Exhaust gas cleaning systems for marine engines fuelled with hydrogen, ammonia and methanol

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This work explores potential configurations of exhaust gas cleaning systems to reduce the impacts of marine engines operated in dual-fuel configuration, using green fuels, such as hydrogen, ammonia, and methanol, which can be produced either from biogenic sources or from carbon dioxide utilization processes. The main scope of these new ship powertrains is the reduction of greenhouse gas emissions, as carbon dioxide, methane, nitrous oxide, and black carbon. Nevertheless, green fuels still impact air quality, while providing an emission profile that allows for new opportunities in gas cleaning applications, potentially making it possible to comply with environmental regulations valid for inland waterways shipping, which are now unreliable for diesel marine engines fuelled with conventional marine fuels. This work is part of the research activities of the "Centro Nazionale per la Mobilità Sostenibile", and it proposes four Exhaust Gas Cleaning Systems (EGCS) to control ship emissions for dual-fuel 4-stroke engines, using marine gas oil (MGO) as a pilot fuel and hydrogen, methanol, or ammonia as primary fuel. The EGCS designs serve two key purposes: reducing gas emissions to comply with regulations for inland waterways shipping and, potentially, conditioning exhaust gases for potential carbon dioxide capture technologies. In the absence of direct experimental data, the study relies on a comprehensive review of existing literature, prioritizing real-world and bench-scale experiments to establish emissions factors for dual-fuel marine engines operated with hydrogen, ammonia, and methanol. The emission factors are compared with the EU Regulation for inland waterway ships, so identifying operating conditions and target values for the proper EGCS design. The EGCS layouts include preliminary equipment specifications, process flow diagrams, and assessments of energy, space, and weight constraints, which represent critical factors for on-board applications. The study highlighted the potential benefits of integrating EGCS and green fuels, ensuring compliance with EU regulations for newly designed ships. Integration is feasible for newbuild units, and retrofit, although potentially challenging, can still provide significant emissions reductions. Besides, the EGCS layouts can be a reliable predictive tool to define new regulatory scenario for future engines, balancing emission reductions and technical-economical limitations.

Keywords: *Sustainable Shipping, Dual-Fuel Marine Engines, Greener Fuels, Exhaust Gas Cleaning Systems (EGCS)*

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