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A 3D-CFD Analysis of Gas Direct Injection for a Dual-Fuel Medium Speed Marine Engine

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ABSTRACT

The international shipping sector continues to grow, and with it the need for low emissions propulsion systems. One such technology is dual-fuel methane / diesel engines, which utilise the high H / C ratio of methane to produce power with a theoretical CO_2 saving of around 25 %. LNG can be easily produced as a green synthetic or bio gas which can be used as a standalone fuel or be substituted into existing fossil LNG at any given ratio. There is a well-established on-shore infrastructure and the handling of LNG is well known and less challenging than other alternatives such as methanol or ammonia. Despite these clear benefits, the main issue facing the widespread use of this technology is the problem of methane slip – unburned methane escaping through the engine's exhaust. Methane is 28 times more harmful to the environment than CO2 on a hundred year basis.

This methane slip is produced by one of three mechanisms: methane from the previous cycle's port fuel injection residing in the intake manifold and being lost through the exhaust during the valve overlap, where intake and exhaust valves are simultaneously open; methane slip due to incomplete combustion as a result of flame extinction near cold wall surfaces, and methane slip due to fuel residing in crevices within the combustion chamber and not taking part in the combustion.

Using direct injection to eliminate slip during valve overlap and target fuel away from cold combustion chamber walls has the potential to drastically reduce methane emissions from these engines, but as yet is not installed on four-stroke dual-fuel engines of this calibre. Overcoming the hurdle of methane slip paves the way for climate-neutral LNG ship operation in the future.

The University of Rostock operates one of the largest dual fuel engines of its kind in Europe, for which a novel gas direct injector for methane has been developed. Using medium pressure direct injection (MPDI) instead of port fuel injection (PFI) offers a high potential for the minimisation of methane slip while improving efficiency and power density at lower cost than high pressure direct injection.

Analysis using three dimensional computational fluid dynamics (3D – CFD) simulation was carried out in order to better understand the mixture formation process within the cylinder using the direct injector, as knowledge of the interaction of the gas jet and air within the cylinder is crucial to designing a successful combustion regime. Different possibilities for the use of MPDI are shown, covering homogenous and inhomogeneous operation, analysed using 3D – CFD.

Keywords: Gas direct injection, methane slip, LNG, dual fuel, medium speed engine, 3D-CFD Simulation.