ANALYSIS OF THE APPLICATION OF THERMAL ENERGY OF EXHAUST GASES ESCAPING FROM TRANSPORTATION AND POWER INSTALLATIONS

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Abstract: *In order to convert thermal energy of exhaust gases from vehicles into some useful work it is necessary to study the complex heat transfer process between exhaust gas and coolant. Three sections can be considered here. The first one – from the coolant's outlet until the beginning of its boiling point; the second one – the boiling section; and at the third one – there is occuring the coolant's temperature rise at the account of heat generated by exhaust gas. The results of theoretical investigations carried out enable us to analyze the effect of heat-exchanger parameters variation on the heat flow quantity.*

KEYWORDS*: TRANSPORTATION AND POWER INSTALLATIONS; AIR-CONDITIONING; EXHAUSTS; EVAPORATOR*

1. Introduction

Thermal energy of exhaust gases of vehicles, which they generate after passing through the exhaust valve, ischaracterized by high amount of heat and operating capacity, which can be implemented through the performance of work or by spending of heat. This requires converting of a certain quantity of thermal energy escaping from the exhaust gases into the useful work, and using of this energy for efficient operation of vehicle's interior heating and air-conditioning system. In this respect, we have to carry out theoretical investigations of heat transfer process by taking into account all those factors, which considerably impact on the complex heat transfer process between exhaust gas and coolant, or on the heat transfer from the hot to cold heat conductor occuring in heat exchanger (Fig. 1), [2].

2. Preconditions and means for resolving the problem

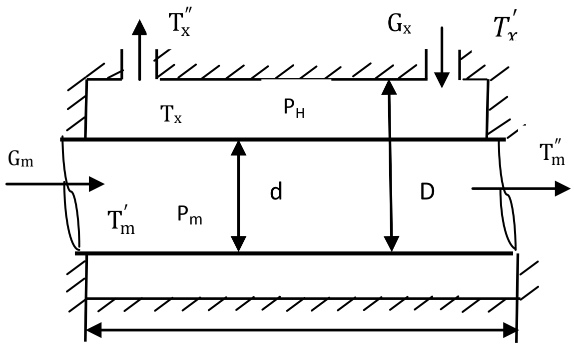

Fig.1. Computational Scheme of Heat [illegible]er Occurring in Heat Exchanger

In accordance with heat transfer processes that take place in heat exchanger, it is possible to emphasize three sections. The first one is beginning at the inlet of collant and ended where the coollant begins to boil. At this section, the coolant's temperature is increasing from T_x' until T_x' , and heat escaping from gas is spent for increasing the coolant's temperature, and the following equation takes place:

$$G_m C_p \frac{\partial T_m}{\partial x} = G_x C_x \frac{\partial T_x}{\partial x}$$

where, G_m–spendings of combustion products per second, which are outgoing from the engine's valve (kg/sec) - represent the time-varying function;

C_p- combustion products heat capacity (j/kg^{0}K);

T_x –coolant's temperature in ^{0}K-time is the time-varying function;

T_m- coolant's temperature in ^{0}K-time is the time-varying function;

G_x- spendings of coolant per second(kg/sec) - represent the time-varying function

The second section is characterized by boiling and the following ratio is typical of tis section:

$$G_m C_p \frac{\partial T_m}{\partial x} = G_x C_x \frac{r}{L'}$$

where, r- is a specific heat of coolant evaporation in accordance with P_H, $T_H$parameters (j/kg);

L'- boiling section's length (m).

The third section is characterized by an increase in coolant's steam temperature from T_H untilT_x''. The differential equation of the energy balance on this section has the following expression:

$$G_m C_p (T_m' - T_m'') = G_x [C_x (T_H - T_x') + r + C_x' (T_x'' - T_H)]$$

where,T_m'andT_m'' - of combustion products at the inlet and outlet of the tube ^{0}K;

T_H–boiling temperature of coolant ^{0}K;

T_x', T_x'' - temperatures of coolant at the inlet and outlet of heat exchanger;

C_x' - heat capacity of water and ammonia steam j/kg(^{0}K).

