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An Investigation on Heat Transfer in Reed Valve Passage

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ABSTRACT

In this paper, a review and discussion has been made on the study of heat transfer previously done in suction and discharge valve. The Significance of making an investigation on the heat transfer coefficient has been point out. A series of experiments on heat transfer in the reed valve passage have been carried out. Since the flow patterns of refrigerant are not the same in different areas of valve passage , it is desirable to obtain heat transfer coefficients in these areas. Therefore, the valve passage is divided into three areas in the experiment. Since the reed valve is quite small, it is difficult to measure the heat transfer coefficient by using the classical method requiring measurement of temperature difference and heat flow, the heat—mass transfer analogy theory—— naphthalene sublimation technique has been used.

Through experiments, four heat transfer correlations for three local areas and for whole passage in a suction valve have been developed. The correlations have been applied to the compressor simulation. With the consideration of heat transfer in reed valve passage, the temperature of superheated refrigerant in valve passage and the mass flow have been determined.

INTRODUCTION

In recent years, the design of refrigerating compressors is made with the help of mathematical models used to describe the physical processes in the compressors. In numerous physical processes, the superheat of the suction gas in refrigerating compressors is one of important aspects concerning refrigeration cycle and is also the factor considered in the optimum design of compressors. Among a variety of heat transfer problems, the detrimental superheat in suction manifold results in an incerase of the power consumed and a decrease of the volumetric coefficient and E.E.R. When refrigerant flows through the narrow valve passage, it absorbs the heat energy from the valve passage surface which in turn effects on the performance of refrigerating compressors. Since the 1970s, some works have been done to determine the average heat transfer coefficients in valve passage:

R. Psakash[1] $Nu = 0.023 Re^{0.8} Pr^{0.4}$

S.W. Brok[2] $\alpha = C_1 + C_2 V$

J.M. Hughes[3] $Nu = 1.48 Re^{0.63} Pr^{0.6}$

In these correlations, Psakash's and Brok's correlations came from basic heat transfer correlations and the Hughes's correlation used for ring type valve was obtained from experiments by using the conventional method in which the heat flux through whole area has to be measured. The heat transfer in reed valve is another important problem in compressor design. The study in this area are not sufficient at this moments.

The present investigation deals with the heat transfer in the reed valve passage. Since the flow patterns of refrigerant are not the same in different areas of valve passage, it is desirable to obtain heat transfer coefficients in each area. Hance, in our experiment the valve passage is divided into three areas as shown in Fig.1,

1. the valve port,
2. the reed,
3. the valve plate surface under the reed.

Since the reed valve is quite small, it is difficult to measure the heat transfer coefficients by using the classical method requiring the measurement of temperature difference and heat flux. Therefore, the heat-mass transfer analogy theory——naphthalene sublimation technique has been applied. The principle of naphthalene sublimation technique can be described as follow:

The mass transfer system is similar to the heat transfer system in their mathematic equations under certain circumstances. If the boundary and geometry conditions of mass transfer system are similar to the conditions of heat transfer system, and the sublimation speed on naphthalene surface is negligible, the solutions of non-dimensional forms for two systems are similar[4]. The mass transfer correlation can be expressed as following

$$Sh = a Re^{b} Sc^{c} \qquad (1)$$

where Sh denotes the Sherwood number, Re the Reynolds number, and Sc the Schmidt number. The heat transfer correlation has similar form

$$Nu = a Re^{b} Pr^{c} \qquad (2)$$

where Nu denotes the Nusselt number, Pr the Prandtl number.

NAPHTHALENE SUBLIMATION EXPERIMENTS

The experiment using mass transfer technique can be carried out as following:
put the naphthalene on the surface of valve passage at which the heat transfer coefficient is going to be determined. Naphthalene will sublimate when the air passes througe the passage surface. After weighing the naphthalene mass sublimated per unit time, and measuring some thermodynamics properties of naphthalene vapor, we can obtain the mass transfer correlation(1). The heat transfer correlation(2) can be developed by substituting the coefficients a, b,c in correlation(1) into correlation(2). The arrangement for experiment is shown in Fig.2. Air is forced through the valve. The air flow rate was adjusted with the aid of a by-pass valve. Three naphthalene blocks having the same shape and structure as the three areas of real suction valve have been prepared for the experiment. The naphthalene blocks were made of aluminium or copper covered with naphthalene. The average mass transfer coefficient B at the surface investigated can be expressed as

$$B = (mRvTw)/(PvsF) \tag{3}$$

where m denotes the mass loss per unit time during the sublimation, Rv the gas constant of naphthalene vapor, Tw the surface temperature of naphthalene, Pvs 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:

