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CONSIDERATION OF HEAT RECOVERY FOR A DIESEL TWO-STROKE ENGINE

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ABSTRACT

From the analysis of the heat balance diagram, it appears that the increase in the effective efficiency is possible by reducing the two categories of heat losses. Constructive and functional measures to provide these recoveries are directed mainly towards reducing the heat flows taken over by the cooling fluid and the exhaust gas. This is determined by the high share of these heat flows against the residual heat. The simplest and cheapest system consists of an exhaust gas turbine or steam turbine, the so-called power turbine, installed on a bypass of the gas exhaust or steam from the boiler, and connected in turn with an electric generator to provide electrical power on board the ship. Modern slow diesel engines have high thermal efficiencies, which can be improved through integration with other power systems. The most efficient way for a two-stroke engine-powered ship is to use its engine's waste heat.

Keywords: heat; recovery; engine; turbine; parameters; steam;.

1. INTRODUCTION

The turbine is a rotary thermal machine that transforms the potential energy of steam into kinetic energy and on it into mechanical energy.

The operating principle of steam turbines is completely different from that of alternative machines.

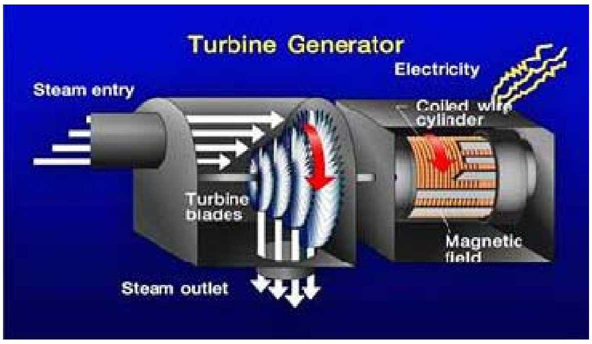

Fig. 1. Steam turbine operation [4]

The difference lies in the way turbine steam works, as well as how to obtain mechanical power at the power flange of these machines. The rotation movement is much simpler than reciprocal movement, and unbalanced forces that occur in mutual movement and produce vibrations can be eliminated in the case of turbines. Energy transformation is continuous - which makes the machine develop great powers. Dynamic forces are just centrifugal, which is easy to balance. The unbalanced force is incomparably lower than in alternative machines and the turbine operation is much smoother. This reduces the fatigue of the material and the turbine foundation is very light.

As compared to alternative machines, turbines have the following advantages:

- because of the lack of oscillating masses, they can achieve great powers,
- no moving parts in contact with the steam can use overheated steam with very high temperature;
- they operate economically and at low pressures;
- they make high speeds;
- the exhaust steam is completely free from oil;
- steam consumption does not increase over time to a very small extent;
- oil consumption is very low;

- for installation in the machine room, a foundation with small dimensions is necessary;
- they achieve a uniform engine torque.

2. MITSUBISHI TYPE 7UEC85LSII MAIN ENGINE

The propulsion of the tanker ship of 300.000 dwt is provided by a Mitsubishi-UE MDE 7UEC85LSII, two-stroke, slow and reversible engine, with a constant overcharging pressure that develops a rated output of 27020 kW at a speed of 76 rpm, the ship shifting with a maximum speed of 15.38 Nd. MAN B&W two-stroke engines from the 30 to 95 cm bore sizes have a total power range from 1,560 kW to 82,440 kW, with units that vary in height from 5,912 to 16,156 mm.

This covers the ME (main engine) (40 to 95 bore), ME-GI (40 to 95 bore), ME-B (30 to 50 bore) and MC (35 to 70 bore) series [1], [2].

Table 1. Main engine characteristics

Characteristics	Value
Bore	850 mm
Stroke	3150 mm
Number of cylinders	7
MCR (maximum continous rating) power	27020 kW
NCR power	22965 kW
Speed	76 rpm

Fig. 2. Main engine type Mitsubishi-UE MDE 7UEC85LSII [5]

3. EXHAUST GAS RECOVERY SYSTEM

In boiler plants, the combustion gases after the boiler circuit are evacuated into the atmosphere to make room for a new amount of gas resulting from the continuous combustion of fuel in the furnace's furnace.

Combustion gases leave the heat containing an appreciable amount of heat; this heat is lost to the atmosphere without being used in the plant and is therefore considered as a heat loss.

From the research carried out by the research institutes as well as from theoretical and practical considerations, it was found that the temperature of the exhaust gases from the boiler always exceeds the saturation temperature of the steam at that pressure.

For example, at a pressure of 16 Kgf / cm2, the saturation temperature of the steam is about 200 0C, and for a steam generating steam the exhaust gas will have a temperature greater than 200 0C. the value of the saturation temperature of the steam can not be reached by the exhaust gas. This can only be done if the boiler has an infinitely high heating surface, which is practically impossible. The gas temperature can not drop below the saturation temperature, because in this case the gases would be converted from a heating agent to a cooling agent, which would only harm the steaming process.

