ENERGETIC ASSESSMENT OF THE SHIP NON-CONVENTIONAL ENERGETIC UNIT

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Abstract

The paper deals with a non-conventional energetic unit equipped with a cooling combustion engine designed as an element for qualitatively new equipment to achieve a more efficient utilization of energy chemically bound in fuel of the combustion engine by transformation of heat into cold via thermocompression.

A simple example illustrates the advantage of a non-conventional energetic system from the point of view of a more efficient utilization of primary energy, i. e. the energy chemically bound in fuel.

Keywords: *non-conventional energetic unit, energetic assessment*

1. Introduction

Energy, the term generally expressing ability for a change of state or process of change of state, is the fundamental existential attribute of the world. One of its forms is an outer expression of the internal state of materials (inner energy), which is thermal energy, or, more exactly, given heat. Part of this form of energy is used by mankind in compliance with its interests, in thermal devices, machines, among which are also thermal engines and cooling devices, i. e. equipment carrying out a circular cycle within the framework of the second thermodynamic law.

2. Energetic assessment of the ship non-conventional energetic unit

Energetic efficiency assessment methods belong to important factors of comparison of energetic systems with thermal devices. General energetic, thermodynamic efficiency (EF) of energetic systems with thermal devices is given by the relation

$$EF = \frac{\sum E_u}{\sum E_u + \Delta E}, \tag{1}$$

where:

ΣE_u – sum of obtained energetic flows,
ΔE – unused energetic flow.

The rate of efficient utilization of thermal energy in these devices is characterized by thermal efficiency, exergy, anergy and by the coefficient of performance (COP). The rate of primary energy utilization (natural gas, liquid fuels, ...) in thermal devices, energetic units using the above mentioned machines, is expressed by a primary energy rate (PER).

The COP expresses attainable useful work of the combustion engine or useful cooling output of the sorption cooling device per one input unit of the given device. The higher the COP achieved by the device the less amount of primary energy consumed to provide the required output energetic flows. The COP can be though used only for comparison of similar devices in the application, i. e., for example, mutual comparison of either combustion engines or absorption devices.

The COP cannot be used for comparison of energetic efficiency of different kinds of devices. For these purposes the assessment by means of the PER is used. The lower the PER value, the higher the rate of primary energy utilization.

3. Energetic assessment

A simple example (for unit input) will be further used to illustrate the advantage of the utilization of the non-conventional energetic unit (presented in other part of the paper) on the ship mainly in relation to utilization of fuel primary energy [2]. The following boundary conditions are assumed for the mentioned example:

⇒ heat flows (input q_h) to the engine Q_M as well as to the cooling engine Q_{MCH} are equal, namely, 1 MJ,
⇒ mechanical work of the engine A_M as well as of the cooling engine A_{MCH} are equal, namely 0.25 MJ,
⇒ also output numbers of the engine COP_A and of the cooling engine COP_{ACH} are equal, namely 0.7,
⇒ input of the pressure pump is zero,
⇒ cooling takes away 30 % of heat (p = 0.3),
⇒ efficiency η_{ACH} of transformation of primary energy into thermal energy including transport into the cooling solution in the cooling engine generator is 0.9,
⇒ total thermal efficiency η_r expressing transport, transfer and transition of heat from the area of cylinder cooling of the independent engine to the working medium of the thermo generator of the independent sorption cooler is 0.85,
⇒ relative cold coefficient of the evaporator of the separate sorption cooler and the combustion engine is 0.85.

Assuming that:

⇒ heats from exhaust gases and from sorption processes are anergic,
⇒ temperatures in the thermo generator are identical in both devices

then the change in the coefficient of the primary energy utilization at its utilization in the cooling engine PER_{CHM} and in the separated aggregate of the combustion engine and sorption cooler PER_{AM} PER_{AM} is obvious from the below. For thermal flow to the cooling engine thermo compressor the following relation holds

$$Q_{GCH} = p \,.\, q_h \,.\, \eta_{ACH} = 0.27\ MJ\ . \tag{2}$$

The coefficient of primary energy utilization rate for the cooling engine can be then determined as follows:

