iGF Industrielle Gemeinschaftsforschung

Schlussbericht

zu IGF-Vorhaben Nr. 205 EN/3

Thema

Tiefgehende Erforschung der RCCI (Reactivity Controlled Compression Ignition) in den Bereichen der Reaktionskinteik, Einspritzung und Verbrennung durch Entwicklung von Modellen und deren Validierung an Prüfständen

Berichtszeitraum

01.08.2017 - 30.06.2020

Forschungsvereinigung

Forschungskuratorium Maschinenbau e.V. - FKM

Forschungsstelle(n)

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2. Netherlands Organization for Applied Scientific Research (TNO)
3. Institut für Technische Verbrennung, RWTH Aachen University
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Ort, Datum

Name und Unterschrift aller Projektleiter der Forschungsstelle(n)

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RCCI in Heavy Duty Engines

Project no. 1284

RCCI-Combustion System in HD Applications Achieving Lowest Fuel Consumption and Emissions

Final report

Abstract:

The simultaneous reduction of fuel consumption and pollutant emissions, namely NO_x and soot, is the predominant goal in modern engine development. In this context, low-temperature combustion (LTC) concepts are believed to be the most promising approaches to resolve the above-mentioned goals. Application of dual fuels, Natural Gas (NG)-diesel, in Reactivity Controlled Compression Ignition (RCCI) mode is a promising high efficient combustion concept that combines Euro-VI engine-out NO_x and PM emissions with 25 % CO_2 reduction compared to mono-fuel diesel and natural gas reference. Different natural gas fuelled concepts exist. Stoichiometric natural gas spark-ignition (SI) combustion is widely accepted because of its maturity and simple after-treatment. Driven by fuel costs and tailpipe CO_2 emission targets, also conventional dual fuel concepts are introduced, in which natural gas is blended in standard diesel combustion. Depending on the injection timing of the diesel pilot injection, the process is either called liquid spark or RCCI. Conventional dual fuel concepts produce significant NO_x emissions as an outcome of the diesel combustion. In RCCI, the well-homogenized mixture of the diesel pilot and the natural gas results in much cooler volume ignition, controlled by injection timing and diesel injection amount.

So far, Single Point Injection and Port Fuel Injection of natural gas have been applied in natural gas-diesel RCCI. In this project, the novel Direct-Injection (DI) Natural Gas technology was applied to reduce in-cylinder CH_4 emission and to maximize thermal efficiency. On a heavy duty single-cylinder engine, the NO_x and soot engine out emissions below the EURO VI target has been achieved. Efficiency in all investigated load points is on a high level, even in the challenging low load area. Yet, the CH_4-emissions are about 50 % over the target value. This CH_4-slip was expected to result from the quenching area due to stopped flame propagation. For the understanding of mixture formation, the 3D-CFD combustion simulations were performed at 10 bar IMEP load point and results were compared with the results of the experiment. To enable the CFD modeling coupled with detailed combustion chemistry, the reaction kinetics of the fuels of interest was investigated both experimentally and numerically. Detailed and reduced kinetic mechanisms were developed and applied in the CFD calculation. The simulated pressure trace shows good agreement with experimental data and lies well in between 100-cycle data from the experiment. Further, at the single-cylinder engine, a new RCCI-Piston shape was introduced with raised compression ratio and at higher compression ratio no knocking was observed. The new RCCI-Piston shape establishes no quenching and raised in-cylinder temperatures to improve CH_4 combustion. In addition to this, for understanding the propagation and the mixture formation of two different reactive fuels in a steady-state condition, the optical fuel injection investigations were conducted in a high-pressure chamber. The optical study shows that RCCI combustion is very sensitive to the chamber temperature and a small change in temperature change can lead to a significant reduction of the ignition delay.

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Related reports:	R596 (2020)

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