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EXPERIMENTAL INVESTIGATION ON HEAT TRANSFER IN THE MANIFOLD OF REFRIGERATING COMPRESSORS*

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ABSTRACT

In this study, a review and discussion has been made on the research work of heat transfer in manifolds previously done. Since it is difficult to determine the heat transfer coefficients in different areas of a suction or discharge chamber by using conventional methods, the mass transfer analogy -- sublimation of naphthalene has been used to develop the heat transfer correlations for the four areas in a suction chamber. The mass transfer experiments were carried out on a model under the stable flow conditions with air as the medium. The correctness of the correlations has been verified through the measurement of the average heat transfer coefficient in the chamber. The maximum deviation of heat transfer coefficients measured from the correlations is within ±10%.

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INTRODUCTION

Since the 1970s, some work have been done to determine the manifold heat transfer coefficients in refrigerating compressors. J. M. Hughes (1) and Dang Jinquan (2) respectively presented the following heat transfer correlations for the valve passage, the suction chamber and the discharge chamber that they have used in their heat transfer experiments:

Hughes:

Valve Passage $Nu = 1.48Re^{0.63}Pr^{0.6}$

Dang:

Suction Chamber $Nu = .033Re^{0.88}Pr^{0.6}$

Discharge Chamber $Nu = .45Re^{0.57}Pr^{0.6}$

These correlations can be used to calculate average heat transfer coefficients over whole area of the passage or the chamber. The correlations were obtained from the experiments by using the conventional method in which the heat flux through the whole area has to be measured.

It has been found that the heat transfer coefficients are not the same in different areas of a chamber, therefore a project has been arranged to determine the heat transfer coefficients in several partial areas of a suction chamber. The conventional method used in literatures (1) and (2) to determine the average heat transfer coefficient over whole chamber area is difficult to be used to obtain the average heat transfer coefficients in each partial area of the chamber, because the heat flux through each area is not easy to be measured. Therefore, the mass transfer analogy has been applied in order to avoid the heat flux measurement.

The principle of mass transfer analogy can be described as follows:

Put the material such as naphthalene on surface S as shown in Fig. 1 at which the heat transfer coefficient is going to be measured. Naphthalene will sublimate when the air passes through surface S. After weighing the naphthalene mass sublimated per unit time, and measuring some thermodynamic properties of naphthalene vapor, we can obtain a mass transfer correlation of the form

$$Sh = aRe^{b}Sc^{c} \tag{1}$$

where Sh denotes the Sherwood number, Re the Reynolds number, and Sc the Schmidt number.

The correlation for heat transfer at the surface S is

$$Nu = a'Re^{b'}Pr^{c'} \tag{2}$$

It is pointed out that there is the following relationship between constants a, b, c and a', b', c':

$$a = a'$$

$$b = b'$$

$$c = c'$$

therefore, constants a', b' and c' and then heat transfer correlation (2) can be obtained after determining constants a, b and c by means of the mass transfer experiment.

In this study, the heat transfer occurring in the suction chamber of a double cylinder semihermetic compressor has been investigated. The chamber surface has been divided into four partial areas; the front area, the back area, the top area and the bottom area. The front and the back area of the suction chamber are represented by lines a-b-c and a-d-c as shown in Fig. 2.

NAPHTHALENE SUBLIMATION EXPERIMENTS

Sublimation of naphthalene is one of the methods frequently used in mass transfer analogy studies. The method appears to have been introduced by Jakob and Kezios in 1953 and has been used in a variety of experimental investigations since that time. The naphthalene used in the experiments is usually of crystal grade, chemical symble $C_{10}H_8$, molecular weight 128.2, melting point between 79 and 80°C, and 0.001% residue after ignition. (3)

The naphthalene sublimation experiments have been done on a model of the suction chamber. The model consists of several plastic plates and blocks, and has basically the same size and structure as the real chamber except the outlet port. There is only one outlet port in the model instead of two valve ports in the real chamber because of their symmetry. The four areas to be investigated have been simulated by four corresponding naphthalene plates, therefore the corresponding plastic plate in the model would be replaced by the naphthalene plate when one area was investigated. The naphthalene plate was cast in a mold made of aluminium and had very smooth surface.

