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Modelling of physical processes of energy conversion in automobile thermoelectric generators

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Abstract

A mathematical model of automobile thermoelectric generator, which converts exhaust heat into electrical energy, is represented. The model is based on the nonlinear equations of thermal flows balance and power balance implemented in MATLAB software by means of quadratic residual optimization methods. Developed model, which includes conversion processes of electrical, mechanical and thermal energies in automobile, enables the calculation of output electrical power of the thermoelectric generator and the fuel economy while preserving the effective horsepower by means of unloading the electromechanical generator, and other characteristics of the thermoelectric generator. Modelling results showed, that the thermoelectric generator usage in automobile engine of 106 kW allows either the fuel economy up to 0,4 l/h or generating the electrical power up to 820 W. The difficulties of obtaining effective operation of the thermoelectric generator at low automobile engine rpm speed were found out.

Keywords: Thermoelectric Generator, Seebeck Effect, Internal Combustion Engine, Efficiency, Utilization Of Exhaust Heat.

Introduction

Available capability of the modern automobile engines is approximately 35 % of the burn-off fuel energy. Another part of the fuel energy is converted into heat and removed by coolant and exhaust. It has a high potential both in effectiveness increasing of the engine operation and in utilization of the heat losses.

One of the most promising [1-5] methods of the energy effectiveness improvement of the vehicles with internal combustion engine (IC-engine) is a direct conversion of exhaust heat into electricity by means of the thermoelectric batteries (TEB), which are based on the Seebeck effect. Despite the relatively low efficiency of such batteries for today (approximately 5-6 %), the quantity of exhaust heat, which is from dozens (for motor cars) to hundreds (for automotive trucks) kW, is enough if not for full, but for partial energy consumption satisfying of the vehicle, that leads to the fuel economy by means of generator unloading. For instance, in a motor car with the engine power of 106 h.p. the thermal flow of exhaust will equal to approximately 80 kW. However, if we convert 20 % of this thermal flow into electricity with efficiency of 5 %, one can obtain 800 W electrical power that may be enough to abandon regular generator. It enables to economize 2 % fuel at generator efficiency of 50 %. Depending on the type of the vehicle, the economy may be up to 5…10 % [4-8].

The whole effectiveness of the vehicle with the thermoelectric generator (TEG) will significantly depend on used process design solutions and engine operation modes. TEG installation at the output collector increases an available temperature difference on the junctures of the thermoelectric batteries (TEB) and consequently increases efficiency of the TEG.

At construction development of the TEG, it is necessary to solve the problem of the heat loss intensification from exhaust to the TEB junctures having limited aerodynamic resistance. At the same time, increasing the thermal flow through the batteries of the TEG will increase the load on its cooling system. However, a great part of electrical power, produced by generator, could be wasted on its operation, and an effectiveness of its installation is extremely low.

Choosing the design solutions, parameters and operation modes of the TEG at its construction development is a highly difficult problem because of necessity, in the design process, to take into account plenty of physical processes and quality parameters. It is also necessary to consider the gasdynamic influence in the flow channel, thermal conductivity in the TEG case, thermoelectric effects in TEB, additional energy losses on the TEG operation, and operation modes of the IC-engine. Complex analysis of the TEG and integral quality parameters determination require the development of model, which includes, in a simplified formulation, basic physical processes in generator.

Nowadays, different models, which enable to calculate the TEG for the IC-engine [6-21], are developed. The models are distinguished by their functionality, used methods and complexity. At the same time, the models, which describe in complex an operation of the IC-engine with installed TEG, taking into account conversion of electrical, mechanical and thermal energy, were not found out. The objective of this work is creating a convenient tool for development and optimization of the TEG construction for the engines of a various purposes. In this work, the mathematical model, which includes the whole complex of processes described above, was developed.

Model Description

Object of study

The TEG construction prototype and its flowchart are represented in Figure 1.

The temperatures marked in: hot surface of the hot heat-exchange unit T_1, hot and cold junctures of the TEB T_2, T_3, cold surface of the cold heat-exchange unit T_4, hot and cold water in the coolant loop T_{w2}, T_{w1}. The other designations are illustrated in this section below.

