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THE RESEARCH OF ENVIRONMENT TEMPERATURE INFLUENCE ON THE INPUT AND OUTPUT EXERGY FLOWS IN AIR-SPLIT CONDITIONERS REFRIGERATION MACHINES

1. Resolution of the problem

A research of perfection of the refrigerating processes and development and improvement of refrigerating machines of air-split conditioners requires the use of modern achievements of thermodynamics. The classic apparatus of science is insufficient to resolve new problems.

Under the influence of these requirements in the last decade there has been designed *exergetic* method. Its main idea is in the introduction, along with common fundamental concept of *energy*, of an additional indicator - exergy, which allows to count the fact that the energy depending on external environment conditions may have a different value for practical use [1-3].

Refrigeration processes occur irreversibly and in each case the irreversibility is the reason for decreasing of the process perfection. This decreasing is not due to loss of energy, it is associated with a decrease in its quality. In the irreversible processes the energy is not disappearing - it is dissipating. Each irreversible phenomenon is the reason for irreversible *loss of exergy* in different links of refrigerating process. Detection and quantitative estimation of the reasons which decrease the process perfection and obtaining information about the possibility of increasing this perfection is the main purpose for exergetic analysis of the refrigerating processes. Therefore, for making an evaluation of the energy efficiency of refrigerating equipment of air-split conditioners it used to apply a general index of energy efficiency, or *exergetic output-input ratio* (exergetic coefficient efficiency).

2. Analysis of recent research and publications

Modern air-split conditioners, which are used to create an appropriate micro-climate in small buildings, achieved certain technical improvements. For further improvement of the efficiency of these air conditioners it is necessary to have a detailed analysis of their functioning.

For this, it has been developed by the authors a method of exergetic analysis of the air-split conditioners refrigerating machines, which is a method of thermodynamic research of refrigeration unit as a whole in general and in its individual parts, so as to get whole information about the processes of energy transformation, which takes place in such systems [4, 5]. The result of the analysis is to find exergetic output-input ratio of process in general and losses of exergy in individual elements of the technical system.

The goal of the work - to define the dependence of the input and output exergy flows of air-split conditioners refrigeration machines from the external temperature of air.

To do this, the following should be identified:

- input and output exergy flows, for example, for air split-conditioner of firm "Sanyo" with standard cooling capacity 2020 W by different external temperature regimes of operation;
- analytical dependence between the input and output exergy flows of selected air-split conditioner of firm "Sanyo" and the external temperature of air.

And it was the task of researches.

3. The statement of main material

The exergetic output-input ratio η_e of air-split conditioners one-step Freon refrigeration machines was determined from its *exergetic balance* for 1 kg/s consumption of circulating working refrigerators agent, which is:

$$e_{in} = e_{out} + \sum d \quad (1)$$

where $e_{in} = l = e_{out}^{comp}$ - input specific exergy flow in the air conditioner compressor (specific work of compressor) [kJ/kg]; $e_{out} = e_{evap}^{air}$ - output specific exergy flow from the evaporator of air conditioner or exergetic specific cooling capacity of air conditioner [kJ/kg]; $\sum d$ - total specific exergy flow losses in all apparatus of air split-conditioner refrigeration machine [kJ/kg].

On this basis, the *exergetic output-input ratio* η_e was determined as follows:

$$\eta_e = \frac{e_{out}}{e_{in}} = 1 - \frac{\sum d}{e_{in}} \quad (2)$$

So, from equation (2) we get, what the exergetic output-input ratio η_e of refrigeration machines of air split-conditioners to be conditioned by *input* e_{in} and *output* e_{out} *specific exergy flows*, that in its turn to depend from *the external temperature of air* t_{H_1} .

Input specific exergy flow was determined as follows:

$$e_{in} = l = \frac{i_2 - i_1}{\eta_{em}} \text{ [kJ/kg]} \quad (3)$$

where i_2 and i_1 - specific enthalpy of the characteristic points of the refrigeration cycle [kJ/kg] (Fig. 1b); η_{em} - electromechanical output-input ratio for compressor.

The absolute temperature of the environment was determined as follows:

$$T_{out} = t_{H1} + 273 \text{ [K]} \quad (4)$$

where t_{H1} - the initial temperature at the inlet of the condenser of air conditioner refrigeration machine.

The absolute average temperature in the evaporator was determined as follows:

$$\bar{T}_C = \frac{t_{C1} + t_{C2}}{2} + 273 \text{ [K]} \quad (5)$$

where t_{C1} and t_{C2} - respectively, the initial and final temperature of the air at the inlet and outlet of the evaporator of air conditioner refrigeration machine [°C].

