Improving Shipping CO_2 emissions: A multi-objective study of marine Waste Heat Recovery Systems

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Background

Holding the global temperature rise below 2˚C, when compared to the global pre-industrial levels, is one of the most challenging compromises taken by the international community. Shipping contributes in 3.3% of the total CO_2 emissions and it is the transport mode with the highest growth, hence it has an important role in achieving the 2˚C goal.

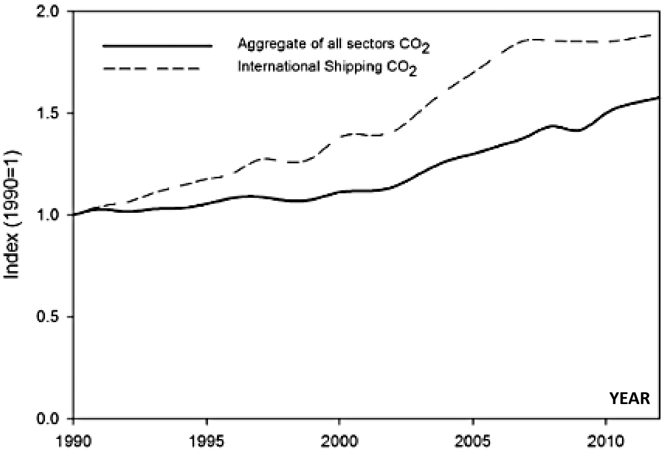

Figure 1.- CO_2 emission average growth between all sectors of human activity and international shipping (Indexed 1990 = 1) [1].

The aim of this research project is to contribute to the reduction in CO_2 and other greenhouse gases emissions by increasing ship's efficiency using the low/medium temperature waste heat available from the ship engine's exhaust gas.

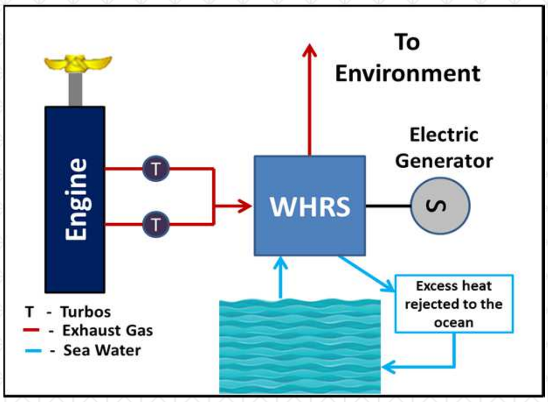

Figure 2.- Marine Waste Heat Recovery System (WHRS) using the available heat in the exhaust gas.

This research **explores the use and performance of different organic Rankine cycles** (ORC) as marine Waste Heat Recovery system (WHRS), under realistic ship operative conditions, to **analyse the advantages of alternative technologies**. Whilst these comparisons have been made for land based systems, its application into shipping environment has been limited.

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Method

A multi-objective optimization method, based in Matlab, using the genetic algorithm with a unique creation function coupled with a weight factor approach based in the Analytic Hierarchy Process (AHP) allowed to find the optimal marine WHRS design.

Results

A two stroke slow speed Diesel engine capable of producing a maximum of 22 MW of power is modelled to understand the performance of the WHRS. In order to convert the WHRS power output to CO_2 emissions reductions, a model of a marine electric generator- consuming 187 g/kWh of marine Diesel oil- will be used.

Working fluid	Water	Heptane	Benzene	Toluene	Hexamethyldisiloxane (MM)	R245FA
Electric Power Output (kW_e)	346	385	410	376	396	370
Mass Flow Rate (kg/s)	0.8	4.5	3.8	4.1	7.1	8.7
Heat Exchanger Area (m^2)	1002	2594	1370	1677	3044	1636

Table 1.- Simulations results: First row shows the WHRS electrical power output in kW_e; Second row shows the working fluids' mass flow rate needed to produce the electrical power output; Third row gives the heat transfer area required by the different WHRS . Green → Best performance /characteristic; Red → Worst performance /characteristic.

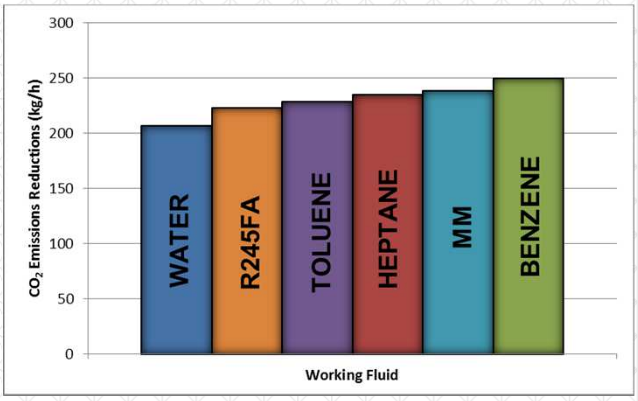

Figure 3.- CO_2 emission reductions per hour from WHRS installed in a 22 MW marine Diesel engine.

Conclusions

ORC WHRS can outperform a typical marine water based WHRS. Benzene can produce 18% more electrical power than the water Rankine Cycle (RC). If flammability is an issue on-board, then R245FA, which is non-flammable, delivers 7% more power than the RC. Translating the power output to CO_2 emission reductions benzene could save up to 250 kg of CO_2 per hour, while R245FA saves 224 and the water RC system saves 207.

The downturn for the organic systems are equipment size, and in the case of flammable fluids, the cost increase due to security and safety systems required to have these fluids on-board.

References

1. Bows–Larkin, A., Mander, S., Gilbert, P., Traut, M., Walsh, C., & Anderson, K. (2014). *High Seas, High Stakes: High Seas Project Final Report* (p. 44). Manchester.