Potential for usage of TEG on ships

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The waste heat potential on a bulk carrier has been evaluated as an initial step to develop a TEG based waste heat recovery system for ships. The medium sized bulk carrier develops 6,2 MW waste heat and the most promising sources for TEG showed to be exhaust from main engine and sludge oil incinerator.

Introduction

Ships are still the most efficient mode of transport taking all environmental aspects into account[1]. More than 80%[2] of all goods shipped in the world are being transported on ships. Ship transport represents a large amount of waste heat, which is utilized as thermal and to some extent as electrical energy.

Engine – waste heat types and characteristics

The main heat source on board is the main engine. The Sankey diagram in figure 1 shows the different fractions of waste heat on a main engine installation with and without electric power generation. The latter is most common. The example in figure 1 is a very efficient engine and still there are potential for alternative technologies like TEG to recover more of the waste heat. Traditionally waste heat is used for heating of heavy fuel oil, accommodation areas and for fresh water generation. This decreases the available temperature levels.

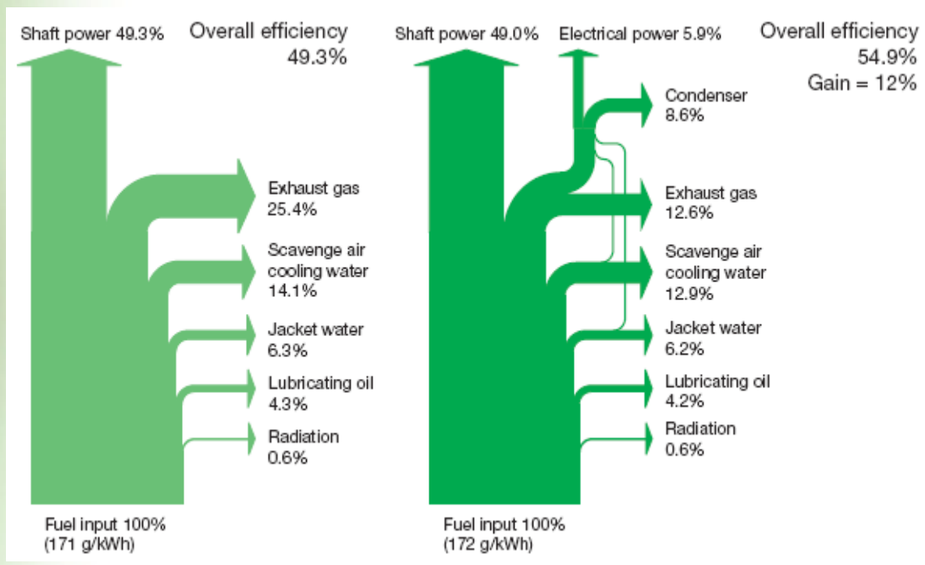

Fig. 1. Heat balance Sankey diagram of Wärtsilä-Sulzer RTA-96C[3]. The diagram on the right shows a waste heat recovery system based on a steam and exhaust turbine.

Incinerators

The incinerators have not been very attractive as a heat source for the ship, mainly because of the limited running time and the need for additional heat is limited. More so, introducing a boiler calls for additional safety measures and extra installation. However the incinerator might prove to be a good candidate for introducing thermoelectric generators. The incinerators have a high possible temperature difference and the advantages of the TEG comply with design criteria's like reliability and low maintenance. The incinerator capacity in kW should be 3% of the main engine power[4].

Fig. 2. TeamTec OG 200C incinerator represents a waste heat source with high temperature.

CASE STUDY

A more in depth study of the waste heat availabilities and usability's have been studied for some typical ships in each of the three biggest classes of ships: bulk ships, container ships and tankers see table 1.

Table 1: Most common types of ships in Clarksons[5]

Type of ship	Number [-]	Median DWT [Mg]	Median installe Power [MW]
Bulk carrier	8500	55100	8.5
Tankers (oil and product carriers)	6800	31540	7.1
Container ships	5900	30740	15.3

As an example a typical bulk carrier of 52000 DWT M/V Rosita in figure 2 has been studied for a more detailed waste heat potential. M/V Rosita has a main engine of 7800 kW installed shaft power as the prime mover and 3 sets of 480 kW auxiliary engines for electricity production. However normal running condition is 85% load on the main engine in normal operation, called CSO, continuous service output. Rosita is accommodating a crew of 23 persons. The running hours on M/V Rosita are in average the last four years 4762 h/year.