Work capacity factor of cold air in the evaporator obtained was determined as follows:

$$\bar{\tau}_e^C = \frac{T_{out}}{T_C} - 1 \quad (6)$$

Specific amount of exergy, which is removed from the evaporator air conditioner as exergy cooling capacity, was determined as follows:

$$e_{out} = q_0 \cdot \bar{\tau}_e^C \text{ [kJ/kg]} \quad (7)$$

where $q_0 = i_1 - i_4$ - specific cooling capacity of the air conditioner [kJ/kg] (Fig. 1b).

The elaborating computer program of the exergetic analysis of air-split conditioners refrigeration machine *without effective compressors cooling* was used for researches.

Technical characteristics of the air-split conditioner “Sanyo” chosen to study by standard external temperature regime $t_{H1} = +35^\circ\text{C}$ and $t_{C1} = +27^\circ\text{C}$: cooling capacity $Q_c^{st} = 2020 \text{ W}$, consumed power $N_{cons}^{st} = 610 \text{ W}$, amount of condensate $W_{cond}^{st} = 0.9 \text{ L/h}$ and, accordingly, exergetic output-input ratio $\eta_e = 0.249$, refrigerators agent Freon-22 (R22). Air flow rates on the evaporator $L_{evap}^{st} = 450 \text{ m}^3/\text{h}$ and condenser $L_c^{st} = 1360 \text{ m}^3/\text{h}$ of conditioner.

To define dependence of the input and output specific exergy flows of the selected conditioner on the external temperature of air, which influences essentially its work, the following input data were accepted:

- the operating temperature of the environment $22 \leq t_{H_1} \leq 40^\circ\text{C}$ (external temperature of air);
- the operating internal (recirculation) temperature of air according to the environment temperature $20 \leq t_{C_1} \leq 29^\circ\text{C}$;
- the finite temperature difference in the evaporator (internal air at the outlet of the evaporator and boiling refrigerators agent) $\Delta t_{\text{evap}} = 2.8^\circ\text{C}$;
- the finite temperature difference in condenser (refrigerant, which condenses and external air at the outlet of the condenser) $\Delta t_c = 4.2^\circ\text{C}$;
- overheating temperature difference in the evaporator $\Delta t_{\text{overheat}} = 10^\circ\text{C}$;
- overcooling temperature difference in the condenser $\Delta t_{\text{overcool}} = 5^\circ\text{C}$;
- adiabatic (indicator) output-input ratio for compressor $\eta_i = 0.8$;
- electromechanical output-input ratio for compressor $\eta_{eM} = 0.9$;
- refrigerators agent - Freon-22 (R22);
- fundamental scheme of the refrigeration unit and work processes in it (Fig. 1).

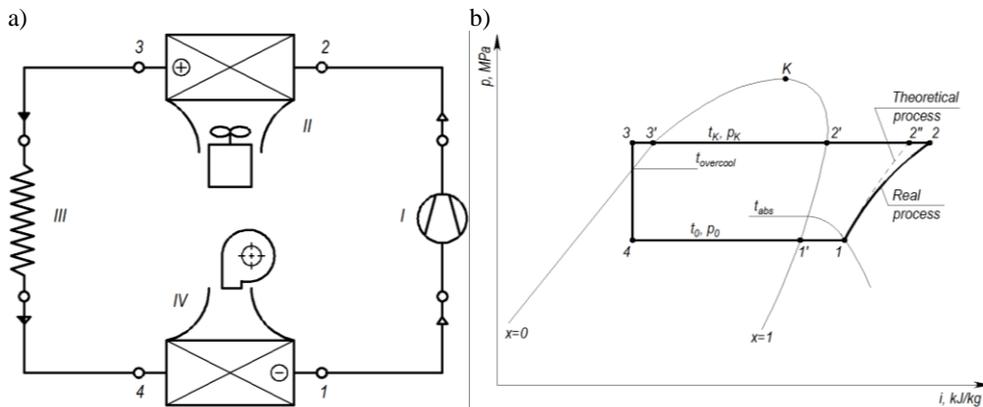


Fig. 1. The refrigeration machines fundamental scheme (a) and construction the processes of its work on diagram (b): I - compressor; II - condenser; III - capillary tube (throttle); IV - evaporator 1, 2, 3, 4 - characteristic points of the refrigeration cycle

The results obtained during the analysis are summarized in Table 1 (technical characteristics of air conditioner by standard external temperature regime are specified in **bold**) and were shown graphically in Figures 2 and 3.