$$COP_{MCH} = \frac{A_{MCH} + Q_{GCH}}{Q_{MCH}} = 0.52\,, \tag{3}$$

$$PER_{MCH} = \frac{1}{COP_{MCH}} = 1.92\ . \tag{4}$$

For the coefficient of primary energy utilization rate for the sorption cooler holds the following:

$$COP_{ACH} = \frac{Q_{OCH} + Q_{KCH} + Q_{ABCH}}{Q_{GACG} + P_{CCH}} \Rightarrow Q_{OCH} = 0.19\ MJ,$$

$$PER_{ACH} = \frac{1}{COP_{ACH}.\eta_{ACH}} = 1.58 \qquad (5)$$

and the coefficient of primary energy utilization rate for the cooling engine is given by the relation:

$$PER_{CHM} = \frac{PER_{MCH}.A_{MCH} + PER_{ACH}.Q_{VCH}}{A_{MCH+Q_{VCH}}} = 1.76\,. \qquad (6)$$

For the separated aggregates the coefficient of primary energy utilization rate can be determined in the following way:

$$\eta_{A}.\eta_{ACH}.\eta_{r} = 0.77,$$

$$Q_{GA} = p.q_h.\eta_A = 0.23\ MJ. \qquad (7)$$

for the motor then holds the following:

$$COP_M = \frac{A_M + Q_G}{Q_M} = 0.52,$$

$$PER_M = 1.92. \qquad (8)$$

For the sorption cooler then holds:

$$COP_A = \frac{Q_O + Q_K + Q_{AB}}{Q_{GA} + P_C} \Rightarrow Q_O = 0.16\ MJ,$$

$$PER_A = \frac{1}{COP_A.\eta_A} = 1.85. \qquad (8)$$

and for the separated aggregates the coefficient of primary energy utilization rate is as follows:

$$PER_{AM} = \frac{PER_M.A_M + PER_A.Q_V}{A_M + Q_V} = 1.9. \qquad (9)$$

If the amount of cold is reduced to the value Q_{0CH} = 0.17 MJ, then, at the unchanged value of heat supplied for the cooling engine generator Q_{GCH} = 0.27 MJ, the amount of heat from the condenser will then be Q_{KCH} = 0.44 MJ. Then, for the same cooling engine using condensed heat the following will held:

$$COP_{MCH} = \frac{A_{MCH} + Q_{CH}}{Q_{MCH}} = 0.52,$$

$$PER_{MCH} = \frac{1}{COP_{MCH}} = 1.92,$$

$$COP_{ACH} \frac{Q_{OCH} + Q_{KCH} + Q_{ABCH}}{Q_{GACH} + P_{CCH}} = 2.17, \qquad (10)$$

$$PER_{ACH} = \frac{1}{COP_{ACH} . \eta_{ACH}} = 0.51.$$

and the total coefficient of primary energy utilization rate of the cooling engine will be:

$$PER_{CHM} = \frac{PER_{MCH} . A_{MCH} + PER_{ACH} . Q_{VCH}}{A_{MCH} + Q_{VCH}} = 1. \qquad (11)$$

3. Conclusion

From the above mentioned it is obvious that in the cooling engine there will be reduction of the PER (from value 1.9 to value 1.0), i. e., there will be increase in the efficiency of primary energy utilization. It is, therefore, quite realistic to use the non-conventional energetic unit with a cooling engine with more efficient utilization of primary energy, i. e. fuel energy, as a classical separated aggregate composed of a combustion engine and sorption cooler.

A more remarkable effect in utilization of fuel primary energy can be achieved when the obtained cold is utilized for the cooling of charging air behind the engine blower. If the charging air was cooled from 313 K to 288 K, a simplified calculation could show that the coefficient of primary energy utilization rate would fall to the value of 0.88.

References

[1] Sojčák, D., *Spaľovací motor s nekonvenčným chladiacim okruhom*, Strojnícka fakulta Žilinskej university v Žiline, doktorandska dizertačná práca, Žilina 2006.

[2] Piroch, P., *Efektívnejšie využitie energie paliva v nekonvenčnom spaľovacom motore*, Strojnícka fakulta Žilinskej university v Žiline, doktorandska dizertačná práca, Žilina 2006.

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