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V. Milovanova
State Academy of Food Technologies

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EXPERIMENTAL RESEARCH AND CONSTRUCTION HEAT CIRCUIT FOR A SEMIHERMETIK
REFRIGERANT RECIPIROTATING COMPRESSOR
Vanda Milovanova, Cand. Sc. (Tech.)
State Academy of Food Technologies, Odessa, Ukraine

ABSTRACT

The given paper is aimed at constructing the general circuit of heat processes in a semihermetic reciprocating refrigerant compressor as a basis of application of new ecology-friendly refrigerants as well as optimizing design parameters of compressor. While performing this work the following problems were solved:

1. Experimental research of heat processes in a semihermetic refrigerant reciprocating compressor on refrigerants R12 and R22 was carried out.
2. Equivalent heat circuit was made to calculate and analyses heat processes in a semihermetic refrigerant reciprocating compressor.
3. A mathematical model was developed for heat processes in a semihermetic reciprocating refrigerant compressor.
4. Temperature state of components of semihermetic refrigerant reciprocating compressor was carried out.
5. Comparison of experimental research and calculation of mathematical model was carried out.

The results of experimental research and the equivalent heat circuit of a semihermetic refrigerant reciprocating compressor can be successfully applied to optimize its design parameters as well as to employ new ecology-friendly refrigerants.

NOMENCLATURE

\( G_a \) - specific mass flow rate of refrigerant, \([\text{kg/s}]\)
\( t_0 \) - boiling temperature, \([\text{K}]\)
\( t_k \) - condensing temperature, \([\text{K}]\)
\( N_e \) - consumed electric power of a compressor, \([\text{Wt}]\)
\( Q_0 \) - refrigerating capacity, \([\text{Wt}]\)
\( E \) - refrigerating factor
\( \lambda \) - delivery factor
\( P_k/P_0 \) - compression ratio of a compressor
\( t_{12} \) - temperature of crankcase oil, \([\text{K}]\)
\( t_{c3} \) - temperature of refrigerant on motor, \([\text{K}]\)
\( t_{c4} \) - temperature of refrigerant in suction channels of the first and the second cylinders, \([\text{K}]\)
\( i \) - the number of \( i \)-th element of compressor structure
\( j \) - the number of \( j \)-th element of refrigerant flow
\( t_i, t_k, t_z, t_p \) - temperatures of the \( i \)-th, \( k \)-th, \( z \)-th and \( p \)-th elements of compressor structure, accordingly, \([\text{K}]\)
\( t_{cj}, t_{cj-1} \) - temperatures of the \( j \)-th and \((j-1)\)-th elements of refrigerant flow, accordingly, \([\text{K}]\)
\( \Lambda_{ik} \) - heat conduction of heat conductivity between the \( i \)-th and \( k \)-th structure elements, \([\text{Wt/K}]\)
\( \Lambda_{zj} \) - heat conduction of heat emission between the \( z \)-th structure element and the \( j \)-th element of refrigerant flow, \([\text{Wt/K}]\)
\( \Lambda_{pj} \) - heat conduction of heat emission between the \( p \)-th structure element and \((j-1)\)-th component element of refrigerant flow, \([\text{Wt/K}]\)
\( n \) - a number of elements connected with the \( i \)-th element of compressor structure
\( s, l \) - a number of compressor structure elements cooled by the \( j \)-th and \((j-1)\)-th refrigerant flow elements,
accordingly

\[ P_i \] - heat emissions in the \( i \)-th element of compressor structure (Wt)

\[ \Lambda_0 = C_p * G_a \] - heat conduction of refrigerant flow, [Wt/K]

\[ C_p \] - coefficient of specific heat of refrigerant, [J/kg K]

**INTRODUCTION**

At present, the importance of the problem of transfer refrigerant compressors for new ecology-friendly refrigerants is increasing and we need to lower their temperature level and at the same time to increase heat and energy efficiency, durability and reliability.

The given paper is aimed at experimental research of heat processes and constructing the equivalent heat circuit and a mathematical model of heat processes in a semihermetic refrigerant reciprocating compressor as a basis of its transfer for new ecology-friendly refrigerants.