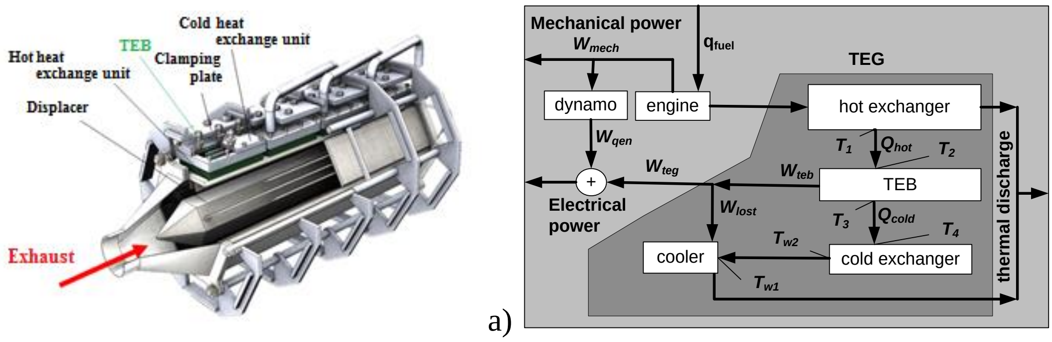

Fig.1. TEG schematic: a) – heat-exchange unit, b) – flowchart

Movement of exhaust through the hexagonal-shaped chamber of the TEG and transmit the thermal flow Q_{hot} to a finned hot heat-exchange unit. Displacer element and heat-exchange unit fins are installed inside the generator camera to intensify the thermal transmission process from exhaust to the TEB junctures. The TEB transforms a part of the thermal power Q_{hot} into electrical power by means of the Seebeck effect. The remaining power Q_{cold} is removed into environment by the cold heat exchange unit, water cooling system and radiator. Since the TEG itself consumes an electrical power W_{lost} on the coolant loop supply and driver electronics, the output power of the TEG W_{teg} will be lower than total battery power W_{teb}. As efficiency of the TEB η_{teb} and the whole TEG η_{teg}, accepted ratios of the output electrical powers to the passing thermal flow Q_{hot} as follows:

$$W_{teg}=W_{teb}-W_{lost}, \quad (1)$$

$$\eta_{teb}=W_{teb}/Q_{hot}, \quad (2)$$

$$\eta_{teg}= W_{teg} /Q_{hot}. \quad (3)$$

Additional energy generation by means of exhaust heat utilization enables the electromechanical generator of automobile to be unloaded and thereby the mechanical effective horsepower to be increased by ΔW_{mech} while preserving a fuel consumption or the fuel consumption to be reduced by Δq_{fuel} while preserving a mechanical power. At the same time, installation of the TEG increases the total mass of automobile that may reduce power-to-weight ratio. Effective work of the TEG requires complex analysis of the TEG parameters (table 1).

TABLE 1. TEG parameters of motor car VAZ 21127 IC-engine

IC-engine parameters and its operational modes		
Exhaust temperatures at TEG input	T_{eg1}^{E}	1070 K
Rotational speed	n_E	800…5800 rev·min^{-1}
Total engine cylinders volume	$V_{\Sigma cyl}$	1.6 l
Engine efficiency	η_{Eg}	0.4
IC-engine generator efficiency	η_{gen}	0.5
Pump efficiency of the cooling water system	η_{w2}	0.8
TEG parameters		
Internal part surface area of heat exchange unit without fins	S_1	0.1548 m^2
Hot junctures area of TEB	S_2	0.108 m^2
Cold junctures area of TEB	S_3	0.108 m^2
Surface of water heat exchange unit	S_4	0.135 m^2
Coolant consumption	G_w	0.05 l·s^{-1}
Finning coefficient in flow channel of TEG	k_{i_eg}	1.3 or 4.0
Intensification coefficient of cooling loop flow channel flux	k_{i_w}	1
Average Seebeck coefficient of TEB material	$\bar{\alpha}_{teg}$	187 μV/K
Average electrical resistivity of TEB material	$\bar{\rho}_{e\_teg}$	0.0018 Ohm·cm
Average coefficient of thermal conductivity of the TEB material	$\bar{\lambda}_B$	0.017 W/cm·K

Included physical processes

The mathematical model of the TEG consider the following physical phenomena:

- heat loss of exhaust in the TEG case flow channel;
- thermal conductivity of the heat exchange units and TEB;
- Seebeck effect;
- heat removing from the TEG case in the cooling water system;
- electrical losses in the cooling loop (supply of pump and ventilator);
- mechanical engine power increase and alternative fuel economy.

