Advanced thermal energy storage systems for optimizing the on-board waste heat recovery

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The maritime industry faces increasing pressure to reduce its carbon footprint and adhere to increasingly stringent environmental regulations established in recent years. The International Maritime Organization has mandated an urgent need to reduce greenhouse gas emissions from maritime shipping, setting the goal of zero emissions by 2050. These concerns are prompting shipbuilders and shipowners to explore innovative technologies aimed at mitigating the environmental impact of ships across all operating conditions.

Among the possible technologies to reduce the energy demands of ships, the exploitation of available waste heat at different temperature levels can be effectively explored to address the mismatch between waste heat generated by engines and the onboard heat demand. This is especially relevant for energy-intensive vessels such as cruise ships, where, when engines are switched off in ports and no recoverable waste heat is available, the only alternative to oil-fueled boilers is the use of thermal energy stored during navigation.

This paper investigates the use of a novel thermal energy storage (TES) system employing a silica gel/water pair for ship applications. A physics-based model of the investigated TES system is implemented in MATLAB, and the tool is preliminarily validated using measurements obtained from scientific literature. Furthermore, to evaluate the energy performance and implications of TES on ships, the developed model is embedded into a ship energy performance simulation tool for whole ship-energy system simulation and optimization. The tool allows for the simulation of the interactions between the TES and the onboard energy systems. To demonstrate the potential of the considered technology, as well as the developed dynamic simulation tool, a case study involving a roll-on/roll-off passenger ship is presented. Significant findings reveal potential fuel savings during port operations and throughout operational hours, leading to a consequential reduction in greenhouse gas emissions. Consequently, the investigated technology shows promise for integration into existing onboard systems, enabling shipowners and shipbuilders to achieve the stringent IMO goals set for 2050.