Fig. 3 shows the experimental arrangement. Air was forced through the model and the air flux meter, and then excluded from the laboratory by the exhauster. The air stream through the model was adjusted with the aid of a by-pass valve.

The average mass transfer coefficient B at the surface investigated can be expressed as

$$B = \frac{mR_v T_w}{P_{vs} F} \qquad (3)$$

where m denotes the mass loss per unit time after sublimation, R_v the gas constant of the naphthalene vapor, T_w the surface temperature of the naphthalene, P_{vs} the vapor pressure of naphthalene at the surface temperature, and F the surface area. The mass loss was measured by weighing. The surface temperature was assumed to be equal to the temperature in the air stream. The vapor pressure of naphthalene was determined from the following correlation:

$$LgP_{vs} = 13.564 - 3729.4/T_w \qquad (4)$$

The Reynolds number and the Sherwood number are

$$Re = \frac{vQD_h}{uA} \qquad (5)$$

$$Sh = \frac{BD_h}{D} \qquad (6)$$

in which v indicates the inlet air density, Q the air flow rate in volume through the model, D_h the hydraulic diameter of the inlet port, A the area of the inlet port, u the air dynamic viscosity at the inlet port, and D the mass diffusion coefficient. $D = r/Sc$, in which the Schmidt number $Sc = 2.5$ and r denotes the air kinematic viscosity.

The mass transfer data obtained for the four areas have been correlated as follows:

at the front area $Sh_1 = 0.14Re^{0.68}Sc^{0.4}$ (7)

at the back area $Sh_2 = 0.14Re^{0.67}Sc^{0.4}$ (8)

at the top area $Sh_3 = 0.10Re^{0.7}Sc^{0.4}$ (9)

at the bottom area $Sh_4 = .082Re^{0.7}Sc^{0.4}$ (10)

It has been assumed that the Sh is proportional to $Sc^{0.4}$ for mass transfer during the development of equations

(7) - (10), since the Nu is approximately proportional to $Pr^{0.4}$ for heat transfer in the suction chamber.

In accordance with heat-mass transfer analogy theory, heat transfer correlations for the four areas will be

at the front area $$Nu_1 = 0.14Re^{0.68}Pr^{0.4} \tag{11}$$

at the back area $$Nu_2 = 0.14Re^{0.67}Pr^{0.4} \tag{12}$$

at the top area $$Nu_3 = 0.10Re^{0.7}Pr^{0.4} \tag{13}$$

at the bottom area $$Nu_4 = .082Re^{0.7}Pr^{0.4} \tag{14}$$

It can be seen from equations (11) - (14) that the two areas parallel to each other (for example, the front area and the back area) have the closest heat transfer coefficients. Fig. 4 and 5 show the results obtained from these equations and the experiments.

The average Nusselt number $\overline{Nu}$ in the suction chamber is determined by the following relation:

$$\overline{Nu} = \frac{\sum_{i=1}^{4} F_i \, Nu_i}{\sum_{i=1}^{4} F_i} \tag{15}$$

where F_i denotes the corresponding area. With this relation, we obtain the correlation of heat transfer over whole area of the chamber

$$\overline{Nu} = 0.12Re^{0.68}Pr^{0.4} \qquad (16)$$

HEAT TRANSFER EXPERIMENT

To verify the correctness of the heat transfer correlations indirectly obtained by using naphthalene sublimation, a heat transfer experiment was carried out on the suction chamber. A electric heater was fixed in the discharge chamber to establish the temperature difference between the chamber wall and the air stream passing through the suction chamber. All the temperatures, including the inlet and the outlet air temperatures, were measured with thermocouples. Thus, the average heat transfer coefficient over whole area of the suction chamber was obtained by measuring the average heat flow rate to the whole wall.

The maximum deviation of heat transfer experimental data from equation (16) is within ±10%. Fig. 6 shows the results calculated from equation (16) and the one obtained from the experiment. The agreement between the calculated and the measured is seen to be satisfactory.

