JSAE 20199014
SAE 2019-01-2164

Evaluation of Water Injection Strategies for NOx Reduction and Charge Cooling in SI Engines

Malte Kauf, Maike Gern

Technische Universität Berlin

Stefan Seefeldt

LaVision GmbH

ABSTRACT

Water injection in spark-ignition engines is one key technology for increasing power, improving fuel efficiency by mitigating knock and meeting future emission standards and is extensively researched today. Finding a suitable injection strategy is necessary to commercially exploit the potential of water injection. In order to evaluate water injection strategies, a better understanding of the mixture formation with water injection is required. Indirect port and direct water injection strategies were compared by highly time resolved in-cylinder water concentration and temperature measurements using an optical spark plug probe. The ignition conditions, mixture formation and performance were assessed in a single cylinder research engine equipped with water injection technology. Variations of engine speed, water/fuel ratio and water injection timing were performed and the effects on exhaust gas temperature and engine-out emissions analyzed in detail. At different operating points, a comparison of direct and indirect water injection concepts was made with regard to mixture formation. The spark plug probe enabled a local assessment of the ignition conditions near the spark. Furthermore, a water efficiency number could be obtained by measuring the in-cylinder temperature directly. In conclusion, a better understanding of water injection is reached and optimum water injection strategies in terms of NOx reduction and charge cooling are derived.

INTRODUCTION

In the future, increased efforts for researching and developing new measures to improve fuel efficiency and emissions for spark-ignition (SI) engines are necessary to comply with new regulations and further improve the engine performance. While at maximum power mixture enrichment for exhaust gas cooling must be avoided, SI engines' efficiencies at high load are limited by knock. Water injection was identified as one promising technology for future SI engine generations to overcome these challenges [1, 2]. The water's high heat of vaporization cools the intake charge and thereby knock mitigation is achieved. The exhaust gas temperature is also reduced by lower charge temperatures and a higher total heat capacity of the charge because of the addition of water. The maximum engine load can be increased by intake air cooling and at maximum power, temperatures of the exhaust turbine and three-way catalytic converter reduced.

Presently, different water injection concepts are researched for SI engines. They include indirect water injection (IWI) in the intake manifold or in the intake ports, direct water injection (DWI) in the cylinder and mixture injections of fuel and water [3]. Water is injected indirectly with low pressures with the target of maximum evaporation rates and minimum intake port wall wetting. For direct water injection, high injection pressures are used. The challenge is finding the optimum injection timing for minimizing wall impingement and vaporizing great amounts of water in a short period of time.

The objective of this experimental study is the assessment of mixture formation of direct and indirect water injection concepts for developing optimum water injection strategies.

EXPERIMENTAL SETUP

WATER INJECTION ENGINE

Single Cylinder Research Engine Specification

Water injection engine experiments were conducted at the Chair of Powertrain Technologies at Technische