Since an accurate description of mentioned processes is difficult and it is necessary to consider them in complex, these processes in the developed model are simplified.

Physical hypotheses of the model

a) TEG represents a set of plates with various areas when heat movement describing in TEG [22-23].

b) Calculation of the heat loss coefficients of the heat exchange units was carried out for averaged temperatures of the flow channels. Contact thermal resistances of the TEG case joints are not considered.

c) Description of thermoelectrical effects was performed according to the technique of O.V. Marchenko [24], which assumes the thermal balance implementation on the TEB case, Kirchhoff's circuit laws, TEB operation in the maximum efficiency mode. Similarly with [24], a smallness of the heat leakage on the TEG protecting case and electrical resistances of the switching, eventually described by correction coefficients, was assumed.

d) Hydraulic losses description was based on calculation of the complex pipeline without local resistances [25].

e) Static temperature distribution and the absence of thermal losses from pulling-out and in the mounting points are assumed;

f) Increment of effective horsepower and a fuel economy calculation was carried out according to energy balance.

g) Connection circuit of the TEG in independent cooling loop is considered, which at latter switching in IC-engine cooling system, enables the calculation of required increase its productivity aimed to feedback effect levelling of the TEG on engine operation.

Parametrization of incoming exhaust

Volume flow rate of exhaust from four-cylinder four-stroke IC-engine, and the average exhaust rate in the flow channel of the TEG are determined in the model as follows:

$$Q_{W\_eg} = k_{type} \frac{V_{\Sigma cyl} n_E}{2} \frac{\rho_{eg}}{\rho_{eg}} \frac{T_0}{T_{eg1}^E},$$

$$k_{type} = \begin{cases} 0,9 \; for\ diesel\ engine \\ 1,16 \; for\ petrole\ engine, \end{cases} \tag{4}$$

$$\bar{V}_{eg} = \frac{Q_{W\_eg}}{S_{\sec\_eg}}, \tag{5}$$

where n_E – engine shaft rotation speed; $V_{\Sigma cyl}$ – IC-engine cylinders volume; T_0 – environment temperature; ρ_{eg} – exhaust density; S_{sec_eg} – cross section of the TEG flow channel.

Heat transfer equations in TEG

Thermal flows through the hot and cold heat exchange unit based on an integral form of the thermal balance equations:

$$Q_{hot} = \left(\frac{\delta_A}{0.5\lambda_A \; S_1 + S_2} + \frac{\delta_{case}}{\lambda_{case} S_2} \right)^{-1} \; T_1 - T_2 \; ,$$

$$Q_{cold} = \left(\frac{\delta_C}{0.5\lambda_C \; S_3^T + S_4} + \frac{\delta_{case}}{\lambda_{case} S_3} \right)^{-1} \; T_3 - T_4 \; , \tag{6}$$

where S_1, S_2, S_3, S_4 – average areas of internal heat exchange unit surfaces, hot TEB joints, cold TEB joints, TEB water cooling loop; Q_{cold} – total thermal flow through the cold heat exchange unit; δ_{case}, λ_{case} – average thickness and thermal conductivity of the TEB wall; δ_A, λ_A – average thickness and thermal conductivity of a hot heat exchange unit, δ_C, λ_C – average thickness and thermal conductivity of a cold heat exchange unit.

Thermal conductivity equation for TEB including volume transformation of thermal power Q_{hot} into electrical power W_{teb} can be expressed as follows:

$$Q_{hot} - \frac{W_{teb}}{2} = Q_{cold} + \frac{W_{teb}}{2} = \frac{S_2 + S_3}{2} \frac{\bar{\lambda}_B}{\delta_B} \left(T_2 - T_3\right), \tag{7}$$

where $\bar{\lambda}_B^{TO1}$, δ_B – averaged thermal conductivity of thermoactive material and thickness of the TEB.

For outer surfaces of hot and cold heat exchange units the condition of convective heat exchange, which includes availability of fins by means of finning correction coefficients and flow intensification (k_{i_w} and k_{i_eg}):

$$\begin{aligned} Q_{hot} &= k_{i\_eg} \alpha_{eg} S_1 \left(T_{eg} - T_1\right), \\ Q_{cold} &= k_{i\_w} \alpha_w S_4 \left(T_4 - 0.5\left(T_{w1} + T_{w2}\right)\right), \end{aligned} \tag{8}$$

where α_{eg}, α_w – heat loss coefficients of hot and cold heat exchange units; T_{w1}, T_{w2} – cooling water temperature of the TEG input and output; T_{eg} – exhaust temperature at IC-engine output.