The dependence of the input specific exergy flow in the selected air conditioner compressor by the temperature of the environment $22 \leq t_{H_1} \leq 40^\circ\text{C}$ was approximated as follows:

$$e_{in} = 0.43 \cdot t_{H_1} + 13,7 \text{ [kJ/kg]} \quad (8)$$

and the dependence of the output specific exergy flow from the evaporator of air conditioner was approximated as follows:

$$e_{out} = 0.26 \cdot t_{H_1} - 2,0 \text{ [kJ/kg]} \quad (9)$$

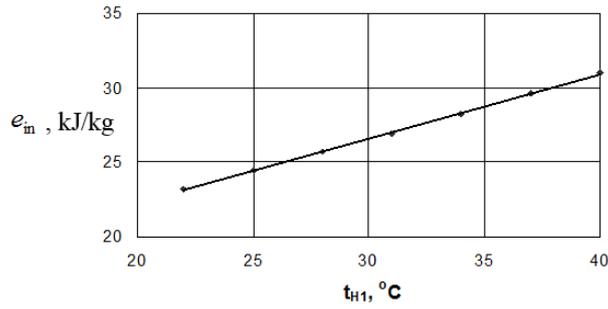


Fig. 2. The dependence of the input specific exergy flow in the air conditioner compressor e_{in} for air split-conditioner of firm “Sanyo” with cooling capacity 2020 W from the temperature of the environment t_{H_1}

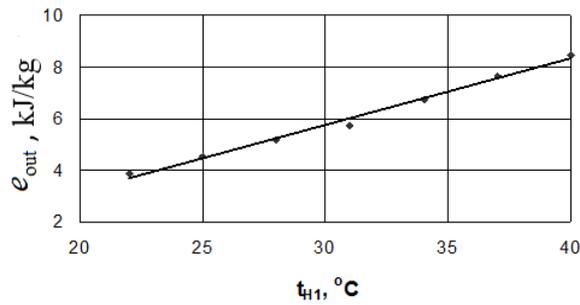


Fig. 3. The dependence of the output unit exergy flow in the air conditioner evaporator e_{out} for air split-conditioner of firm “Sanyo” with cooling capacity 2020 W from the temperature of the environment t_{H_1}

The maximum error of calculation by the equation (8) is 0.4%, and the equation (9) - 5.2%.

TABLE 1

The research results of dependence of input and output specific exergy flows and exergetic output-input ratio for air split-conditioner of firm “Sanyo” with cooling capacity 2020 W from external air temperature

t_{H_1} [°C]	t_{C_1} [°C]	Q_c^{oper} [W]	η_e	$e_{in} = l$ [kJ/kg]	e_{out} [kJ/kg]
35	27	2020	0.249	28.8	7.17
22	20	2050	0.166	23.2	3.85
25	22	2071	0.185	24.5	4.52
28	24	2091	0.201	25.7	5.16
31	26	2111	0.214	26.9	5.76
34	27	2060	0.238	28.2	6.73
37	28	2010	0.258	29.6	7.64
40	29	1959	0.274	31.0	8.50

Conclusions

Analyzing the received data in Table 1 and in Figures 2 and 3, we can come to the following conclusions. The increasing of external temperature of air from 22 to 40°C, that it in 1.82 once, leads to an increasing of the input specific exergy flow in compressor of the selected conditioner from 23.2 to 31.0 kJ/kg, that it in 1.34 once, and the output specific exergy flow from the evaporator - from 3.85 to 8.50 kJ/kg, that it in 2.21 once.

So, the exergetic analysis of the air split-conditioner refrigeration machine operating in working conditions showed that the maximum values of exergetic output-input ratio in it is due by high temperatures of environment and, consequently, for slightly increased input specific exergy flow in the compressor and considerable increasing output specific exergy flow from the evaporator. Therefore, from the point of view of exergetic analysis to use the selected split-conditioner of the standard cooling capacity 2020 W for providing a microclimate in the room it is more economic with higher efficiency of exergetic output-input ratio $\eta_e \geq 0.214$ at temperatures of environment $t_{H_1} \geq 31^\circ\text{C}$ and, accordingly, at the input specific exergy flow in the compressor of the conditioner $e_{in} \geq 26.9$ kJ/kg and output specific exergy flow from the evaporator $e_{out} \geq 5.76$ kJ/kg.

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Abstract

The elaborating method of the exergetic analysis of air split-conditioners one-step Freon refrigeration machines was used in this article. The dependence of input and output specific exergy flows and exergetic output-input ratio for refrigeration machine of air split-conditioner of firm "Sanyo" with cooling capacity 2020 W for refrigerators agent R22 from different temperatures of environment was defined.

Badania wpływu temperatury otoczenia na wyjściowe i wejściowe przepływy egzergetyczne w urządzeniu typu air split-conditioners refrigeration

Streszczenie

W artykule zastosowano metodę analizy egzergetycznej urządzeń typu air split-conditioners refrigeration. Zdefiniowano zależność wyjściowych i wejściowych przepływów egzergetycznych oraz stosunku przepływów egzergetycznych dla urządzenia typu air split-conditioners refrigeration firmy Sanyo o wydajności chłodzenia 2020 W od różnych temperatur otoczenia.