Ignition behaviour of marine diesel fuels under engine like conditions

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)

Abstract

In view of the large (and further increasing) range of fuels applied in marine diesel engines, there is a clear need for obtaining a better understanding of the effect of those fuels on the key in-cylinder processes governing the combustion characteristics of these engines. For this purpose, a constant volume chamber representative of the combustion system of large marine diesel engines has been complemented with a device allowing the investigation of small fuel quantities and the resulting setup has been used for studying the combustion behaviour of typical marine diesel fuels at conditions relevant for large marine two-stroke diesel engines. Specifically, two clearly distinct heavy fuel oils have been compared to a light fuel oil.

Two optical measurement techniques were used to complement the findings made on the basis of rate of heat release analysis. A combination of the shadow imaging technique with the OH*-chemiluminescence method was applied to investigate spray tip penetration, ignition delay, ignition location, flame lift off as well as flame development of the heavy fuels in comparison with a light fuel oil.

The ignition delay was found to be more than doubled with the heavy fuels, whereas the distance of the ignition spot from the injector was only marginally affected. During the very early combustion, light fuel oil burned quicker than the heavy fuels, but once the conditions were right to allow fast evaporation of the heavy fuels, the flame expansion was at comparable rates for all fuels. The shape and position of the flame area in the later stage on the other hand also exhibits a distinct influence of fuel quality as the area covered by the flame is clearly larger for the heavy fuel oil cases. At the same time, the flame lift-off for those fuels is also increased compared to the reference fuel. However, the evaluation of the overall combustion behaviour on the basis of the heat release rate analysis data shows that this difference in initial behaviour disappears during the main combustion phase. In fact, the overall combustion quality was virtually the same for all cases.

Introduction

The global ecological changes have triggered actions at various levels and big efforts have been made towards reducing the environmental impact of human activities in many sectors. In recent years, also shipping has come more and more into the focus of legislative bodies, resulting in the introduction and further development of the MARPOL Annex VI [1]. This regulation aims at limiting the emissions of pollutants such as NO\textsubscript{x}, SO\textsubscript{x} and particulate matter as well as at the further enhancement of the efficiency of marine transport in order to minimize the output. As a consequence, the priorities in the development of power systems in this sector are eventually changing and a considerably more thorough optimization is required. This can only be achieved on the basis of an in-depth understanding and profound knowledge of the processes related to combustion in marine diesel engines and the fuels which are used during the actual operation of those engines: Investigations of the injection process, mixture formation, ignition behaviour and combustion characteristics at conditions representative of such combustion systems are required for establishing the necessary insight into these highly complex in-cylinder phenomena. Ultimately, this enables and expedites the optimization and development of concepts and solutions for efficient diesel combustion, either directly, or on the basis of the application of computational fluid dynamic tools, which have been developed further making use of the fundamental reference data with regard to spray and combustion characteristics generated in the context of such investigations.

Traditionally, marine diesel engines always had to cope with a significantly higher variety of fuels than the engines applied in any other sector; however, the range of fuel qualities an engine sees in the course of its lifetime, has been clearly extended in the past years and can be expected to grow even further in the future. For many years, distillate fuels were only used during commissioning and just before major overhauls. Today, as a consequence of the above mentioned emissions control requirements, regular switching between heavy and light fuel qualities during operation has become a necessity, with eventually stricter requirements towards the fuel quality (sulphur content in particular) applied when sailing in so-called emission control areas. On the other hand, the quality of the residual fuels normally used when operating in the open sea is also varying substantially, depending on provenance and processing of the crude oil basis. In view of the ever increasing cost pressure, which can only partly be dealt with by operational measures such as slow steaming [2, 3], the shipping industry is continuously looking for alternative, more cost effective fuels [4]. In fact, ships are today partly sailing with fuels that are not in compliance with engine designers’ recommendations (e.g. [5]). In order to be able to assess the consequences of the application of such fuels, it is essential to better understand the spray morphology and the combustion