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# THE DEPENDENCE OF EXERGY LOSSES IN ELEMENTS OF AIR SPLIT-CONDITIONERS REFRIGERATING MACHINES FROM ADIABATIC AND ELECTROMECHANICAL OUTPUT-INPUT RATIO FOR COMPRESSOR



**The elaborating method of the exergetic analysis of air split-conditioners one-step Freon refrigeration machines was used in this article. The dependence of exergy losses for compressor, condenser, throttle and evaporator of air split-conditioner of firm "Sanyo" with cooling capacity 2020 W from adiabatic and electromechanical output-input ratio for compressor was defined.**

**Key words: exergetic analysis, split-conditioner, exergy**

**Використано розроблений ексергетичний метод аналізу роботи одноступеневих хладонових холодильних машин split-кондиціонерів. Встановлено залежність втрат ексергії у компресорі, конденсаторі, дроселі та випарнику split-кондиціонера фірми "Sanyo" холодопродуктивністю 2020 Вт від адіабатичного та електромеханічного ККД компресора.**

**Ключові слова: ексергетичний метод, split-кондиціонер, ексергія**

**Resolution of the problem.** Refrigeration machines, that are used in air split-conditioners, needs right choice of energy efficient modes of their operation, the establishment of which is possible by using exergetic method of analysis of their work [1, 2, 3].

Exergy analysis allows to set the maximum thermodynamic possibility refrigerator, to determine losses of exergy in it and justify recommendations for the improvement of its individual elements. And for this we must thoroughly examine all aspects of air split-conditioners refrigerating machines.

**Analysis of recent research and publications.** The exergetic analysis of one-step refrigeration machines most detailed presented in [1], which is unapplied for air split-conditioners refrigeration machines, in which the evaporator and condenser are washing by appropriate air, while in contour of refrigeration machine another refrigerant is circulating. Also, this method of analysis is brief highlighted in [2, 3].

For this, it had been developed by authors a method of exergetic analysis of the air split-conditioners refrigerating machines (*without effective compressors cooling)* [4, 5]. In this method, used fundamental scheme of the refrigeration machine, what is showed in Fig. 1, *a*, and therefore the construction process of its work on *p,i*–diagram – in Fig. 1, *b* and refrigerators agent – Freon-22 (R22). This 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 a systems. 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 exergy losses for compressor, condenser, throttle and evaporator of air split-conditioners refrigeration machines from adiabatic and electromechanical output-input ratio for compressor. To do this, the following should be identified:

- losses of exergy for compressor, condenser, throttle and evaporator of air split-conditioner of firm "Sanyo" with cooling capacity 2020 W from adiabatic and electromechanical output-input ratio for compressor;

- analytical dependence between losses of exergy for compressor, condenser, throttle and evaporator of chosen air split-conditioner of firm “Sanyo” and adiabatic and electromechanical output-input ratio for compressor.

And it was the task of researches.

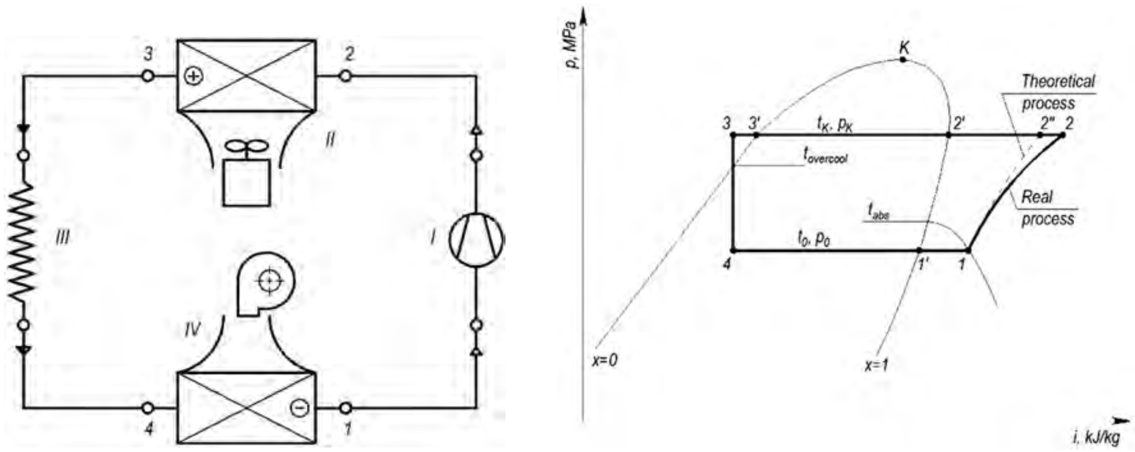
**The statement of main material.** The exergetic output-input ratio $\eta_e$ of air split-conditioners one-step Freon refrigeration machines was determined from its *exergetic balance* for 1 kg/s consumption of circulating working refrigerators agent, which is:

$$e_{in} = e_{out} + \Sigma d \text{, kJ/kg,} \tag{1}$$

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; $\Sigma d$ – total specific exergy flow losses in all apparatus of air split-conditioner refrigeration machine, kJ/kg.