At preliminary calculations, the heat loss coefficients α_{eg} and α_w were determined by equations for the straight-through tubes with the gas [26] and liquid [27]

$$\begin{aligned} &\alpha_{eg} = \frac{\mathrm{Nu}_{eg}\,\lambda_{eg}}{d}, \ \mathrm{Nu}_{eg} = 0,022\,\mathrm{Re}_{eg}^{\,0.8}\mathrm{Pr}_{eg}^{\,0.43}\,\varepsilon_{Leg}, \\ &\alpha_w = 1,55\varepsilon_{Lw}, \left(\mathrm{Re}_w\ \mathrm{Pr}_w\ \frac{D_c}{L_c}\right)^{1/3} \left(\frac{0,5\mu_w\left(T_{w1} + T_{w2}\right)}{\mu_w\left(T_4\right)}\right)^{0.14}, \\ &\varepsilon_{Leg} = \varepsilon_{Lw} = 1, \end{aligned} \tag{9}$$

λ_{eg}, Nu_{eg}, Re_{eg}, Pr_{eg} – thermal conductivity, Nusselt, Reynolds and Prandtl numbers of exhaust; Re_{eg}, Pr_{eg} – Reynolds and Prandtl numbers of exhaust; d – averaged diameter of the TEG chamber flow channel; D_i, L_i – diameters and cooling loops, μ_w, Re_w, Pr_w – dynamic viscosity and Reynolds and Prandtl numbers for water in cooling loop; D_c, L_c – diameter and length of the cooling channel.

Coefficients ε_{Leg} and ε_{Lw} are assumed to be equal 1 for reserve increase. An accurate analytical determination of the heat loss coefficients is hardly possible because of the flow channel complex geometry; moreover, the fins are expected to be installed on it, so obtained from (9) and (10) values are preliminary. Further, for accuracy increasing and considering the real geometry, heat loss coefficient of the heat exchange units may be corrected experimentally or while 3D modelling of the gas and fluid flow.

The equations (6), (7) and (8) and the thermal balance equation for cooling liquid

$$Q_{cold} = G_w \rho_w c_{pw} \left(T_{w2} - T_{w1}\right), \tag{11}$$

where G_w,, ρ_w, c_{pw} – volume flow rate, density and thermal capacity of the cooling liquid.

These equations form the resolving equation system, which requires additional conditions of heat exchange (9), (10) and state equations of the TEB.

Thermoelectric effect description

Thermoelectric Q factor of the TEG can be expressed as follows:

$$z = \frac{\bar{\alpha}_{teg}^{\,2}}{\bar{\rho}_{e\_teg}\bar{\lambda}_B \left(1+\varepsilon_\kappa\right)\left(1+\varepsilon_p\right)}, \tag{12}$$

where $\bar{\alpha}_{teg}$, $\bar{\rho}_{e\_teg}$ и $\bar{\lambda}_B$ – averaged thermo-emf coefficient, resistivity and heat-conduction coefficient used in TEB thermoelectric materials; ε_p and ε_κ – coefficients, which indicate electric losses on the switching layers and heat leakages on protective coatings respectively (while calculations, the following values were assumed $\varepsilon_p=6\cdot10^{-2}$, $\varepsilon_\kappa=5\cdot10^{-2}$).

Accordingly, the efficiency and output electrical power of the TEB expressed as

$$\eta_{teb} = \frac{\Delta T_{teb}}{T_2}\frac{M-1}{M+\frac{T_3}{T_2}}. \tag{13}$$

$$W_{teb} = \eta_{teb} Q_{hot}. \tag{14}$$

Where

$$M = \sqrt{1+z\bar{T}_{teb}} \tag{15}$$

ΔT_{teb} – temperature gradient on the TEB junctures, $\bar{T}_{teb}$ – average temperature of the TEB.

The geometry of the thermoelements (number of pair of branches N and cross section areas of p-type and n-type branches (S_p and S_n) were determined as follows

$$N = \frac{V_{teg}}{2\bar{\alpha}_{teg}\Delta T_{teb}}\left(1+\frac{1}{M}\right), \tag{16}$$

$$S_p = \frac{Q_{hot}\delta_B}{\bar{\lambda}_B\left(1+\Psi\right)\Delta T_{teb} N}\frac{1}{M}\frac{1-\eta_{teg}/2}{1+\varepsilon_\kappa}. \tag{17}$$

$$S_n = \Psi S_p. \tag{18}$$

Where

$$\Psi = \sqrt{\frac{\rho_{e\_n}\lambda_p}{\rho_{e\_p}\lambda_n}}, \tag{19}$$

V_{teg} – electrical voltage on TEB.

