Validation and Initial Application of a Novel Spray Combustion Chamber Representative of Large Two-Stroke Diesel Engine Combustion Systems

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Abstract

The application of state-of-the-art Computational Fluid Dynamics (CFD) tools to the simulation of combustion in large marine diesel engines continues revealing the need for further development of the models used for the description of the spray processes in particular. Such development is, however, suffering from the lack of relevant validation data, considering the physical dimensions and operational parameters involved, including flow characteristics of the process gas and fuel quality. Therefore, a novel experimental setup has been realized, allowing the study of spray and combustion processes at conditions typical of large two-stroke marine diesel engines. Its core element is a disk-shaped constant volume spray combustion chamber of diameter 500 mm with peripheral injection into a swirling flow and equipped with comprehensive options for granting optical access. In order to achieve realistic thermo- and fluid dynamic conditions at start of injection, the chamber is fed with pressurized and heated process gas provided by a pressure vessel/heat regenerating system, via inclined intake channels. The chamber design includes various injector arrangement options and the injection system is prepared for running on typical marine fuels. Following the completion of the setup, the first focus was its validation against the requirements and design specifications in terms of the pressure and temperature ranges envisioned as well as regarding the swirl pattern at start of injection. The initial application involved the visualization of the spray evolution of either single or multiple sprays from the injector tip by means of shadow imaging techniques, thereby varying temperature and pressure at start of injection and considering both non-reactive and reactive cases. These investigations have fully confirmed the potential of the setup for studying spray and combustion processes at conditions relevant to large marine diesel engine combustion and have provided valuable insight already into the spray characteristics at such conditions.

Introduction

Despite the fact that promising results have been reported for the application of currently available CFD tools for the simulation of combustion in marine diesel engines ([1], [2], [3]), limitations remain to apply in terms of their predictive quality, in particular when using them for the simulation of large two-stroke (marine) diesel engines (e.g. [4]). These can – at least partly – be traced back to uncertainties related to the description of the spray processes at conditions relevant to those engines, as the existing spray models have been developed for considerably smaller engines running at higher speeds and using fuel of much higher quality. As a consequence, their validation was commonly also performed against data from small spray combustion chambers operating on high-grade fuels and at conditions only partly reflecting the situation in large marine diesel engines. In fact, relevant validation data for those applications, considering their physical dimensions and operational parameters, were not available so far.

Therefore, in the context of the HERCULES research program [5] funded under EC's Framework Programmes [6], a novel experimental setup has been realized [7], allowing the study of spray and combustion processes at conditions typical of large two-stroke marine diesel engines, in particular involving the following features:

- A combustion chamber of sufficiently large dimensions with very pronounced swirl pattern of the process gas.
- Injection from the periphery of the combustion chamber, thereby simulating a two- or three-injector configuration, where the individual injectors may be equipped with multiple orifices of different orientation and partly also varying diameter, the size of the individual orifices being in the one millimeter range.
- Pressure and temperature levels at start of injection exceeding 120 bar and 900 K.

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