**EXPERIMENTAL RESEARCH**

At first, experimental research was carried out in order to obtain experimental data on varying actual temperatures, heat emissions, heat conduction and heat extraction coefficients in various parts of a semihermetic compressor. As an object of experimental research a semihermetic reciprocating refrigerant compressor was selected. This is designed to work in a wide range of temperature regimes with refrigerants R12 and R22. That’s why the compressor was tested in the whole range of operational conditions on refrigerants R12 and R22. Heat research of a semihermetic refrigerant compressor was carried out on a calorimetric stand and on the special stand “Gas ring”. While testing heat and energy factors of a compressor were determined in a wide range of operational conditions. Great attention was paid to experimental determination of working temperatures of compressor parts and of refrigerant flow components. Thermocouples TXK (chromel – kopal) with a wire diameter of 0.3 – 0.5 mm completed with an automatic potentiometer KC114 were installed in the compressor for this purpose.

Thermocouples were installed in compressor parts and in refrigerant tract. As a result of experimental research of a semihermetic refrigerant compressor the following experimental dependencies were obtained:

1) dependence of refrigerant flow \( G \) (kg/s) upon boiling temperature \( t_0 \) (K) under different condensing temperatures \( t_k \) (K);
2) dependence of the consumed electric power of a compressor \( N \) (Wt) upon boiling temperature \( t_0 \) (K) under different condensing temperatures \( t_k \) (K);
3) dependence of refrigerating capacity \( Q_0 \) (Wt) upon boiling temperature \( t_0 \) (K) under different condensing temperatures \( t_k \) (K);
4) dependence of a refrigerating factor \( E \) upon boiling temperature \( t_0 \) (K) under different condensing temperatures \( t_k \) (K);
5) dependence of delivery factor \( \lambda \) upon compression ratio of a compressor \( P / P_0 \).

As a result of experimental research, dependencies of compressor parts temperatures and of refrigerant flow temperatures upon the boiling temperature \( t_0 \) (K) were obtained while running a compressor on refrigerant R12 under condensing temperatures \( t_k = 303 \) K (30°C), \( t_k = 313 \) K (40°C), \( t_k = 323 \) K (50°C), \( t_k = 333 \) K (60°C) and \( t_k = 343 \) K (70°C) and while its running on refrigerant R12 under condensing temperatures \( t_k = 303 \) K (30°C), \( t_k = 313 \) K (40°C) and \( t_k = 323 \) K (50°C). Fig. 1, 2, 3, 4 demonstrate examples of experimental dependencies obtained.
The results of an experiment give a full idea of the character, intensity and range of varying the working temperatures of compressor parts and refrigerant flow in operating conditions range.

It became clear that while running a compressor on refrigerant R12 in the whole range of operational conditions the temperatures of its parts and of refrigerant flow do not reach legitimate limit values (Fig. 1, 2). At the same time while running on refrigerant R22 at the boiling temperature \( t_0 = 243 \text{ K} (-30^\circ \text{C}) \) under high condensing temperature conditions \( t_k \) (K) the windings temperature and the pumping temperature reach considerable values which are dangerous for compressor operation (Fig. 4).

Some diagrams of varying the temperature of refrigerant flow components, temperature of some compressor parts and temperature of oil considerably differ in their shape from the conventional ones while operating a compressor on R12 and at high condensing temperatures. At condensing temperatures \( t_k = 323 \text{ K} (50^\circ \text{C}) \) and \( t_k = 333 \text{ K} (60^\circ \text{C}) \) working temperatures diagrams for crankcase oil \( t_{12} \) (K), for refrigerant R12 on motor exit \( t_3 \) (K) and in suction channels of the first and the second cylinders \( t_4 \) (K) have their minimum between \( t_0 = 278 \text{ K} (5^\circ \text{C}) \) and \( t_0 = 288 \text{ K} (15^\circ \text{C}) \) (Fig. 1).

