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COMPARATIVE ANALYSIS OF THERMOELECTRIC AND COMPRESSION HEAT PUMPS FOR INDIVIDUAL AIR CONDITIONERS AT ELEVATED AMBIENT TEMPERATURES

The paper presents the results of comparative analysis of thermoelectric and compression heat pumps for their use in human air conditioners at elevated ambient temperatures.
Key words: thermoelectric heat pump, compression heat pump, human air conditioner.

Introduction

General characterization of the problem. In the literature, reference is made to the possibility of human body air-conditioning by various methods [1 – 9]. Of particular interest are methods based on the use of compression and thermoelectric heat pumps. This is due to their advantages, namely high energy conversion efficiency and possibility of operation both in cooling and heating modes. Paper [10] gives a comparative analysis of thermoelectric and compression heat pumps for individual air conditioners with respect to their energy and weight-and-size characteristics in the range of ambient temperatures 20 – 30 ºC. This enabled us to identify the advantages of thermoelectric heat pumps under low supply powers (up to 500 W) which correspond to operating conditions of human air conditioners.

However, of particular interest is the use of human air conditioners at elevated ambient temperatures (37 °C and more), which is related to complicated human body heat exchange with the environment. As shown by the analysis of the literature, such operating conditions of heat pumps are understudied.

The purpose of this paper is to determine the opportunities for further quality improvement of individual human air conditioners based on thermoelectric and compression heat pumps by their comparative analysis under elevated ambient temperatures.

Calculation of energy characteristics of thermoelectric heat pump

For comparative analysis of characteristics of heat pumps, computer calculations of thermoelectric heat pump were performed on the basis of a physical model presented in Fig 1. It comprises thermoelectric modules 1, the hot 3 and cold 6 heat exchangers, thermal contact resistances between them 4, 5 and liquid pumps 2, 7 which assure motion of heat carriers through heat exchangers (W_1, W_2). Temperature differences along heat exchangers are considered to be minor and can be ignored.

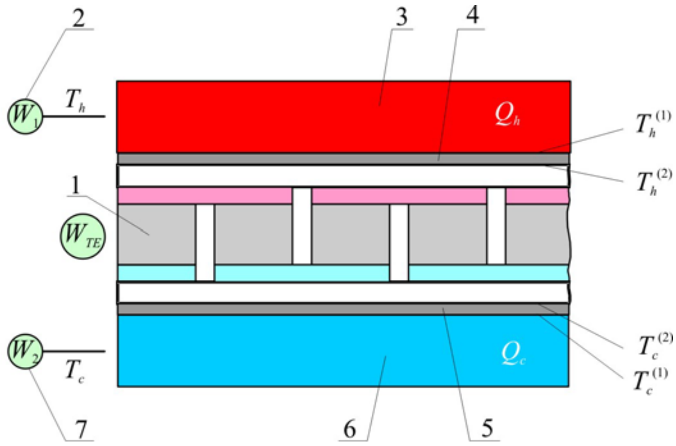

Fig. 1. Physical model of thermoelectric heat pump.

A system of equations describing coefficient of performance as a function of parameters of physical model elements is determined from heat balance equations in the heat pump:

$$\begin{cases} Q_c = \chi_1 (T_c^{(1)} - T_c) \\ Q_c = \chi_2 (T_c^{(2)} - T_c^{(1)}) \end{cases}, \quad (1)$$

$$\begin{cases} Q_h = \chi_3 (T_h^{(2)} - T_h^{(1)}) \\ Q_h = \chi_4 (T_h^{(1)} - T_h) \end{cases}, \quad (2)$$

$$Q_h = Q_c + W_{TE}. \quad (3)$$

Here, T_c – cold heat carrier temperature, $T_c^{(1)}$ – cold heat exchanger temperature, $T_c^{(2)}$ – cold side temperature of thermoelectric module, T_h – hot heat carrier temperature, $T_h^{(1)}$ – hot heat exchanger temperature, $T_h^{(2)}$ – hot side temperature of thermoelectric module, χ_1 is thermal resistance of the cold heat exchanger 6, χ_2 is thermal contact resistance 4, χ_3 is thermal contact resistance 5, χ_4 is thermal resistance of the hot heat exchanger 3, Q_c is cooling capacity of thermal pump, Q_h is its heating efficiency.

