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COOLING FLUIDS AND AMBIENT TEMPERATURE: SENSITIVITY PERFORMANCE OF A CONTAINER SHIP ORGANIC RANKINE CYCLE UNIT

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ABSTRACT

The objective of this work was to design organic Rankine cycle units that are cooled by air or seawater and show the changes in net power output and power requirement as the ambient air temperatures change both geographically and seasonally. The organic Rankine cycle unit uses the available waste heat from the scavenge air system for a 4,100 TEU container ship. This work uses a two-step single objective optimisation capable of selecting 14 design characteristics of the organic Rankine cycle unit with the aim of minimising the vessel's CO_2 emissions. The work contributes to the study of off-design operation and different cooling fluids for marine waste heat recovery systems. The results show that the organic Rankine cycle unit is more adaptable to ambient air temperatures when using seawater as a cooling fluid while air is attractive for extremely low ambient temperatures.

ORGANIC RANKINE CYCLE UNIT

Air enters the 2-stroke Diesel engine turbocharger increasing its pressure but also its temperature which in turn reduces the air's density. In order to have a denser air, its temperature after compression is cooled via the organic Rankine cycle (ORC) boiler (see Fig.1). The waste heat absorbed evaporates the working fluid, R1233zd(E), and at the expander, coupled with an electrical generator, electrical power is generated and feed to the ship's grid. The excess heat not used is rejected to the cooling medium, either seawater or ambient air. This work focuses on the implications of using different cooling fluids at different seawater and ambient air temperatures to have the maximum impact on the container ship CO_2 emissions.

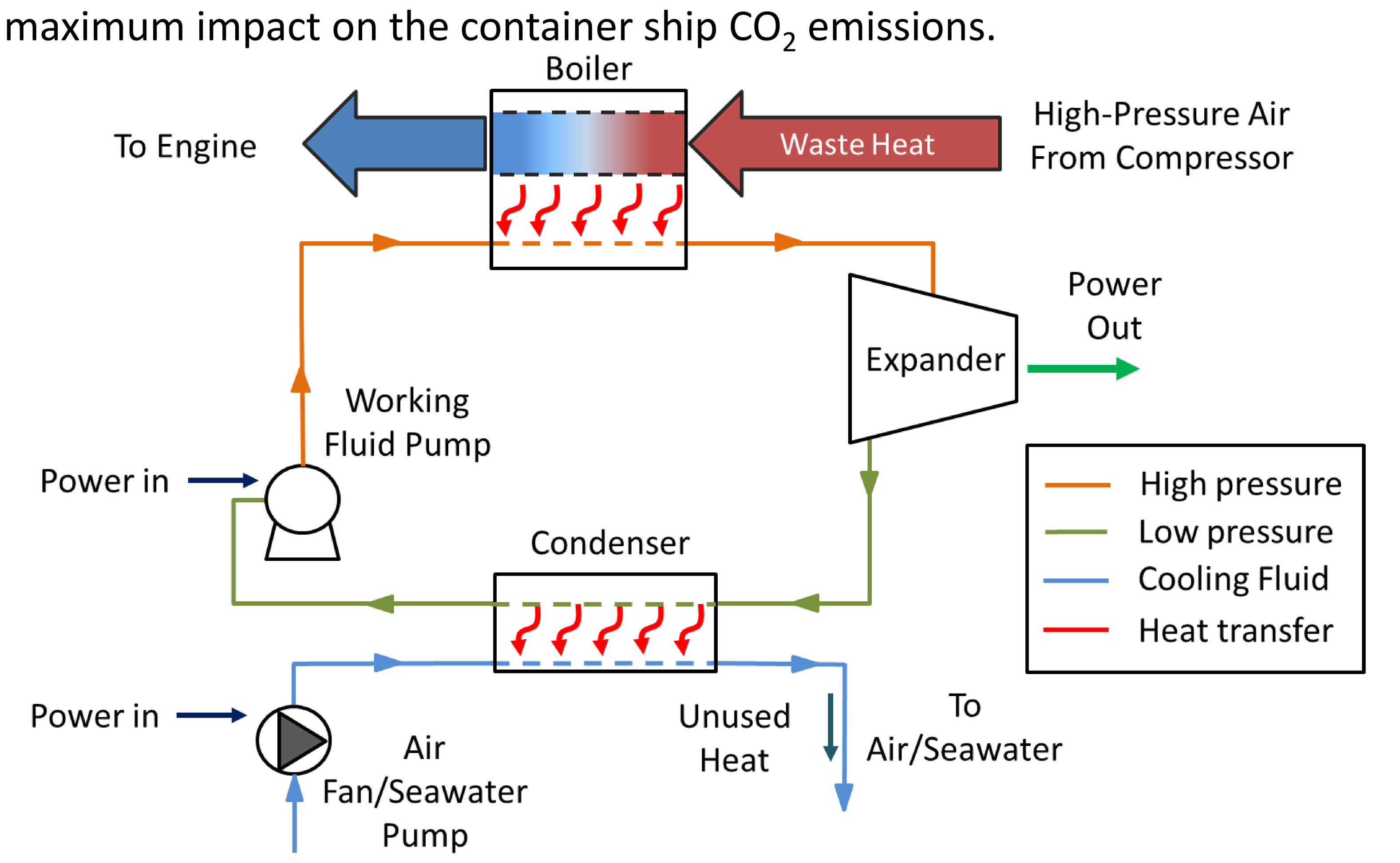

Fig. 1: Organic Rankine cycle unit schematic used in this study.

