ENTROPIC-STATISTICAL ANALYSIS OF CO_2 REFRIGERATION MACHINES OPERATING IN TRANSCRITICAL AND SUBCRITICAL CYCLES

Shaforostov D. D.
A.M. Pidhornyi Institute of power machines and systems of the NAS of Ukraine, Kharkiv

In modern energy systems, increasing attention is paid to the use of carbon dioxide (CO_2) as a working fluid, particularly in systems operating under transcritical and subcritical cycles. The choice of a specific cycle is determined by the thermodynamic characteristics of the process and the efficiency of energy utilization.

Transcritical and subcritical CO_2 cycle machines exhibit significant differences that affect their efficiency and structural features. In the subcritical cycle, the processes of evaporation and condensation are clearly defined, whereas in the transcritical cycle, the condensation zone is replaced by a gas cooling process. This alters the heat transfer dynamics, system operating parameters, and energy losses.

One of the main distinctions between these modes lies in the characteristics of the heat exchange processes. In the subcritical cycle, the conventional zones of evaporation and condensation ensure efficient heat transfer, while in the transcritical cycle, gas cooling in the supercritical state of the working fluid modifies the nature of heat exchange.

This study considers the steady-state operation of a cyclic mechanical refrigeration machine.

An entropic-statistical analysis of CO_2-based machines operating in both cycles is conducted.

The analysis is based on the second law of thermodynamics, including the evaluation of entropic losses in the cycle associated with internal hydraulic resistance (ΔS_{int}) and thermal leakage into the environment (ΔS_{leak}):

$$\frac{1}{COP} = -1 + \frac{T_{cond}}{T_{evap}} - \frac{T_{cond}\Delta S_{int}}{Q_{evap}} + \frac{T_{cond}\Delta S_{leak}}{Q_{evap}},$$

where COP – the coefficient of performance of the refrigeration machine; T_{evap} and T_{cond} – the temperatures of the refrigerant in the evaporator and condenser, respectively; and Q_{evap} – the cooling capacity.

The obtained results allow the determination of optimal operating parameters for such machines in terms of thermodynamic efficiency.

In particular, it has been established that the transcritical cycle is more efficient at high ambient temperatures, whereas the subcritical cycle has an advantage at lower temperatures.

To improve efficiency, energy losses should be taken into account, hydraulic resistance minimized, and heat exchange equipment optimized.