Required parameters of the TEB construction and produced electrical power by generator may be determined at given thermoelectric materials and thickness of the TEB, measured voltage V and thermal mode.

Determination of energy losses on TEG operation

Energy losses in the model are determined by additional hydraulic losses in the cooling system W_w and by expenses on the forced radiator air-cooling W_a. Hydraulic losses calculation was carried out without considering the local resistances according to Nikuradse [25]:

$$
\begin{gathered}
W_{lost} = W_a + W_w, \\
W_a = a_a Q_{cold}, \qquad W_w = \Delta p_w G_w \eta_{w2}, \\
\Delta p_w = \rho_w \frac{8 G_w^2}{\pi^2} \sum_i \frac{\lambda_{w\_hydro\_i} L_i}{D_i^5}, \\
\lambda_{w\_hydro\_i} = \begin{cases} \dfrac{64}{\mathrm{Re}_{wi}}, \text{ if } \mathrm{Re}_{wi} \le 2300, \\ \dfrac{3{,}2 + 221 \mathrm{Re}_{wi}^{0.237}}{1000}, \text{ if } \mathrm{Re}_{wi} > 2300, \end{cases}
\end{gathered}
\tag{20}
$$

where $\lambda_{w\_hydro\_i}$ –hydraulic resistance coefficient of the channel, η_{w2} – cooling water pump efficiency.

The coefficients W_w and W_a reflect additional power losses in unified cooling system of IC-engine and TEG on additional load of the cooling system.

Quality characteristics determination of the TEG

Generated power of the TEG, including energy losses on its operation, will be slightly smaller the total power generated by TEB

$$W_{teg} = W_{teb} - W_{lost}. \tag{21}$$

But for the TEG efficiency η_{teg} and additional effective horsepower by means of IC-engine generator unloading ΔW_{mech} one can write out the following expressions

$$\eta_{teg} = \frac{W_{teg}}{Q_{hot}}. \tag{22}$$

$$\Delta W_{mech} = \frac{W_{teg}}{\eta_{gen}}. \tag{23}$$

where η_{gen} – efficiency of conventional generator.

Reduction of fuel consumption while preserving an output engine power was determined by following expression

$$\Delta q_{fuel} = \frac{W_{teg}}{\eta_{gen} \eta_{Eg} c_{fuel} \rho_{fuel}}, \tag{24}$$

where η_{Eg} – IC-engine efficiency, c_{fuel}, ρ_{fuel} – fuel heating effect and fuel density.

The calculation technique of O.V. Marchenko determines the area and number of thermoelements required for maximizing TEB efficiency at given thermal mode. In order to verify that the pairs of N thermoelements with the area of S_p and S_n can be located on TEB, which has selected dimensions, an assemblability coefficient of the TEG was introduced

$$k_{fit} = \frac{\min(S_2, S_3)}{N \left(S_p + S_n\right)}. \tag{25}$$

For k_{fit}=1 the whole internal volume of the TEB should be filled by the thermoelements. Because of necessity to have space between them and an internal switching location it is required to provide k_{fit}>1,2. If k_{fit}>2, the construction probably will be noneffective, because not the whole area of the TEB will be used.

Implementation of calculation model

The following unknown variables were chosen: Q_{hot}, T_1, T_2, T_3, T_4, T_{w2}.

The system of the six nonlinear algebraic equations for thermal flows (4)-(11) was taken into account as resolving system. Nonlinearity reasons:

– properties of liquid and gas depend on temperature $\rho_{eg}(T)$, $\rho_w(T)$, $\lambda_{eg}(T)$, $\lambda_w(T)$, $\mu_w(T)$. These characteristics are defined by interpolating dependences on referenced data [26].
– dependence of the heat loss coefficients on viscosity, which is changed with temperature;
– nonlinearity of TEG dependence W_{teb}= *function*(Q_{hot},T_2,T_3).