$$\lg Pvs = 13.564 - 3729.4/Tw \tag{4}$$

The Re number and the Sh number are

$$Re = (V\dot{Q}Dh)/(uA) \tag{5}$$

$$Sh = (BDh)/D \tag{6}$$

where V indicates the inlet air density, $\dot{Q}$ the air flow rate in volume through the passage, Dh the diameter of suction valve port, A the area of suction valve port, u the air dynamic visscosity at the inlet port, and D the mass diffusion coefficient. The mass transfer data obtained in three areas of suction valve have been correlated as follows:

at valve port $\quad Sh = 0.071Re^{0.80}Sc^{0.3}$ (7)

at reed $\quad Sh = 0.13Re^{0.71}Sc^{0.3}$ (8)

at the valve plate surface under the reed

$$Sh = 0.12Re^{0.7}Sc^{0.3} \tag{9}$$

According to the heat-mass transfer analogy theory, heat transfer correlations for the three areas will be

at valve port $$Nu = 0.071Re^{0.8}Pr^{0.3} \quad (10)$$

at reed $$Nu = 0.13Re^{0.7}Pr^{0.3} \quad (11)$$

at the valve plate surface under the reed

$$Nu = 0.12Re^{0.7}Pr^{0.3} \quad (12)$$

It can be seen that the heat transfer correlations(11) and (12) are nearly of the same. The resulis obtained from correlations and experiments are shown in Fig.3 through Fig.5. The average $\overline{Nu}$ number in suction valve passage is

$$\overline{Nu} = (\sum_{i=1}^{3} F_i Nu_i)/(\sum_{i=1}^{3} F_i) \quad (13)$$

where F_i denotes the corresponding area. With this relation, the $\overline{Nu}$ number over whole area of suction valve can be written:

$$\overline{Nu} = 0.11Re^{0.73}Pr^{0.3} \quad (14)$$

The average $\overline{Nu}$ number measured in discharge valve is

$$\overline{Nu} = 0.11Re^{0.72}Pr^{0.3} \quad (15)$$

The calculated results from correlations(14) and (15) are shown in Fig.6. A heat transfer experiment was carried out on the discharge valve passage with the classical method requiring the measurment of heat flux to check the heat transfer data calculated from correlation(14). An electrical heater was used to establish the temperature difference between the valve and the air stream passing through the valve passage. The temperatures, including the inlet and the outlet air temperatures, were measured with thermocouples. The maximum deviation between the calculated and the measured results is within $\pm$ 10%.

MATHEMATICAL SIMULATION OF REFRIGERATING COMPRESSOR

Mathematical modeling is an efficient way of studying the basic behavior of refrigerating compressors. During the modeling, equations are applied to describe the processes occuring in compressor. A mathematical model used to describe the thermophysic processes in cylinder, valve and chambers has been developed. The heat transfer correlations in the model come from above experiments. Since the simulation of compressor requires simultaneous solution of a large number of differential equations, the Runge-Kutta method was applied. The instantaneous temperatures temperatures of superheated refrigerant and the mass flow rate during suction process have been calculated, as shown in Fig.7 and Fig.8.

CONCLUSIONS

1. It is the first time to develope heat transfer correlations for reed valve of reciprocating compressor by using the technique of naphthalene.

2. The area of reed and the area of valve plate surface under the reed have nearly the same heat transfer correlations, but the heat transfer correlations in above two areas are different from the heat transfer correlation in valve port.

3. Valve passages similar in structure have similar heat transfer correlations.

4. An mathematical model of consideration thremophysics process including the heat transfer process in reed valve passage has been developed.

REFERENCE

[1] R.PraKash, " Mathematical Modelling and Simulation of Refrigerating Compressors", Proc. of the 1974 Purdue Compressor Technology Conference.

[2] S.W.Brok, " Modelling of Cylinder Heat Transfer— Large Effect, Little Effect?", Proc. of the 1980 Purdue Compressor Technology Conference.

[3] J.M.Hughes, " Experimental Investigation of Some Thermodynamics Aspects of Refrigeration Compressors", Proc. of the 1972 Purdue Compressor Technology Coference.

