Design and feasibility study of marine SCR units for methanol dual-fuel engines

Domenico Flagiello, Domenico Ricchiari & Francesco Di Natale

Department of Chemical, Materials and Production Engineering, University of Naples Federico II, Naples, Italy

E-mail: *domenico.flagiello@unina.it*

Maritime shipping serves as a cornerstone of the global economy, handling 90% of international trade. However, it contributes 3% to global greenhouse gas (GHG) emissions. To tackle this environmental issue, the International Maritime Organization (IMO) has set a target to reduce emissions by 50% compared to 2008 levels by 2050. Achieving this ambitious target requires significant advancements in ship designs, propulsion systems, and the development of low- or zero-carbon fuels, alongside extensive global infrastructure investments. Methanol is emerging as a strong contender among low-carbon alternative fuels. A widely produced chemical, green methanol can be derived from renewable resources, offering a carbon-free solution while substantially improving ships' Carbon Intensity Indicator (CII) ratings. Methanol is already available at more than 100 ports worldwide, a number expected to grow. Engine manufacturers have invested more than a decade in methanol applications, such as Wärtsilä dual-fuel methanol-diesel engines powering the Stena Germanica. This 240-meter ferry, converted in 2015, demonstrates a 7% reduction in tank-to-wake carbon emissions compared to Marine Gas Oil (MGO) operations, as well as decreases in SO_x, NO_x and particulate matter. However, Tier III compliance requires the implementation of selective catalytic reduction (SCR) systems for NO_x. As part of the research activities of the “Centro Nazionale per la Mobilità Sostenibile”, this work focuses on designing SCR systems for vessels powered by MGO and methanol dual-fuel engines. This includes analyses of CAPEX & OPEX, as well as space and weight limitations, crucial for on-board systems. The case study considers a reference marine engine with a maximum power of 10 MW operating at 75% of maximum load, which represents the typical cruising operation of the vessel and is assumed as the most limiting condition for the design. The design adopts reference SCR model equations and technical manufacturers' guidelines to provide a preliminary design under some calculation assumptions. For MGO engines, Low-Dust configuration is used, whereas methanol engines rely on longer-lasting Tail-end configuration. Both designs ensure Tier III NO_x compliance for a 10-year operational lifetime. The study also explores innovative catalysts, such as Cu-zeolites and $IrRu/Al_2O_3$, alongside widely used V_2O_5-$WO3/TiO_2$. This research shows potential compatibility of SCR units with exhaust gases 4-stroke dual-fuel methanol engine, opening new possibilities for more efficient and sustainable maritime practices.

Keywords: *Sustainable Shipping, Dual-Fuel Marine Engines, Methanol, Marine SCR systems*

Acknowledgements: This research was developed within the “CN-MOST – Spoke 3 (Waterways)” research activity, funded under the National Recovery and Resilience Plan (PNRR) of the Italian Ministry of University and Research (MIUR); funded by the European Union – NextGenerationEU.