Resolving system was solved in MATLAB software by searching quadratic weighted residual minimum based on optimization methods during 3 stages:

– linearized model approach at approximately given averaged temperatures k_{fit}=1 and $\eta_{teb}=0{,}05$;
– local constrained minimum searching by means of genetic algorithm, incorporated MATLAB methods. To ease the solution of optimization problem, using genetic algorithm in six-dimensional space of unknown variables, the limitations on variable values are considered:

$$T_{eg}^{E} \geq T_1 \geq T_2 \geq T_3 \geq T_4 \geq T_{w2} \geq T_0,\ T_{w2} \leq 373^{o}K,\ Q_{hot}>0. \qquad (26)$$

A genetic algorithm optimization advantage is the searching possibility of constrained global minimum for nonsmooth or even discontinuous objective functions [27].

– correction of solution by Nelder-Mead method.

Results And Discussion

The calculations were carried out by the example of motor car VAZ 21127 IC-engine with the power of 106 h.p. and suggested TEG prototype. The influence of IC-engine shaft rotation speed and coolant flow on performance characteristics of the TEG is considered. In both cases, the calculations were carried out for two values of intensification coefficient and finning coefficient of the TEG flow channel k_{i_eg}. ($k_{i\_eg\_min}$=1,33 and $k_{i\_eg\_max}$=4).

Influence of IC-engine rotation speed

Increasing of rotation frequency n_E leads to increasing of exhaust speed, heat loss intensification and TEG power W_{teb}. Because of the low heat loss intensity at low shaft rotation speed, generated by TEB power drops sharply (figure 2).

Practically, there are no temperature differences on the hot T_1-T_2 and cold T_3-T_4 heat exchange units, which indicate a low influence of its thermal resistance.

The most important factor, which influences on the TEG power and efficiency, is the heat transfer intensity of exhaust. An increase of k_{i_eg} by 3 times (for instance, by increasing the fins area) leads to the thermal flow increase Q_{hot}, but no more than 2 times. Further increase of k_{i_eg} will allow TEG effectiveness improvement just at low IC-engine rotation speed.

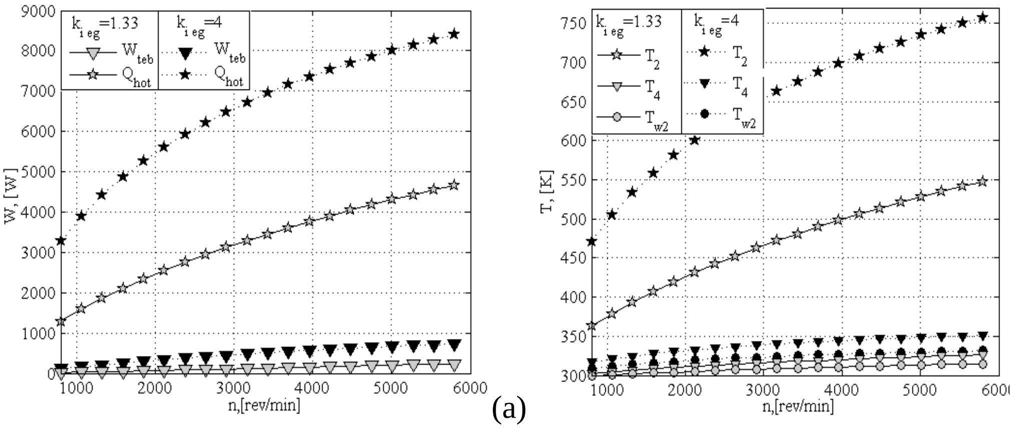

Fig.2. Influence of IC-engine shaft rotation speed n_E (a) – on TEG power W_{teg} and supplied thermal flow Q_{hot}, (b) – on specific temperatures

Moreover, adding of fins and heat exchange intensificators will increase the construction cost and exhaust aerodynamic resistance.

Thermal flow increase through the TEG increases the TEG electrical power consumption W_{lost} on its operation, because of losses on cooling system air-cooling W_a (figure 3). In this example, electrical power losses on the coolant W_w are incomparably lower.