[4] E.R.G.EcKert & R.I.Gddstein, " Measurement in Heat Transfer", 2nd Edition, McGraw-Hill, 1976

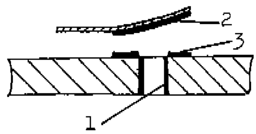

Fig.1 Three Local Areas

1. Valve Port 2. Reed
3. Valve Plate Surface under the Reed

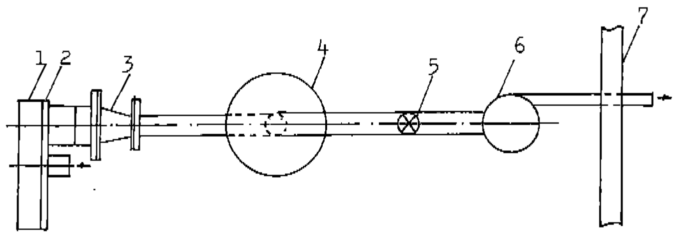

Fig.2 Sketch of Experiment Arragement

1. Chamber 2. Model 3. Nozzle 4. Air Flux Meter
5. By-pass Valve 6. Exhauster 7. Wall

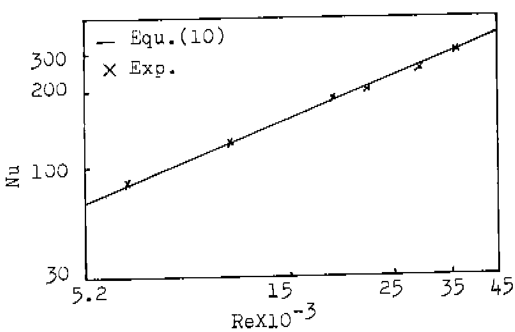

Fig.3 Heat Transfer in Valve Port

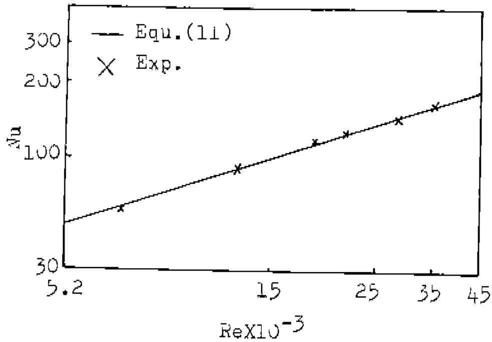

Fig.4 Heat Transfer in Reed

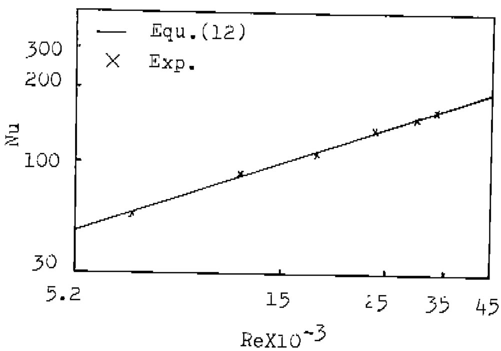

Fig.5 Heat Transfer in Valve Plate Surface under the Reed

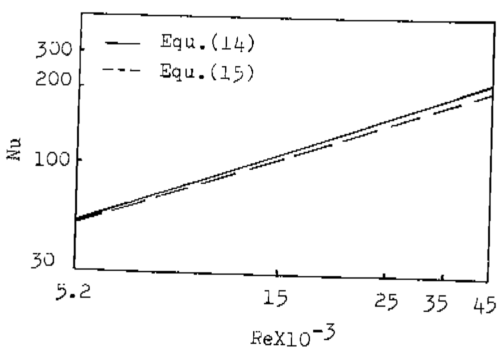

Fig.6 Heat Transfer in Suction Valve and Disharge Valve

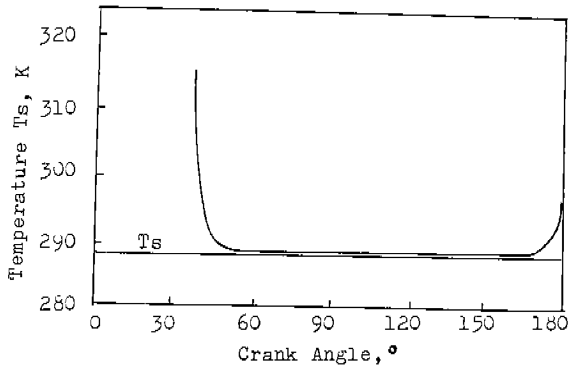

Fig.7 Instantaneous Temperatures of Refrigerant in Suction Valve Outlet

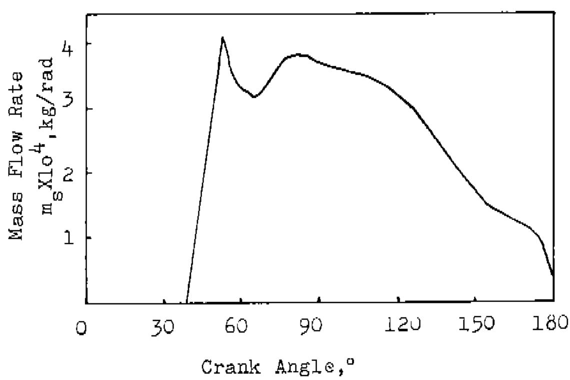

Fig.8 Mass Flow Rate during Suction Process