First of all, in order to calculate the process parameters we determine the heat conductivity coefficients. For this purpose, it is necessary to calculate [1]:

a) Combustion products density

$$\rho_m = \frac{P_m}{R T_m} \text{kg/m3}$$

b) Combustion products instantaneous velocity

$$W_m = \frac{4 G_m}{\pi d^2 \cdot \rho_m} \text{m/sec} \ .$$

c) Reynolds number for combustion products flow in the tube

$$R_e = \frac{W_m d}{\gamma_m}$$

where, γ_m- combustion products kinematic viscosity (m^2/sec).

d) Nusselt number

$N_u = 0{,}023 R_e^{0,8} \cdot P_r^{0,43}$if R_e=23,40^3 ÷10^4

$N_u = 0{,}023 R_e^{0,8} \cdot P_r^{0,43}$if R_e=10^4 ÷5·10^6

where, P_r–combustion products Prandtl number

e) Heat-transfer coefficient on the internal surface of tube is calculated in following way

$$\alpha_1 = \frac{N_u \cdot \lambda_m}{d}$$

where, λ_m–is a coefficient of heat conductivity of combustion products W/m^{0}K.

Since the coolant's spendings and velocity in heat exchanger are knot known, we have to set and then verify theheat-transfer coefficient at the external surface of tub. At the first stage, it is possible to derive $\alpha_2 \approx \alpha_1$, and then the heat-transfer coefficient is determined by the following formula:

$$K = \frac{1}{\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{1}{\alpha_2}}$$

Combustion products temperature at the outlet from the tube

$$T_m^{''} = T_H + (T_m^{'} + T_H) exp \left[\frac{-2\pi pKdL}{C_m C_p}\right] (^0\text{K.}) ;$$

Heat exchanger heat capacity

$$N_T = G_m C_p (T_m^{'} - T_m^{''}) \ \ (\text{W}) .$$

Coolant's spendings per second at the outlet of heat exchanger

$$G_x = \frac{N_T}{C_x (T_H - T_x^{'}) + r + C_x^{'} (T_x^{''} - T_H)} \text{kg/sec.}$$

Thus and so, for each instantaneous quantity of G_m and T_m, we determine the coolant's spendings at the outlet, and the average spendings of approximately one cycle will be

$$\overline{G_x} = \frac{1}{T_e} \int_0^{T_e} G_x dT$$

Just after we have determined the average spending of coolant, we can determine theheat-transfer coefficientd$_2$in the following succession:

$$W_x = \frac{4G_x}{\pi (D^2 - d^2) \rho_x} \text{m/sec}$$

where, D –is heat-exchanger's internal diameter, (m);

d- diameter of outlet tube of the engine, (m);

ρ_x–coolant density, (kg/m^3).

Reynolds number

$$R_{ex} = \frac{W_x (D - d)}{\gamma_x}$$

where, γ_x–coolant's kinematic viscosity, (m^3/sec).

Nusselt number

$\text{N}_\text{u} = 0{,}08\text{R}_\text{ex}^{0,9} \cdot \text{P}_\text{rx}^{0,4}$, if R_ex=2,3 $\cdot 10^3 \div 10^4$

$\text{N}_\text{u} = 0{,}023\text{R}_\text{ex}^{0,8} \cdot \text{P}_\text{rx}^{0,43}$, if R_ex=$10^4 \div 5 \cdot 10^6$

Heat-transfer coefficient α_2

$$\alpha_2 = \frac{N_u \cdot \lambda_x}{D - d}$$

where,λ_x–coolant's heat conductivity coefficient (W/m^{0}K);P_rx - Prandtl number for coolant.

After this, we will calculate heat flow repeatedly taking into account the verified quantity of α_2.

3. Conclusion

After theoretical calculation of heat-transfer process, there are determined the parameters of heating and air-conditioning system of the vehicle's interior.

The results of theoretical investigations carried out enable us to analyze the effect of heat-exchanger parameters variation on the heat flow quantity, which are required for the effective operation of heating and air-conditioning system of vehicle's interior.

4. Literature

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