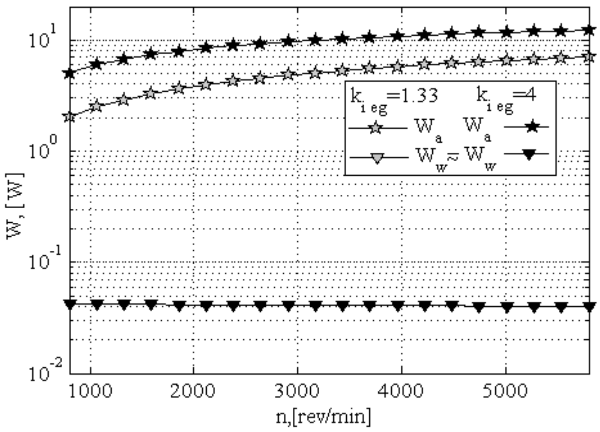

Fig.3. Influence of IC-engine shaft rotation speed n_E on electrical consumption of the TEG components: hydraulic losses W_w and losses on ventilator operation W_a

Increase of k_{i_eg} and engine rotation speed significantly increases generated power W_{teg}, fuel economy Δq_{fuel} and efficiency of the TEG η_{teg} (figure 4).

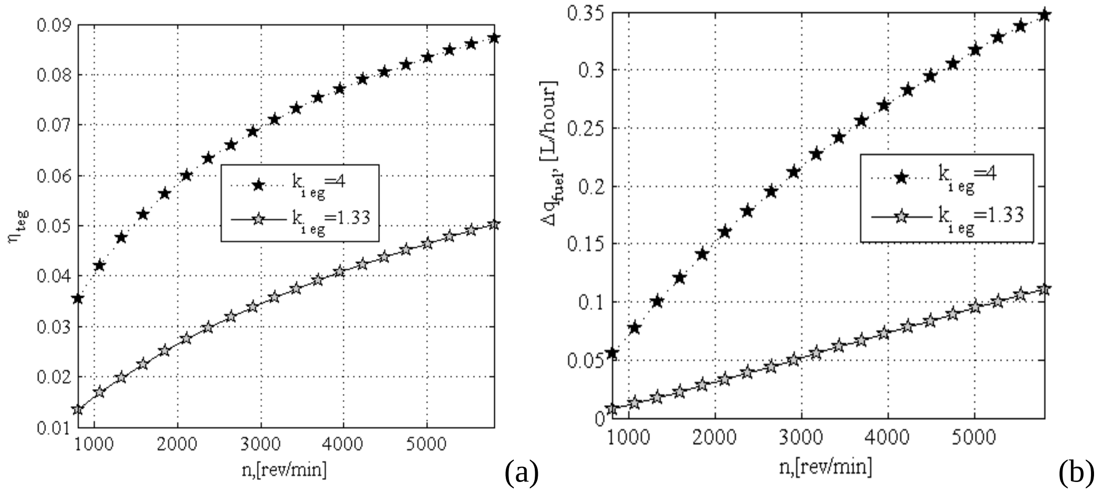

Fig.4. Influence of IC-engine shaft rotation speed n_E: (a) – on TEG efficiency; (b) – on fuel consumption reduction Δq_{fuel}

Influence of water consumption in the cooling system

The heat loss coefficient of the hot heat exchange unit is constant at increasing of volume flow rate of water in the cooling system G_w from $5\cdot10^{-5}$ to $1\cdot10^{-3}$ $m^3\cdot s^{-1}$ and not depending on consumption of coolant. In this case, the heat loss coefficient of the cold heat exchange unit increases by 4 times. Intensity increase of a heat removal weakly increases the thermal flow Q_{hot} supplied to the TEB, because the temperature of the heat exchange unit cold wall at G_w>10 $l\cdot min^{-1}$ is also reduced negligibly (figure 5).