As a rule, exhaust gases from the ship's boats have a temperature of between 300-500 °C. The heat loss with the exhaust gases Q_2 is inevitable as a phenomenon but not quantitative.

The heat flow thus recovered can be used for:

- production of saturated water vapor for hard fuel heating and ship needs,
- production of superheated water vapor for supplying a turbo-generator for power generation.

The heat loss with the exhaust gases Q_2 can be presented by the difference between the enthalpy of the gases at the outlet of the chimney (I_g) and that of the air introduced into the boiler (I_a).

Lost heat flow is:

$$\dot{Q}_2 = I_g - I_a \quad [kJ/h] \tag{1}$$

The steam turbine will start at the main engine capacity of 30-35%, followed by the gas turbine at a power of 40-50% of the main engine.

4. TURBOGENERATOR SYSTEM ONBOARD SHIP

On board ship there is a turbo generator with the following characteristics:

- type: multi-stage condensing turbine,
- rated output: 1100 kW,
- turbine rated speed: 11730 rpm,
- generator rated speed: 1800 rpm,
- rotation: clockwise,
- H.P. pressure EGE MODE: 0.59 MPa, BLR MODE: 1.81 MPa,
- H.P. temperature EGE MODE: 235 °C, BLR MODE: saturate,
- L.P. pressure EGE MODE: 0.29 MPa,
- L.P. temperature EGE MODE: saturate,
- exhaust pressure: 6.7 kPa,
- permanent speed variation within 5%;
- maximum main steam pressure: 2 MPa,
- maximum main steam temperature: 400 °C.

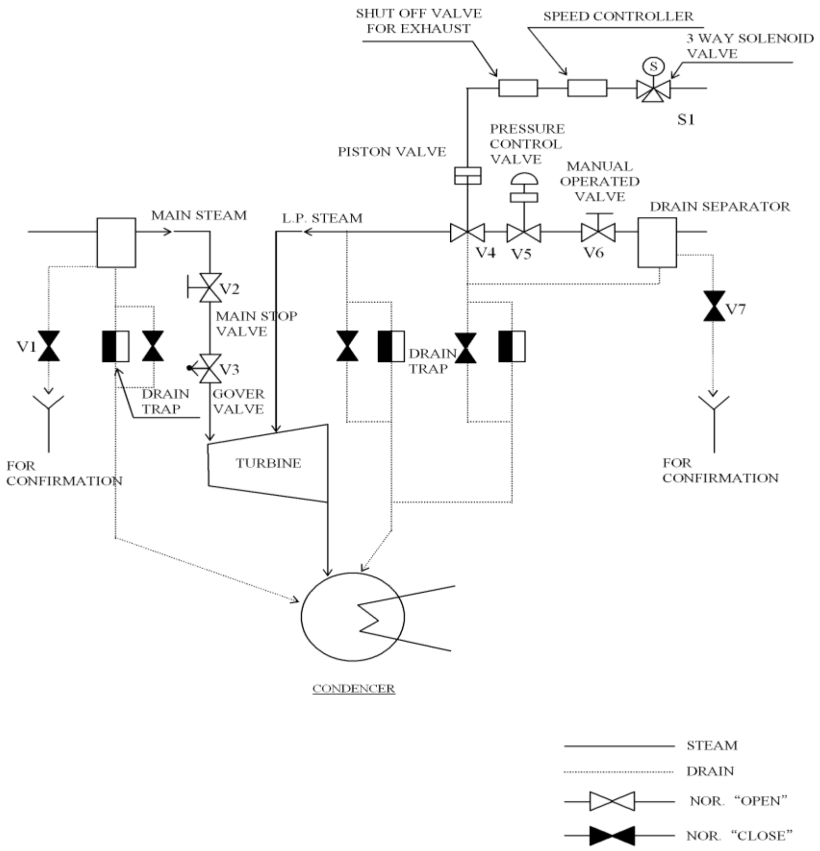

Fig. 3. Steam turbine system

Table 2. Gas economizer characteristics.

Characteristics	Low-pressure evaporator	Steam separator	High-pressure evaporator	Superheater
Evaporating mass, Kg/h	2420	2420	5710	5410
Designed pressure, MPa	0.98	**0.59**	2.65	2.16
Steam temperature, °C	Sat	Sat	Sat	245
Gas flow 85% MCR, Kg/h	179800	179800	179800	179800
Inlet gas temp 85% MCR, °C	263	263	263	263