CONCLUSIONS

It is the first time in the study of heat transfer in refrigerating compressors to use the technique of naphthalene sublimation to develop the heat transfer correlations for partial areas in a suction chamber of a semihermetic compressor. The heat transfer correlations presented in this paper have been verified to have the maximum deviation within ±10 percent from the corresponding heat transfer data obtained in the experiments.

It is suggested that the two areas parallel to each other in the suction chamber have the closest heat transfer coefficients.

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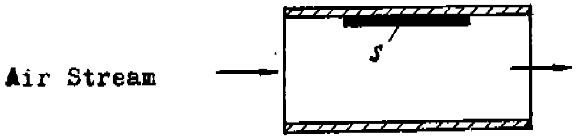

Fig. 1 Surface S to be Measured

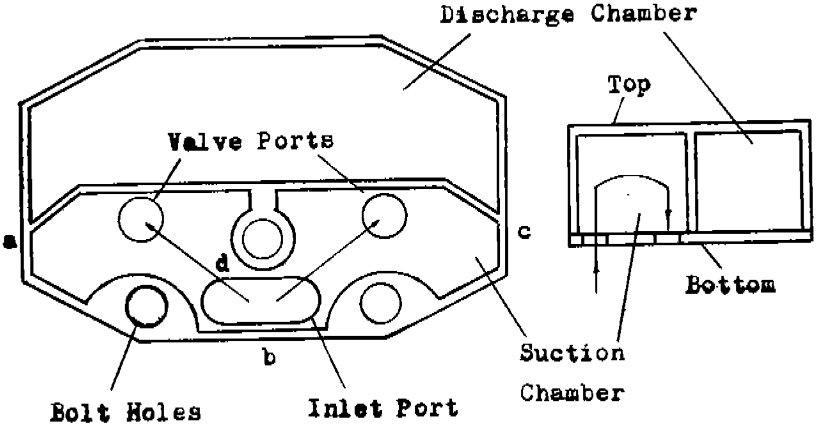

Fig. 2 Sketch of the Chambers

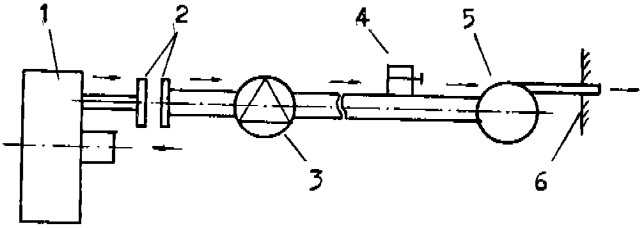

Fig. 3 Sketch of the Experimental Arrangement
1. the model 2. the connectors
3. the air flux meter 4. the by-pass valve 5. the exhauster 6. the wall

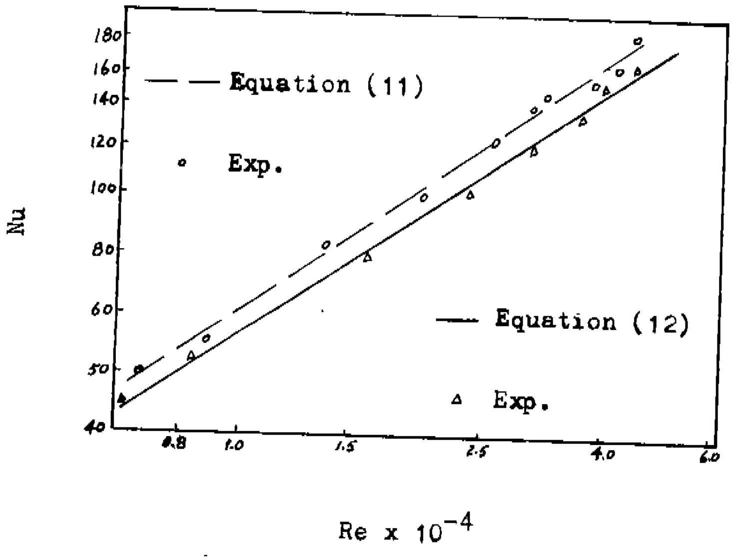

Fig. 4 Heat Transfer in the Front and the Back Areas.

