Evaluation of PDA Applicability in Regard to Heavy Fuel Oil Spray Investigations

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Abstract The better understanding of the key in-cylinder processes must be seen as a prerequisite for the further development and optimization of large marine Diesel engine combustion systems. The existing extensive set of reference data with respect to the macroscopic behaviour of fuel sprays at relevant conditions including various fuel qualities, which have been acquired on an experimental facility specifically devised for this purpose, shall now be extended towards microscopic spray characterization. The particular challenge in this context is related to the opaque nature of the heavy fuel oil (HFO) widely used on those engines, which is associated with limitations with respect to the applicability of optical measurement techniques such as PDA. Therefore, a thorough assessment of the practical implications of applying PDA on HFO sprays has been conducted, starting from the theoretical evaluation of the optical properties. The most suitable configuration for the actual experiments has been identified on the basis of extensive pre-studies involving dedicated test setups for validating the PDA droplet size measurements. In this context, in-depth analyses have been made in order to determine the refractive index required for the proper investigation of specific configurations. Using a scattering angle of 90° in combination with perpendicular polarized light, first measurements have been performed in a HFO spray and the results compared against corresponding data obtained for light fuel oil at a scattering angle of 70° and parallel polarization. The fuel quality has a clear impact both on the velocity and size distribution. In particular, the average diameter of the HFO droplets is bigger and the distribution covers a larger range, which is in line with the expectations in view of the different composition and physical properties. Hence, the applicability of PDA for HFO spray investigations could be confirmed and a suitable setup identified for delivering high quality results.

1. Introduction

In order to improve large marine Diesel engines to meet upcoming emission requirements (Annex VI of MARPOL 73/78, 2009), the combustion system optimization is one important aspect. A unique optically accessible experimental facility – the so-called Spray Combustion Chamber (SCC) – has been developed, which enables the investigation of injection and combustion processes at relevant physical dimensions (bore) and operational parameters (pressure, temperature), including typical flow characteristics and injection of a wide range of marine Diesel fuel qualities. The use of non-intrusive optical measurement techniques contributes to a better understanding of the fuel injection and the ensuing spray processes as well as mixture formation, ignition behaviour and combustion (see Herrmann et al., 2007). Moreover, it allows the acquisition of reference data for the validation of simulation models (e.g. Schulz et al., 2013).

Phase Doppler Anemometry (PDA) is a well-established experimental technique for droplet velocity and size investigations. In particular, fuel injection and atomization processes of gasoline or Diesel sprays can be characterized with regard to velocity profiles and droplet sizes, see e.g. Wigley et al., 1999 and Schneider, 2003. Due to the optical characteristics of these high quality fuels the light scattered from the droplets is recorded at a specific scattering angle where a single scattering mode dominates. Many investigations are therefore performed with parallel polarized light under the Brewster angle configuration, where first order refraction is the dominant scattering mode. Using this configuration, the refracted light shows a quite good linear dependency of the particle size upon the measured phase difference (Schneider, 2003). At the SCC, first PDA measurements in a light fuel oil (LFO) spray were performed (Schulz et al., 2013)