Results

The maximum power returned to the ship is 545 kW_e which represents about 33% of the maximum power output of a single auxiliary engine. In regards to CO_2 emissions, the vessel without an ORC installed, under ISO conditions (i.e. ambient air temperature at 25°C) emits about 1053 t. The maximum CO_2 emission reductions from any ORC design was 10.8 t which represents about 1.0% of the total vessel's emissions.

Fig. 2 shows the CO_2 emission reduction achieved by the proposed ORC unit relative to the total CO_2 emissions emitted from the ship's auxiliary engine at Winter (ambient air at 10°C), ISO (ambient air at 25°C) and Tropical (ambient air at 45°C) conditions.

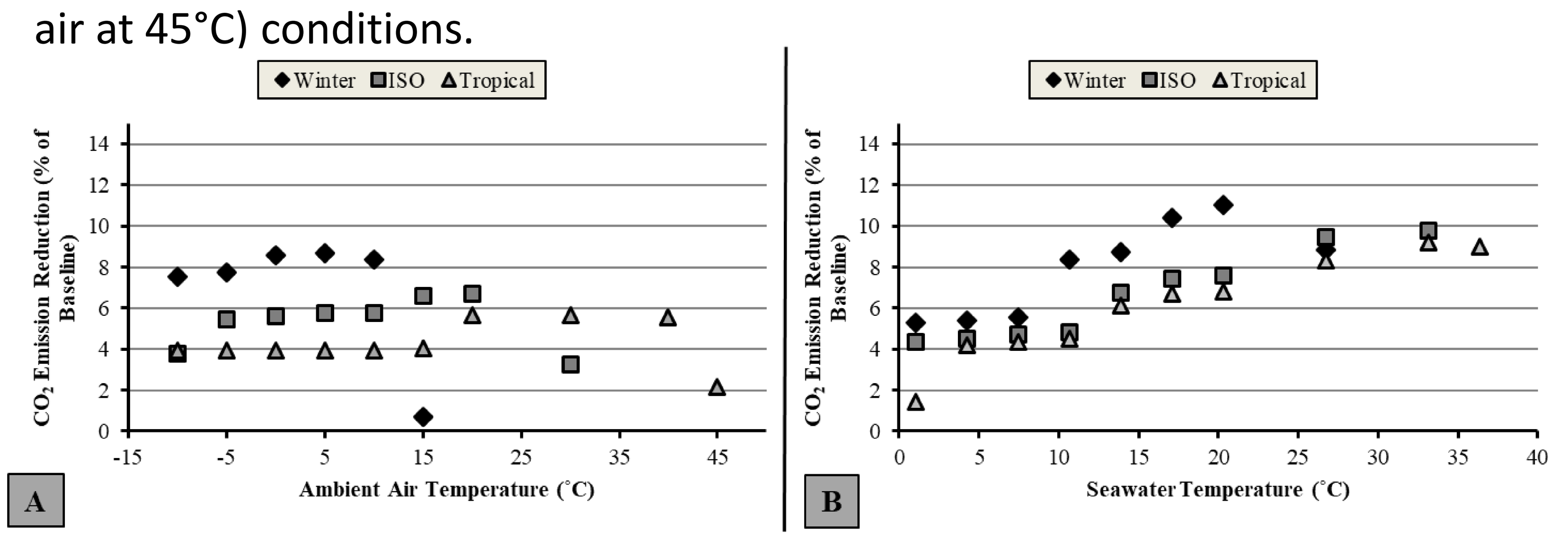

Fig. 2: CO_2 emission reduction as percentage of total auxiliary engine CO_2 emissions and assuming the ship operates 100 hours under each tested ambient air temperature. A) Air; B) Seawater.

CONCLUSION

With the use of a hypothetical 4,130 TEU containership powered by a two-stroke slow speed Diesel engine it was possible to test the performance of different ORC unit designs at off-design conditions with the aim of reducing the CO_2 emissions. If the ship is going to operate under low ambient air temperatures in the majority of its operational life, then a low design temperature and using air as coolant can bring the largest benefit. On the other hand, if the ship will be navigating in long routes throughout the year a seawater-cooled WHRS with high design ambient air temperature can give great operational flexibility. It is important to consider that an air condenser unit will occupy up to six times more volume than a seawater condenser.

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