Optical Diagnostics of Fuel Injection and Ignition in a Marine Two-stroke Diesel Engine

Author, co-author (Do NOT enter this information. It will be pulled from participant tab in MyTechZone)

Affiliation (Do NOT enter this information. It will be pulled from participant tab in MyTechZone)

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ABSTRACT

A combination of optical and laser based methods have been employed for simultaneously studying fuel jet penetration and ignition behaviour of fuel jets inside the cylinder of a large marine two-stroke diesel engine during operation. Tests were performed on a four-cylinder Diesel engine with a bore diameter of 0.5 meter. Optical access was obtained through a custom designed engine cover. A double pulsed laser was employed for global illumination of the liquid fuel jet. For detection a dual camera set-up was employed, which allowed both simultaneous fuel jet and flame emission imaging, or dual frame fuel jet imaging for velocity measurements. From the data recorded the liquid penetration, jet cone angle, jet penetration velocity, ignition location, ignition time and flame lift-off could be extracted.

Data was recorded for two different charge densities and temperatures, for two different atomizer designs, and for two different fuels. The fuel jet was observed to ignite at a position around 1/4 of the length downstream. The penetration length, ignition time and lift-off length were found to decrease with increased cylinder pressure and temperature. A conventional atomizer was observed to produce a slightly narrower and longer fuel jet with increased lift-off, compared to a sliding valve atomizer. For heavy fuel oil an increase of width towards the end of the jet and a more wrinkled appearance was observed, compared to marine gas oil. Fuel jet front velocities were found to peak just above 100 m/s after about 0.3 CAD after start of injection.

INTRODUCTION

Two-stroke Diesel engines dominate as prime movers for freight ships due to their unrivalled efficiency and reliability. The fuel injection systems of such engines differ from those of smaller engines in several respects. Fuel is injected from two or three atomizers, located at the periphery, with holes arranged in a non-symmetric fashion. The orifice diameters are typically in the millimetre range and injection durations can be tens of milliseconds. Data on fuel spray and auto-ignition for this size of Diesel injectors is a prerequisite for development and optimization of injection systems and for validation of computational fluid dynamic (CFD) tools. In contrast to the situation for smaller engines reference data for conditions representative of large marine engines, in particular from actual engine experiments, is very scarce. The aim of the work presented here was to acquire data on fuel jet and ignition development under realistic running conditions in a full size marine two-stroke engine, as a function of charge condition, atomizer design and fuel type.

Optical diagnostics has started to make progress in medium- and low-speed marine engines only over the last five years. Examples of techniques employed include high-speed photography [1,2,3,4], IR imaging [5], laser Mie scattering for fuel jet imaging [5,6,7,8,9,10], and even particle image velocimetry (PIV) for velocity measurements [11]. Detailed datasets on fuel jet, spray and ignition development have also been acquired in constant volume combustion chambers [12,13,14,15,16,17,18,19,20] and in rapid compression machines [21,22] using optical techniques, under conditions relevant for large marine Diesel engines.

Implementation of optical diagnostics in a large marine engine is challenged by cylinder size, vibrations, thermal loads, soot loads, as well as safety requirements. Here, an engine cover featuring a number of optical ports was used to obtain optical access to one of the four cylinders of a marine Diesel engine. The engine features a bore diameter of 0.5 m and a stroke of 2.2 m. The engine cover has 24 optical ports from the side and the top, and through positioning of optical elements deep inside the optical ports efficient wide-angle illumination and detection can be achieved [5,10]. All optical hardware was mounted directly onto the engine in order to reduce vibrational and thermal drifts in alignment. Combined laser Mie scattering and flame emission imaging was employed to acquire detailed information on the liquid penetration, fuel cone angle, jet penetration velocity, ignition location, ignition time and flame lift-off. This imaging method was used to investigate effects of changing charge density and temperature, atomizer design,