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

$$\eta_e = \frac{e_{out}}{e_{in}} = 1 - \frac{\Sigma d}{e_{in}}. \tag{2}$$




*a)* *b)*

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

Technical characteristics of chosen to study the air split-conditioner "Sanyo" by standard external temperature regime $t_{H_1}$ = +35°C and $t_{C_1}$ = +27°C: cooling capacity $Q_c^{st}$ = 2020 W, consumed power $N_{cons}^{st}$ = 610 W, amount of condensate $W_{cond}^{st}$ =0,9 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 m$^3$/h and condenser $L_c^{st}$ = 1360 m$^3$/h of conditioner.

*Indicator output-input ratio for compressor* $\eta_i$ affects the value of the specific enthalpy of dry superheated steam of refrigerant $i_2$ after its compression in the compressor and, accordingly, to the specific indicator work of the compressor $l_i$, and *electromechanical output-input ratio for compressor* $\eta_{em}$ – to the specific real work of the compressor $l$, that in general affects the specific input exergy flow to the compressor motor $e_{in} = l$, and thus the exergetic output-input ratio $\eta_e$ of air split-conditioners refrigeration machines. However, the indicator and the electromechanical output-input ratio for compressor of air split-conditioners refrigeration machines affect not only the exergetic output-input ratio of refrigeration machines, but the parameters of all their elements: compressor, condenser, throttle (capillary tube) and the evaporator and adequate exergy losses in them.

To define the dependence of exergy losses for compressor, condenser, throttle and evaporator of air split-conditioners refrigeration machines from adiabatic and electromechanical output-input ratio for compressor, which influence essentially on its work, were accepted the following input data:

- adiabatic (indicator) output-input ratio for compressor $0,7 \le \eta_i \le 0,9$ (for the standard process $\eta_i$ = 0,8);
- electromechanical output-input ratio for compressor $0,75 \le \eta_i \le 0,95$ (for the standard process $\eta_{ем}$ = 0,9);
- the standard temperature of the environment $t_{H_1}$ = 35°C (external temperature of air);
- the standard internal (recirculation) temperature of air according to the environment temperature $t_{C_1}$ = 27°C;
- the finite temperature difference in the evaporator (internal air at the outlet of the evaporator and boiling refrigerators agent) $\Delta t_{evap}$ = 2,8°C;
- the finite temperature difference in condenser (refrigerant, which condenses and external air at the outlet of the condenser) $\Delta t_c$ = 4,2°C;
- overheating temperature difference in the evaporator $\Delta t_{overheat}$= 10°C;
- overcooling temperature difference in the condenser $\Delta t_{overcool}$ = 5°C;
- refrigerators agent – Freon-22 (R22);
- fundamental scheme of the refrigeration unit and work processes in it (Fig. 1).

The results obtained during the analysis are summarized in the table (technical characteristics of air conditioner by standard adiabatic and electromechanical output-input ratio for compressor are specified in *italics*, **bold** – operating technical characteristics of air conditioner by proposed adiabatic and electromechanical output-input ratio for compressor) and was shown graphically in Fig. 2, 3, 4 and 5.

*Table*

**The research results of dependence losses of exergy for compressor, condenser, throttle, evaporator and exergetic output-input ratio for air split-conditioner of firm “Sanyo” with cooling capacity 2020 W from adiabatic and electromechanical output-input ratio for compressor**