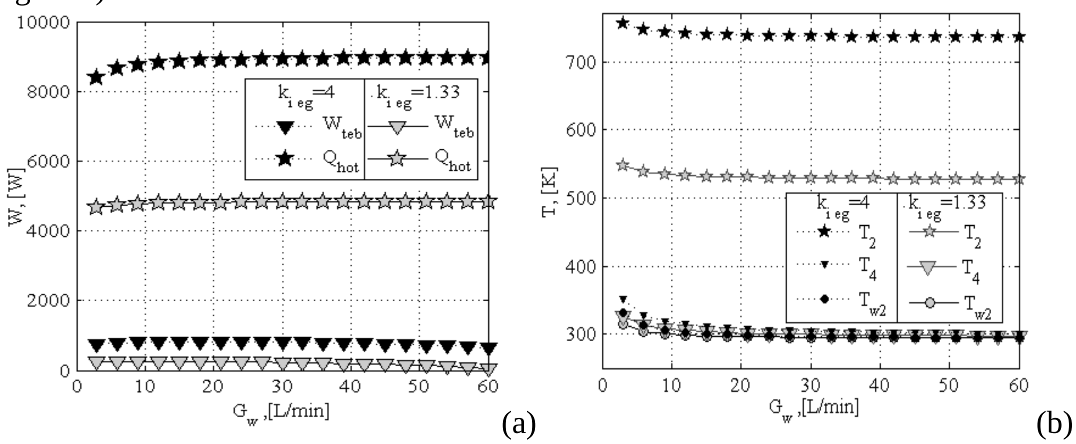

Fig.5. Influence of volume flow rate of water G_w: (a) – on the TEG power W_{teg} and passing through it thermal flow Q_{hot}; (b) – on specified temperatures

Augmentation of volume flow rate by 20 times increases power losses on water pumping in the cooling loop by 4660 times. If volume flow rate of water G_w=5·10^{-5} m^3·s^{-1}, the losses W_w are incomparably lower (approximately 500 times) than W_a, but at G_w=1·10^{-3} m^3·s^{-1} the hydraulic losses W_w are greater than losses on ventilator operation W_a by 8 times, that significantly decreases the total power generated by TEG, TEG efficiency η_{teg} and a fuel economy Δq_{fuel} (figure 6).

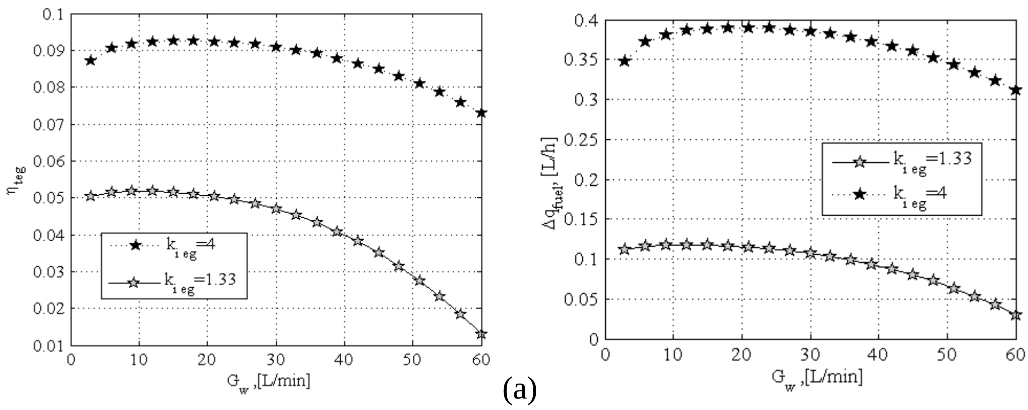

Fig.6. Influence of volume flow rate of water G_w: (a) – on TEG efficiency η_{teg}, (b) – on fuel consumption reduction Δq_{fuel}

In order to ensure TEG effectiveness, it is necessary to choose reasonably the construction parameters and, when necessary, change them (for instance, increase the diameter of the cooling system channels) or operation modes parameters of the TEG (for instance, consumption of a pumped coolant). By liquid consumption management in the cooling system, one can regulate the TEG parameters (power or efficiency) in unfriendly environment, for instance, at low engine rotation speed.

Conclusion

Developed mathematical model allows choosing the automobile construction parameters of the TEG and estimation its effectiveness in a various operation modes.

It was established, that the TEG operation effectiveness (TEG efficiency η_{teg} and generated power W_{teg}) is determined preliminary by the heat loss coefficient of the hot heat exchange unit α_{eg} and by its finning coefficient k_{i_eg}.

Modelling results showed, that usage of VAZ 21127 engine with the power of 106 kW one can reach the TEG efficiency up to 9 %, that corresponds to the fuel economy Δq_{fuel} up to 0,4 l/hr and TEG power W_{teg} up to 820 W.

At the same time, considering that the heat exchange of exhaust and coolant with the TEG case substantially influences on its operation effectiveness, and the complexity of an internal TEG construction does not allow solving the problem of the gas flow and thermal flows in analytical form, because of turbulent flow and edge heat leakages, it is reasonable to consider these phenomena in details by numerical solution of differential equations system based on fundamental equations of 3D nonstationary transfer aimed to check accepted physical hypotheses.

However, the question about possibility of effective TEG operation for all engine rotation speeds and transition processes in engine still open.

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