Fig. 3. M/V Rosita managed by Ugland Marine Services AS is a typical bulk carrier. The engine of 7.8 MW represents a large source of waste heat (photo Ugland).

Table 2. Waste heat sources on M/V Rosita. Values are collected from test record of official sea trial at CSO[6], main engine room data by MAN[7], and machinery reports. Incinerator values are not from the installed incinerator, but from a similar TeamTec OG 200C incinerator. *values are calculated

Heat source\Ship	Medium	Temp. [C]	Quantity	Estimated TEG power [kW]
Electrical generating unit	Flue gas	340	* 0.69 Nm3/s	10,0
incinerator *	Flue gas	340	0.68 Nm^{3d}/s	9,7
Main engine Exhaust after boiler	Flue gas	210	14,18 Nm^3/s	42,4
Main engine scavenge air cooling	air	162	13,92 Nm3/s	46,4
Excess Steam From boiler	Sat. steam	159	* 0.087 kg/s	5,9
Main engine Cooling water	Fresh water	83	18 kg/s	11,8
FW generator unit, boiling water	Fresh water	61	* 8.3 kg/s	4,3
lubrication oil cooler	Lubrication oil	49	46 kg/s	2,1
FW generator unit, condenser	salt water	37	* 25 kg/s	0,4

The amount of power calculated in table 2 also dependent on the cold side temperature. In this case it is reasonable to use the sea water temperature as the limiting temperature, here 29 ˚C. Another necessary assumption is the temperature level the TEG installation is able to reduce the medium to before it is emitted or returned. This results in a total waste heat production of 133 kW assuming a figure of merit Z=2 and using the average value between Temp in table 2 and a lower temperature limit as T_h in the following formula to calculate the efficiency[8]:

$$\eta = \frac{T_h - T_c}{\frac{3T_h}{2} + \frac{T_c}{2} + \frac{4}{Z}}$$

The main engine is the source of the majority of the waste heat. The reason for a higher power potential for the scavenge air compared with the main engine exhaust is the lower temperature limit of the medium is set to 160°C for the exhaust and 43°C for scavenge air.

DISCUSSION AND CONCLUSION

Although the main engine produces the vast majority of waste heat on board ships, the quality of the heat is low as some of the heat already has been utilized. In order to take advantage of the main benefits of TEG like modularity and flexible design, it is reasonable to focus on smaller heat streams with higher temperatures that have not been utilized already. The flue gas from the auxiliary engines is also interesting but normally only one out of three is running at sea voyage and all generator sets has separate flue gas stacks. A TEG installation in the waste oil incinerator has a potential to utilize the high temperature in the combustion chamber and is a good candidate to focus on.

FUTURE WORK

Incinerators are selected as the most promising application of TEG by the company TeamTec. Especially as the incinerators have interesting temperature levels, and the company has an extensive experience with sludge oil incinerators.

In order to test thermoelectric generator module performance a test station has been developed, see fig. 4 The goal for the test station was to be able to test modules for high temperature, and incorporate a control system that allows dynamic testing. Another feature of the test rig is the possibility to vary the temperature gradient over the surface of the TEG module. This feature enables us to verify 3D modelling of TEG module behaviour with a greater level of accuracy than with a uniform temperature in the heating element.

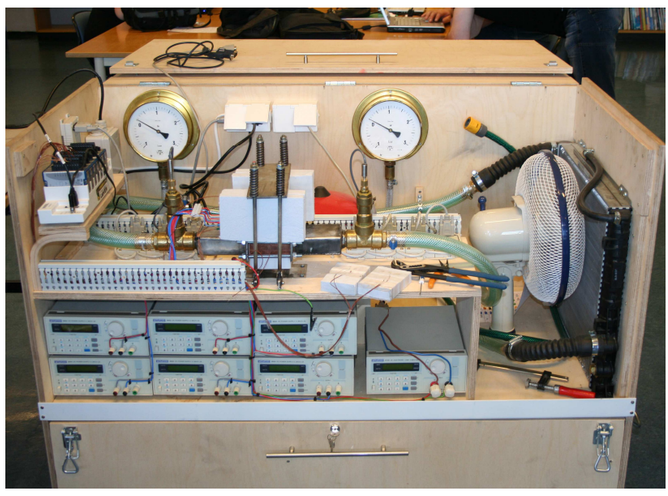

Fig. 4. Test station for thermoelectric modules

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