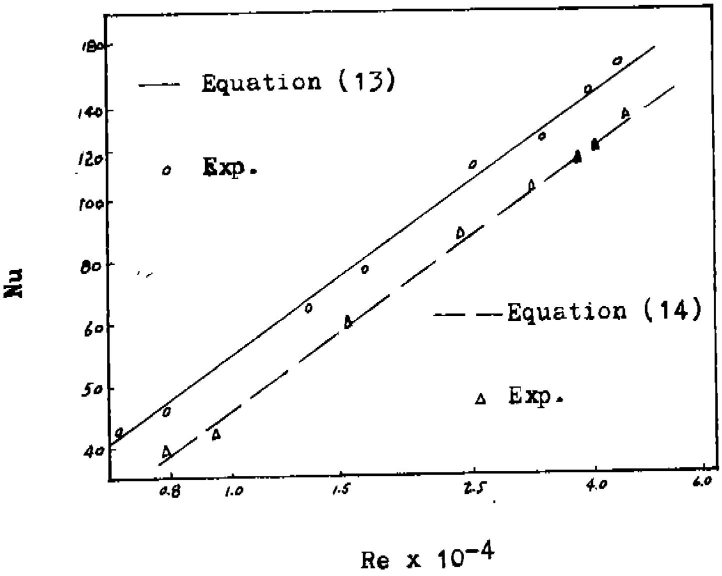

Fig. 5 Heat Transfer in the Top and the Bottom Areas

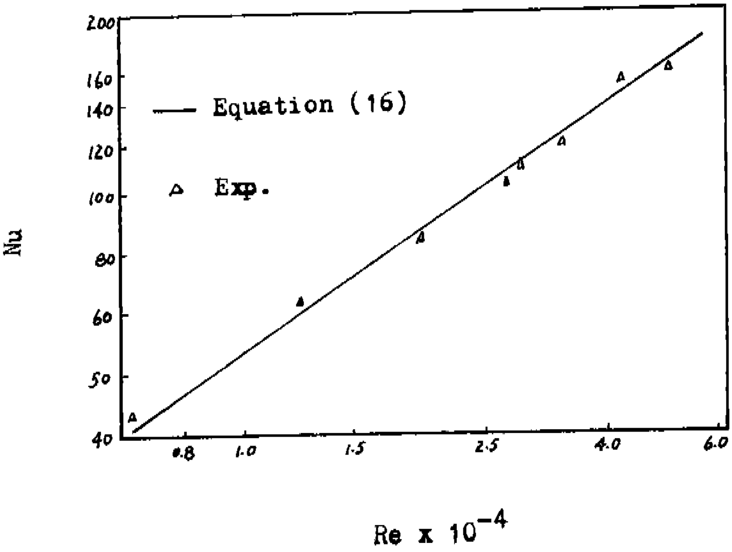

Fig. 6 Heat Transfer in the Suction Chamber

THE TEMPERATURE MEASUREMENT FOR ROTARY COMPRESSOR WITH OIL INJECTION

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ABSTRACT

The discharge temperature of rotary compressors with oil injection is generally measured by a thermometer directly put in the discharge pipe. Oil and gas are mixed and have different temperatures, so that the measurement is not exact. In this paper, a measuring method placing a centrifugal sheath for separating oil from gas, is put forward, in which the discharge temperature can be more exactly measured. The method is convenient in use and has a simple structure and a good stability through experiments. In order to analyse the error of the measurement, a inequality is built according to the two phase flow theory, then count out the one-side-maximum error.

SYMBOLS

t_G	gas temperature
d	diameter of centrifugal separating sheath hole
Z	pipe length
Q	quantity of heat transfer
C_{PG}	isobaric specific heat of gas
W_G	mass flow of gas
L_o	volume flow of oil
τ	time
F	area
δ_{oo}	one-side-maximum-relative error
δ_{oa}	one-side-maximum-absolute error
δ_o	relative error