thickened Flame Model, simulations runtimes could be reduced by about a factor of 16 while achieving a correct description of laminar flame speeds. Statistical evaluation of an operating point with 47 of 100 working cycle above the knock limit has revealed a connection between the local conditions at the spark plug and center of combustion, which itself is linked to the knock tendency. In another supporting task, 3D-CFD combustion simulations have been utilized to verify the resonance theory for gasoline application, which has been considered for the novel knock controller.

The novel knock controller approach developed in the 0D simulation was converted from a pure functional description into a real-time RCP-ECU model in several steps and was functionally tested and validated. The model complexity was simplified and parameterized for the validation of the potentials shown in the simulation for the target engine. The validation then took place on the target engine in thermodynamic testing.

The newly developed knock control concept achieved an efficiency advantage of up to 0.54 % compared to conventional knock control and reduced the exhaust gas temperature by up to 20 K. The results are achieved without additional measurement devices, so without impact on overall engine complexity.

The objective of the research project was achieved.

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Related reports:	R603 (2022)

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