Experimental Analysis of Fuel Alternatives for Marine Propulsion Systems

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Abstract

Work Package 1 of the European Union's HERCULES-2 project [1] has the objective to develop an injection system allowing for fuel flexible engine operation. Such an injection system must cover the spectrum from classic fuels – residuals from the petrochemical industry – to the far end marked by liquid fuels like ethanol and/or methanol. The Spray Combustion Chamber [2] – a device developed and improved during earlier HERCULES-projects – was chosen to investigate the spray and combustion morphology of two fuel alternatives. As a reference Light Fuel Oil was applied and investigated with a new injector type which allows for variable flow area. Spray penetration of the alternative fuels shows strong differences, compared to classic fuels. The reason for this is expected in the lower viscosity and reduced compressibility of the alcohols, which both influence in-nozzle flow and hence spray tip penetration. The thermodynamic analysis shows a trend towards a good portion of pre-mixed combustion. This is a consequence of the pilot injection, which might still need some improvement on the exact timing, in combination with the swirl velocity. But the rate of heat release looks promising and for the engine tests following this year, a sound knowledge basis could be generated. For the first time CH_2O-LIF was applied for the demanding conditions, present in the combustion chamber of large marine diesel engines. First signals could be recorded, but unfortunately the signal to noise ratio was far from useable. Further investigations are therefore necessary. The injector design proved a good repeatability and a stable spray pattern.

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Introduction

Marine industry faces interesting times: The newest LNG-powered, low pressure gas engines are an interesting option for ship owners [3]. Nevertheless, as not for every application an LNG installation is available yet, liquid fuels still play a major role in merchant shipping industry. Large marine two-stroke engines for the propulsion of merchant vessels are nowadays powered with Heavy Fuel Oil (HFO), Marine Diesel Oil (MDO), Marine Gasoil (MGO) or a similar, convenient distillate waste stream fuel. The Global Sulfur Cap in 2020 (GSC2020) [4] or the ongoing discussions about Black Carbon [5] have the potential to change this. With the GSC2020 for example, the Sulphur content of any sea-going fuel will be limited to 0.5%. This probably will give room for alternative fuels. For todays' shipping sector alcohols are interesting only in very special cases, as their availability and price are not competitive enough. Further, they represent a fuel type on the far end of a wide spectrum of possibilities. A fuel injection system which is able to inject everything from residual fuels up to methanol would likely be able to cover most of the possible (liquid) alternatives in the future. But the requirements for such an injection system are enormous: The spectra of viscosity, energy density and lubricity for such a fuel variety are wide along the different dimensions: The kinematic viscosity spans from 1 cSt to over 700 cSt at 50°C, whereas the energy density of the alcohols is half of classic marine fuels. For the alcohols the lubricity is very low, what makes a long and reliable operation of the moving components challenging.

To explore the possibilities and to express the willingness for a drastic change in the propulsion of merchant vessels, a prototype version of such an injection system was developed within the HERCULES-2 project. In the Work Package 1 an injector and adjoining components were designed and manufactured to investigate different fuel types under engine relevant conditions. The core of the new system is a new type of injector with variable flow area. The needle which evolved from the FAST-design [6] allows controlling two different levels of spray orifices. The injector needle has three positions as can be seen in Figure 1:

1. <u>Needle closed:</u>
   When the injector is without electricity spring-operation of the needle closes all orifices against the combustion pressure.
2. <u>Medium opening position:</u>
   For classic fuels with high calorific value, the needle opens the first step, up to half the design lift and allows a lower row of spray orifices to inject fuel.