Reference Data Generation of Spray Characteristics in Relation to Large 2-Stroke Marine Diesel Engines Using a Novel Spray Combustion Chamber Concept

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Abstract

The availability of appropriate reference data for combustion in large 2-stroke marine diesel engines is a prerequisite for the further development of Computational Fluid Dynamics tools. In order to enable the acquisition of such data at relevant physical dimensions (bore) and operational parameters (pressure, temperature), including flow characteristics (swirl) and the low fuel qualities involved, a novel experimental test facility has been realized. The core element is a disk-shaped constant volume spray combustion chamber of diameter 500 mm with peripheral injection into a swirl flow. Thermo- and fluid dynamic conditions at start of injection similar to those in real engines are achieved by feeding the chamber via inclined intake channels with pressurized and heated process gas provided by a pressure vessel/heat regenerating system. The chamber design includes comprehensive possibilities for optical access as well as various injector arrangement options and the injection system is prepared for running on typical marine fuels. Reference data for the fuel spray propagation has been acquired by means of shadow-imaging measurements: This involved the variation of key parameters such as gas pressure and temperature (up to 9 MPa, 930 K), number of injector orifices and the spray orientation (10 deg counter- to 40 deg co-swirl) of a single-hole nozzle relative to the gas flow. The spray propagation data collected at conditions representative of the operation of large 2-stroke marine diesel engines contributes to a better understanding of the underlying phenomena and enables the validation of simulation tools at such conditions.

Introduction

Limitations continue to apply for the utilization of currently available Computational Fluid Dynamics (CFD) tools for the combustion system development and optimization of large 2-stroke marine diesel engines (e.g. [1]), despite the fact that promising results have been reported [2–4] in recent years. The mere dimensions (bore/stroke up to 960/3150 mm), time scales (down to 61 rpm) and specifics (e.g. injector size, nozzle hole sizes up to 1 mm and above) already constitute a major challenge for the application of the models developed for considerably smaller engines running at higher speeds and using fuel of much higher quality than customary fuels used in marine diesel engines.

Various investigations using optically accessible engines or motored devices [5, 6] are reported to study injection processes such as mixture formation, ignition and combustion. Additionally, in order to realize an improved optical accessibility and with regard to simpler boundary conditions, other test rig concepts have been defined. Some combustor vessels are designed as open flow-through constant pressure systems [7, 8], which yield a high repetition rate but cannot reproduce the pressure rise following the ignition, flame establishment and the heat release. Therefore, other optically accessible closed chamber concepts such as rapid compression machines [9, 10] or high-temperature pressure constant volume vessels [11–13] have been employed for a range of investigations [14, 15].

Note that the spray models used so far have commonly been validated against data from those small spray combustion chambers operating on high-grade fuels at conditions representative of smaller (automotive, truck, train) engines. Therefore, there have been various attempts to develop further experimental setups allowing the investigation of spray processes reflecting the situation in large marine diesel engines [16–20]; however, none of them has proven capable so far to fulfil the complete set of requirements for being considered adequately representative of the combustion system of large 2-stroke engines. Hence, relevant validation data for those applications, in view of their physical dimensions and operational parameters, were not available so far.

Therefore, in the context of the HERCULES research program [21] funded under EC's Framework Programmes [22], in order to study combustion processes at conditions typical of large 2-stroke marine diesel engines, a novel test facility [23] involving the following features has been realized:

- Combustion chamber of sufficiently large dimensions, pronounced swirl flow pattern of the gas phase

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