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Development of a reference experiment for large diesel engine combustion system optimization

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Abstract: The further development and application of computational fluid dynamics (CFD) simulation for combustion system optimization of large Marine Diesel engines suffers from lacking information on the actual characteristics of spray, combustion and emissions formation processes at conditions relevant for those engines. In particular, the models commonly available for those processes have been developed for considerably smaller engines running at higher speed and on substantially higher fuel qualities. Such models have typically been validated against data from reference experiments in small spray combustion chambers operated at conditions, which are partly far from the ones applying in Marine Diesel engines during fuel injection and combustion. Moreover, such experiments are hardly capable of providing sufficiently detailed data for typical Marine fuel qualities.

In order to overcome this deficiency, a new spray combustion chamber was to be developed in the context of the HERCULES research program. This novel test facility should allow the optical investigation of flow, spray, combustion and emissions formation at conditions typical of the combustion system in large two-stroke diesel engines. In particular, pressure, temperature and swirl should be close to the levels experienced in those engines and the arrangement of the injectors should allow the investigation of interactions of sprays originating from different injectors. Additionally, it should be able to cope with a wide range of fuel qualities.

Based on this requirement specification, a basic concept has been developed, using a disk-shaped constant volume combustion chamber, whose diameter corresponds to the bore of a typical large Marine Diesel engine. It is equipped with a series of windows in the various chamber walls, specifically designed for allowing adjusting virtually every desired observation field. In order to achieve realistic thermo- and fluid dynamic conditions at start of injection, the chamber is fed with pressurized and heated fresh gas, via tilted intake channels. The gas, which can be either nitrogen or air, is provided by an accumulator system combined with a regenerator containing a large number of electrically heated small flow cells. The chamber design includes various injector arrangement options in order to allow modelling all typical two-stroke engine configurations and investigating the associated interaction effects. The injection system is tailored to the operational requirements of the facility and prepared for running on light as well as heavy fuels.

The entire development involved careful considerations of all aspects of the design and operation, including the requirements associated with the experimental methods to be applied. Comprehensive simulations have been performed for the proper layout and dimensioning of the key components, both in terms of the thermo- and fluid dynamic behaviour and the mechanical design and safety.

The resulting experimental setup allows for the first time the investigation of in-cylinder processes of large Marine Diesel engines at conditions relevant for those applications and it will be extensively used over the following years not only for generating validation data, but also for actual combustion system optimization purposes. This unique capability is believed to make it a reference setup for this kind of application.