With the further increase of \( t_0 \) (K) preset temperatures are increasing. The temperatures of crankcase oil \( t_{12} \) (K), of refrigerant flow on motor exit \( t_3 \) (K) and in a suction channel of the first cylinder \( t_4 \) (K) are monotonously increasing at \( t_k = 343 \text{ K} (70^\circ \text{C}) \) when varying temperatures range \( t_0 \) is from 273 K (0°C) to 298 K (25°C). The diagrams of R12 working temperatures in the hotter points of refrigerant tract (from the refrigerant flow temperature in a suction channel \( t_4 \) (K) of the second cylinder to the temperature of a flow in a suction collector \( t_6 \) (K), and the diagrams of liners walls temperature \( t_7 \) (K) of both cylinders at \( t_k = 333 \text{ K} (60^\circ \text{C}) \) and \( t_k = 343 \text{ K} (70^\circ \text{C}) \) also have some deviations from conventional form but they are not obvious. To our mind, such character of varying working temperatures of flow components and of compressor parts when operating on refrigerant R12 is accounted for the fact that the dependencies minimal area of these temperatures correspond to maximum of a diagram for coefficient of efficiency in a motor. A relatively non-clear character of influencing the higher preheating of refrigerant R12 in a motor on temperatures of the hotter compressor points (Fig. 2) is account for increasing influence of heat extractions in compressor cylinders on these temperatures.

A lack of similar effect in compressor operation on the refrigerant R22 is due to its higher heat-extraction coefficients and, therefore, to the better cooling capacity of this refrigerant (Fig. 3, 4).

CONSTRUCTION HEAT CIRCUIT

Experimental research resulted in the equivalent heat circuit of a semihermetic refrigerant compressor [1]. Calculations were carried for stationary regimes of compressor operation, and all components of a compressor were treated as homogeneous ones. Heat exchange processes of compressor parts and of a built-in motor with each other and with refrigerant flow were regarded as a main object of simulation.

Methods of temperature field simulated varying the temperature of stator windings of a build-in motor and of cooling refrigerant flow along a stator. Fig. 2 shows equivalent heat circuit for a semihermetic refrigerant compressor. Similarly, equivalent heat circuit was made for a refrigerant flow.

A system of heat balance equations [2] was constructed according to equivalent heat circuit for compressor parts and for a refrigerant flow. Usually these equations are of the following form:

1). for the \( i \)-th element of compressor structure

\[
t_i \sum_{k=1}^{n} \Lambda_{ik} \sum_{k=1}^{n} t_k \Lambda_{ik} = P_i
\]

2). for the \( j \)-th element of refrigerant flow

\[
t_j (2\Lambda_0 + \sum_{z=1}^{s} \Lambda_{z0}) - \sum_{z=1}^{s} t_z \Lambda_{z0} - \sum_{p=1}^{l} t_p \Lambda_{p0} - t_{c, j-1} (2\Lambda_0 - \sum_{p=1}^{l} t_p \Lambda_{p0}) = 0
\]

As a result a system of linear equations was obtained that completely describes heat processes in a semihermetic refrigerant reciprocating compressor.
The calculation of the equivalent heat circuit of a semihermetic refrigerant compressor resulted in constructing diagrams for temperature dependencies of refrigerant flow and compressor structure elements on its operational conditions (Fig. 5). Thus, a great deal of calculated and experimental data was obtained on varying working temperature fields of a semihermetic refrigerant reciprocating compressor.

CONCLUSIONS

Comparison and analysis of calculated and experimental data (Fig. 6, 7) have shown that the developed methodic of calculation completely reflects heat processes in a semihermetic refrigerant compressor and can be effectively used in calculating the working temperatures of compressor elements in the whole range of its operational conditions. The results of experimental research and methodic for calculation and construction of equivalent heat circuit of a semihermetic refrigerant compressor can be successfully applied to employ new ecology-friendly refrigerants as well as to optimize its design parameters.

REFERENCES


Fig.1 Diagram of varying the temperature of refrigerant R12 on motor exit

Fig.2 Diagram of varying the temperature of refrigerant R12 on pumping channel
Fig. 3 Diagram of varying the temperature of refrigerant R22 on motor exit

Fig. 4 Diagram of varying the temperature of refrigerant R22 on pumping channel

Fig. 5 Equivalent heat circuit of a semihermetic refrigerant compressor
Fig. 6 Comparison of calculated and experimental data

- \( t_0 = -15^\circ C, \ t_k = 30^\circ C \)
- \( t_0 = 5^\circ C, \ t_k = 30^\circ C \)

Fig. 7 Comparison of calculated and experimental data

- \( t_0 = -25^\circ C, \ t_k = 40^\circ C \)
- \( t_0 = -5^\circ C, \ t_k = 40^\circ C \)