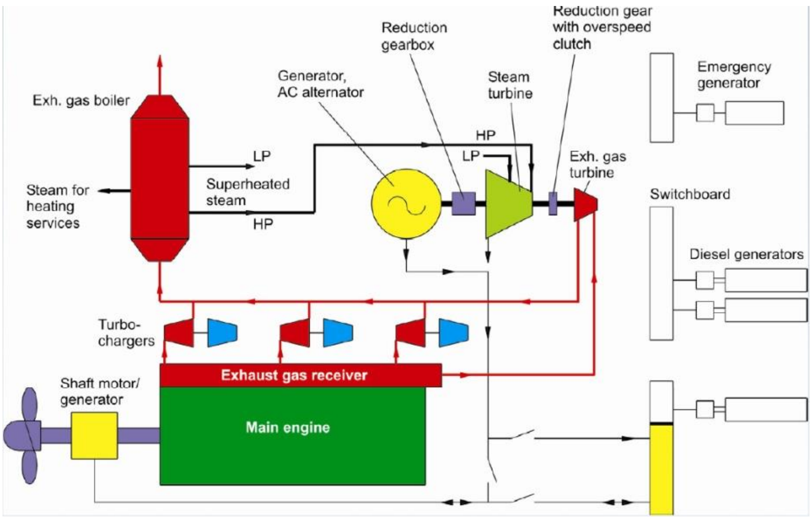

Fig. 4. Combined recovery system [6]

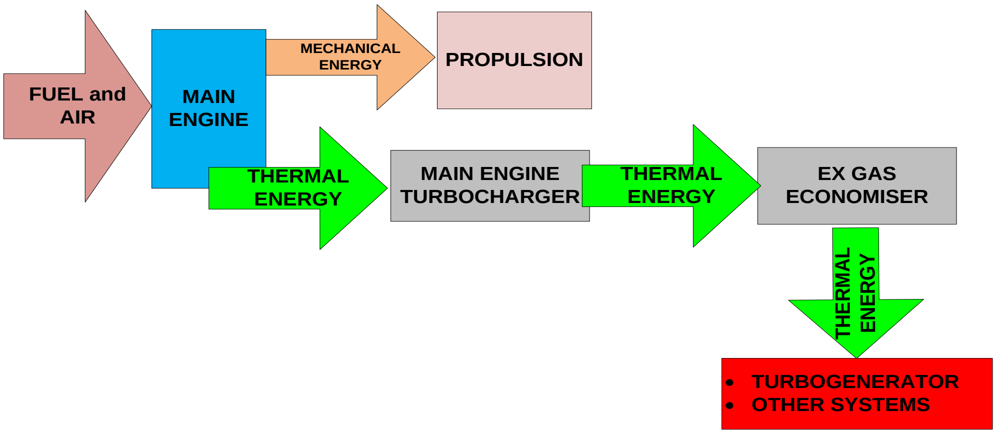

Fig. 5. Simplified Sankey diagram

5. STEAM TURBINE PARAMETERS CALCULUS

Calculation of the steam flow, m_{steam}:

$$m_{steam} = d_z \cdot P = 5.5 \cdot 10^3 \quad [kg/h] \qquad (2)$$

where $d_z = 5[kg/kW]$ is the steam flow. $P = 1100$ kW is the steam turbine power.

Calculation of the saturated temperature is:

$$t_{sat} = 100 \cdot p^{0.25} = 206.26 \quad [°C] \qquad (3)$$

where $p = 18.1$ bar p is the working pressure.

Calculation of superheated temperature is:

$$t_{si} = t_{sat} + 150°C = 356.26 \quad [°C] \quad (4)$$

where $t_{sat} = 206.26$ °C t_{sat} – the saturated steam temperature.

Energy flow in turbine will be:

$$\dot{Q}_a = \frac{P}{\eta_a} = 1.467 \cdot 10^3 \quad [kW] \qquad (5)$$

where, $\eta_a = 75\% \, \eta_e$ is the turbine efficiency.

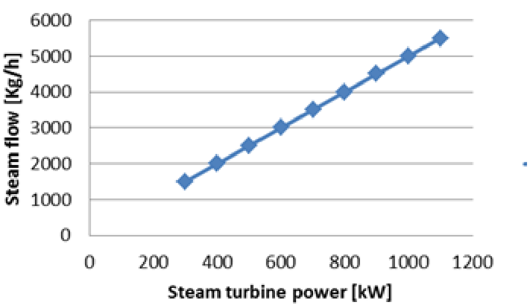

Fig. 6. Steam turbine power vs steam flow

5. CONCLUSIONS

The paper treated the energy analysis of a VLCC (very large crude carrier) tanker ship, based on a real measurement onboard ship. The energy analysis was used for calculating the potential for waste heat recovery on the tanker power demand among consumers.

By installing a steam turbine (often called a turbo generator), the obtainable steam production from the exhaust boiler system can be used for electric power production.

The power output from the power turbine may be added to the generator via a reduction gear with a special clutch. However, first, the steam turbine will start at 30–35% MCR main engine power, followed by the power turbine, which starts power production at 40 to 50% MCR. Using a steam generator system, it will be possible to recover around 5 to 8%, depending on the main engine size, engine rating, and ambient conditions.

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