| $\eta_i$ | $\eta_{em}$ | $D_{compr}$, % | $D_c$, % | $D_{thr}$, % | $D_{evap}$, % | $e_{in} = l$, $\frac{kJ}{kg}$ | $e_{out}$, $\frac{kJ}{kg}$ | $\eta_e$ |
|---|---|---|---|---|---|---|---|---|
| 0,70 | 0,90 | 31,9 | 29,8 | 6,2 | 10,2 | 32,9 | 7,17 | 0,218 |
| 0,75 | 0,90 | 28,0 | 31,0 | 6,7 | 11,0 | 30,7 | 7,17 | 0,234 |
| *0,80* | *0,90* | *24,1* | *32,4* | *7,1* | *11,7* | *28,8* | *7,17* | *0,249* |
| 0,85 | 0,90 | 20,2 | 33,3 | 7,6 | 12,4 | 27,1 | 7,17 | 0,265 |
| 0,90 | 0,90 | 16,3 | 34,5 | 8,0 | 13,2 | 25,6 | 7,17 | 0,280 |
| 0,80 | 0,75 | 36,8 | 26,8 | 5,9 | 9,8 | 34,5 | 7,17 | 0,208 |
| 0,80 | 0,80 | 32,6 | 28,6 | 6,3 | 10,4 | 32,4 | 7,17 | 0,222 |
| 0,80 | 0,85 | 28,3 | 30,3 | 6,7 | 11,1 | 30,5 | 7,17 | 0,235 |
| *0,80* | *0,90* | *24,1* | *32,1* | *7,1* | *11,7* | *28,8* | *7,17* | *0,249* |
| 0,80 | 0,95 | 19,9 | 33,9 | 7,5 | 12,4 | 27,2 | 7,17 | 0,263 |
| **0,90** | **0,95** | **11,7** | **36,4** | **7,2** | **13,9** | **24,2** | **7,17** | **0,296** |

In table $D_{compr}$, $D_c$, $D_{thr}$, $D_{evap}$ – accordingly, relative *loss of exergy in* compressor, condenser, throttle and evaporator, *%;* $e_{in} = l$ – input specific exergy flow in the air conditioner compressor (specific work of compressor), kJ/kg; $e_{out}$ – output specific exergy flow from the evaporator of air conditioner or exergetic specific cooling capacity of air conditioner, kJ/kg; $\eta_e$ – the exergetic output-input ratioof air split-conditioner refrigeration machine.

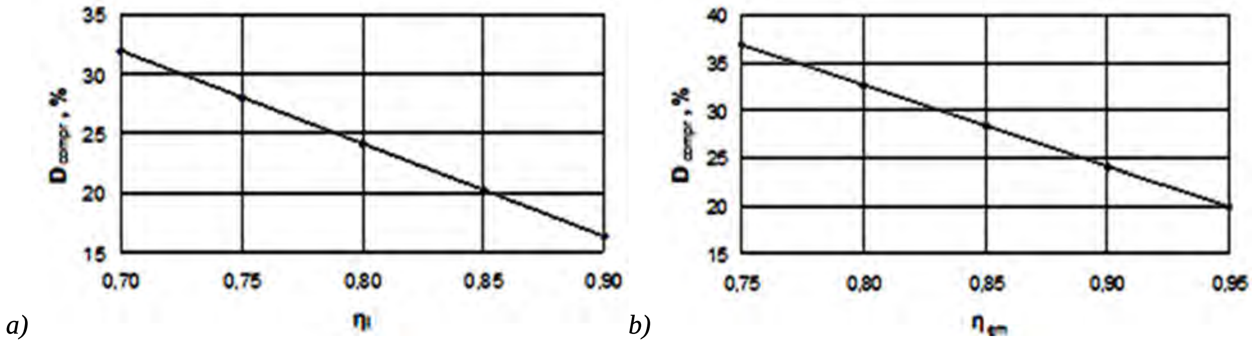



*Fig. 2. The dependence of the relative exergy losses in compressor $D_{compr}$ for air split-conditioner of firm "Sanyo" with cooling capacity 2020 W from adiabatic $\eta_i$ (a) and electromechanical $\eta_{em}$ (b) output-input ratio for compressor*