With regard to (1) – (3), the expression for a real coefficient of performance of thermoelectric heat pump will be given by:

$$\varepsilon_r = \frac{Q_c}{W_{TE} + W_1 + W_2} = \frac{\alpha I (T_c + Q_c N_1) - 0.5 I^2 R - \lambda (T_h - T_c - (Q_h N_2 + Q_c N_1))}{W_{TE} + W_1 + W_2}, \quad (4)$$

where $N_1 = \frac{(\chi_1 + \chi_2)}{\chi_1 \chi_2}$, $N_2 = \frac{(\chi_3 + \chi_4)}{\chi_3 \chi_4}$.

In the simulation, structural parameters of thermoelectric heat pump, as well as computer simulation procedure described in detail in [10] were used. The results of simulation are given below.

Comparison of thermoelectric and compression individual human air conditioners

For comparison, analysis of the literature on compression heat pumps at elevated ambient temperatures was performed. Analysis shows that the use of compression heat pumps is restricted by maximum ambient temperature 45 °C [11]. In so doing, the value of cooling efficiency with a rise in temperature drastically decreases. Despite scarce information on the characteristics of compression heat pumps at elevated temperatures, it has been found in [12, 13] (Fig. 2). The reported compression heat pump has electric power 3 kW, which does not correspond to the range of using individual human air conditioners. However, using the dependences of efficiency of compression heat pumps on their power obtained in [10], the dependences of coefficient of performance of compression heat pumps on ambient temperature for their different powers were found (Fig. 2).

For illustrative reasons we graphically construct a comparative characteristic of the coefficient of performance of compression and thermoelectric heat pumps versus ambient temperature (Fig. 2).

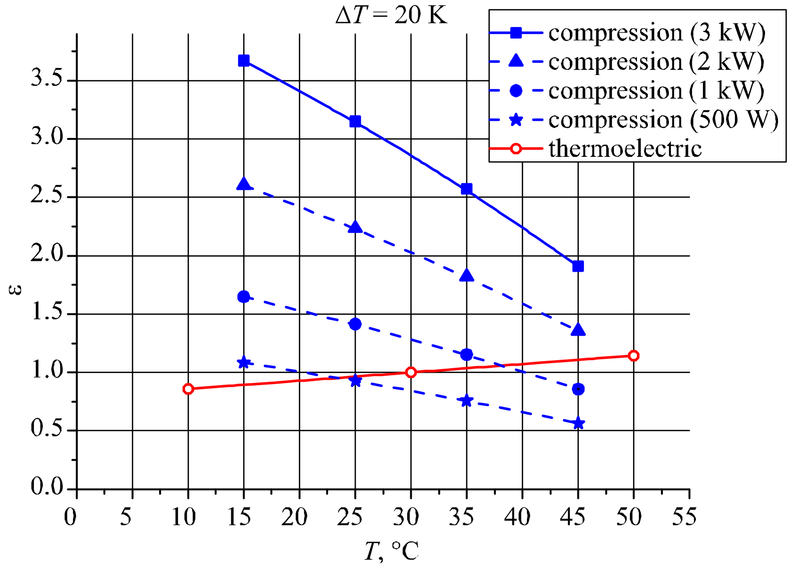

Fig. 2. Dependence of coefficient of performance of compression (blue lines) and thermoelectric (red line) heat pumps on the ambient temperature.

As is evident from Fig. 2, coefficient of performance of compression heat pumps considerably decreases with a rise in ambient temperature. Coefficient of performance of thermoelectric heat pumps in this case not only does not decrease, but even increases. Thus, thermoelectric heat pumps offer a definite advantage over compression pumps at elevated ambient temperatures in the range of low cooling capacities (up to 500 W), which correspond to operating conditions of human air conditioners.

Conclusions

1. Coefficient of performance of thermoelectric heat pump was calculated versus ambient temperature and shown to increase with a rise in temperature.
2. Coefficient of performance of compression heat pumps was shown to drastically decrease with a rise in ambient temperature.
3. It was established that thermoelectric heat pumps offer a definite advantage over compression heat pumps at elevated ambient temperatures (above 30 °C) in the range of low cooling capacities (up to 500 W), which correspond to operating conditions of human air conditioners.

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