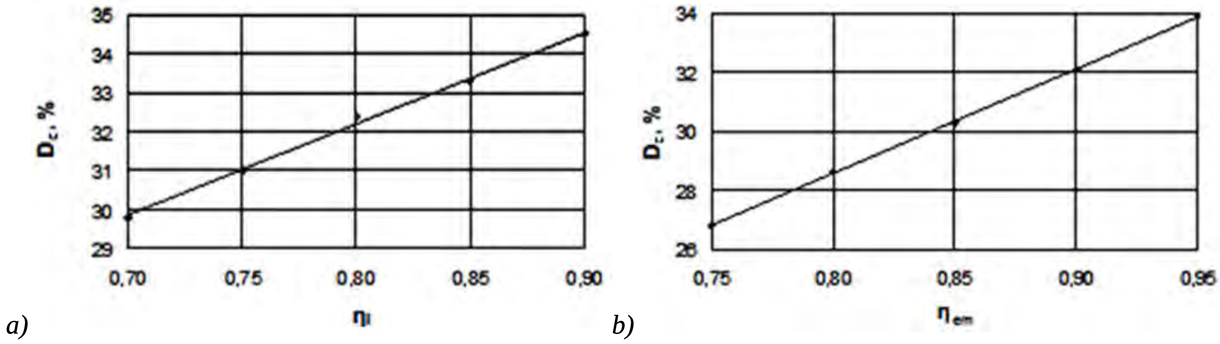



*Fig. 3. The dependence of the relative exergy losses in condenser $D_c$ for air split-conditioner of firm "Sanyo" with cooling capacity 2020 W from adiabatic $\eta_i$ (a) and electromechanical $\eta_{em}$ (b) output-input ratio for compressor*

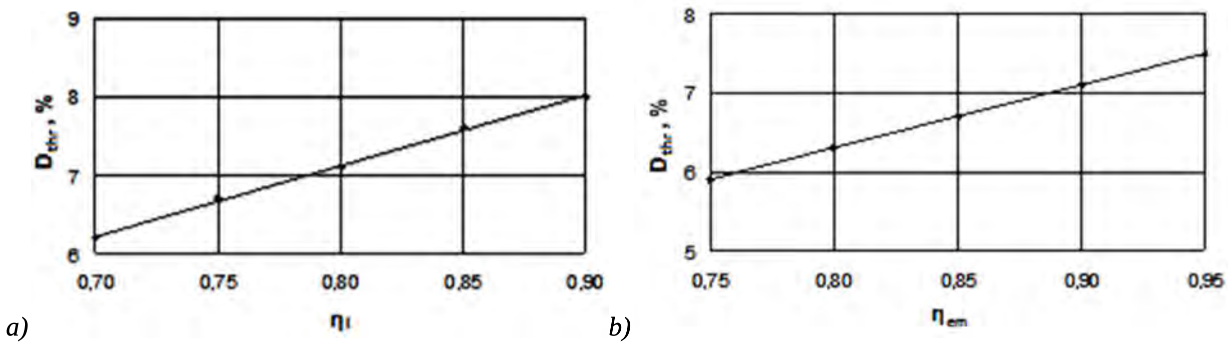



*Fig. 4. The dependence of the relative exergy losses in throttle $D_{thr}$ for air split-conditioner of firm "Sanyo" with cooling capacity 2020 W from adiabatic $\eta_i$ (a) and electromechanical $\eta_{em}$ (b) output-input ratio for compressor*

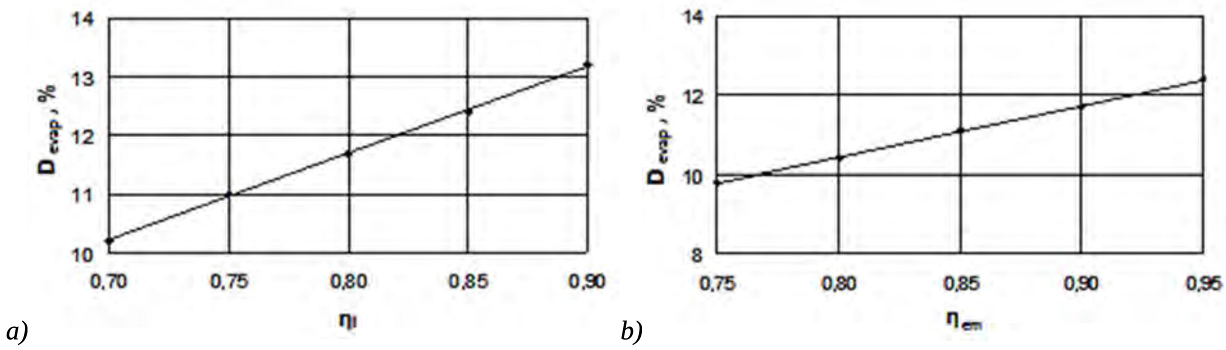



*Fig. 5. The dependence of the relative exergy losses in evaporator $D_{evap}$ for air split-conditioner of firm "Sanyo" with cooling capacity 2020 W from adiabatic $\eta_i$ (a) and electromechanical $\eta_{em}$ (б) output-input ratio for compressor*

The dependence of the relative exergy losses of chosen air split-conditioner from adiabatic $0{,}7 \le \eta_i \le 0{,}9$ and electromechanical $0{,}75 \le \eta_{em} \le 0{,}95$ output-input ratio for compressor was approximated as follows:

– for compressor

$$D_{compr} = 162{,}6 - 78 \cdot \eta_i - 84{,}6 \cdot \eta_{em}\text{, \%;} \tag{3}$$

– for condenser

$$D_c = 23{,}5 \cdot \eta_i + 35{,}4 \cdot \eta_{em} - 18{,}5\text{, \%;} \tag{4}$$

– for throttle

$$D_{thr} = 9 \cdot \eta_i + 8 \cdot \eta_{em} - 7{,}3\text{, \%;} \tag{5}$$

– for evaporator

$$D_{evap} = 15 \cdot \eta_i + 13 \cdot \eta_{em} - 12\text{, \%.} \tag{6}$$

The maximum error of calculation by the equation (3) is 0,4%, by the equation (4) – 0,7%, by the equation (5) – 0,4% and by the equation (6) – 0,8%.

**Summary.** Analyzing the received data in the table and in Fig. 2, 3, 4 and 5, we can come to the following conclusions. The increasing of adiabatic output-input ratio for compressor of chosen air split-conditioner $\eta_i$ from 0,7 to 0,9, that is in 1,286 once, leads to a significant decreasing of the relative exergy losses in compressor $D_{compr}$ from 31,9 to 16,3%, that it in 1,96 once, in the condenser to a slight increasing $D_c$ – from 29,8 to 34,5%, that it in 1,158 once, in the throttle to a significant increasing $D_{thr}$ – from 6,2 to 8,0%, that it in 1,29 once, and in the evaporator to a significant increasing $D_{evap}$ – from 10,2 to 13,2 %, that it in 1,294 once, by exergetic output-input ratio $\eta_e$ increasing from 0,218 to 0,280, that it in 1,284 once or 28,4%, and an increasing of electromechanical output-input ratio for compressor of chosen air split-conditioner refrigeration machine $\eta_{em}$ from 0,75 to 0,95, that it in 1,267 once, - to a significant decreasing of relative exergy losses in the compressor $D_{compr}$ from 36,8 to 19,9%, what it in 1,85 once, in the condenser to a significant increasing $D_c$ – from 26,8 to 33,9%, that it in 1,265 times, in the throttle to a significant increasing $D_{thr}$ – from 5,9 to 7,5%, what it in 1,271 once, and to a significant increasing in the evaporator $D_{evap}$ – from 9,8 to 12,4%, what it in 1,265 once, by exergetic output-input ratio $\eta_e$ increasing from 0,208 to 0,263, that it in 1,264 once or 26,4%. So, it is best to reach the highest values of adiabatic and electromechanical output-input ratio of the compressor, that is 0,90 – adiabatic and 0,95 – electromechanical. The using of the proposed adiabatic and electromechanical output-input ratio of the compressor instead of standard values, respectively 0,80 and 0,90, will lead to increasing of exergetic output-input ratio $\eta_e$ from 0,249 to 0,296 , what is 18,9%, this is quite significant. It should be noted, that the output specific exergy flow from the evaporator of air conditioner is independent of the adiabatic $\eta_i$ and electromechanical $\eta_{em}$ output-input ratio for compressor.

So, exergetic analysis of the air split-conditioners refrigerating machine by standard external temperature conditions and different values of the adiabatic and electromechanical $\eta_{em}$ output-input ratio for compressor showed that it has higher values of exergetic output-input ratio by the highest values of the adiabatic and electromechanical output-input ratio for compressor. Therefore, in terms of exergetic analysis to use chosen air split-conditioner with standard cooling capacity 2020 W for provide a microclimate in the room it is more economic with higher exergetic output-input ratio by standard external temperature regime and proposed values of adiabatic compressor output-input ratio for compressor $\eta_i$ = 0,90 and electromechanical output-input ratio for compressor $\eta_{em}$ = 0,95 and , respectively, by significant reduced the relative exergy losses in compressor $D_{compr}$ = 11,7%, slightly increased – in the condenser $D_{c}$ = 36,4%, slightly increased – in the throttle $D_{thr}$ = 7,2% and slightly increased – in the evaporator $D_{evap}$ = 13,9% for refrigerator chosen air split-conditioner refrigeration machine "Sanyo". Obviously, because of this exergetic output-input ratio increase by 18,9%, that is significant.

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