1978

Dynamic Investigations of Suction Valves in a Small Refrigerating Compressor

Marian Luszczycki

DYNAMIC INVESTIGATIONS OF SUCTION VALVES IN A SMALL REFRIGERATING COMPRESSOR

Marian Łuszczycki, Docent, Instytut Aparatury Przemysłowej i Energetyki, Politechnika Krakowska, Kraków, Poland

INTRODUCTION

Designers drafting valves, which are the most essential elements of high-speed compressors, are faced with many problems solving of which goes beyond the limit of theoretical considerations. Therefore it is necessary to carry on comprehensive and penetrating laboratory investigations within this field. Such investigations are an experimental verification of numerous calculation methods and computer simulation programs. Badly designed valves can be an origin of heavy energy losses. There are common structures of high-speed compressors, in which energy consumption necessary for overcoming the flow resistance through valves, ranges from 20-25 % of indicated power [1,2,3,5,7].

Valve work can be affected by many factors like: compressor rotary speed, average piston speed, flow velocity in valve sizing, suction and discharge pressure, pressure pulsation in the installation, spring characteristics, lift quantity, mass of the valve movable parts, friction and aerodynamical properties of the valve. Thus, it is very difficult to consider in calculations all these factors, especially in the case of changing conditions of the compressor work. The most unfailing way of the valve structure appreciation can be obtained on the grounds of plotted graphs of the valve plates displacement and records of pressure runs in the cylinder and in valve chambers. The complete set of charts, drafted in normal conditions of the compressor work, affords a possibility of many-sided analysis of the valve work. At the present moment charts of the valve plates displacement are plotted mainly with a help of electrical methods, by means of non-contact capacitance transducers or inductance transducers [3,4,6,7].

RECORDING OF CHARTS OF THE VALVE PLATES DISPLACEMENT

Charts of the valve plates displacement have been plotted by means of the capacitance transducer which was constructed on the grounds of a rule applied before by Söchting [6]. The transducer serves a purpose of converting the to and fro motions of the valve plate into the electric impulse. It is a small cylindrical condenser /Fig. 1/, one screen of which is a sleeve of 3 mm inside diameter, settled in a non-movable part of the valve, and isolated from its mass with a great care. The other screen of the condenser is a mandrel of 1,5 mm diameter, fixed to the valve plate. The whole valve is carefully isolated from the compressor case and head. A change of ΔC capacitance of the condenser with a coincident mandrel displacement Δh, in rela-

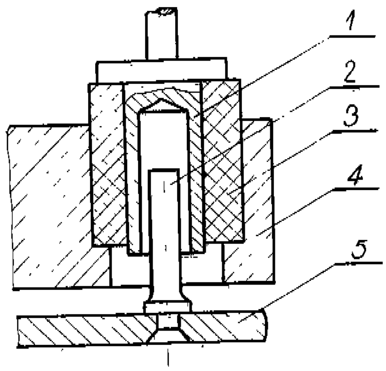

Fig. 1. A scheme of the capacitance transducer installation in the valve: 1 - sleeve, 2 - mandrel, 3 - insulation, 4 - valve case, 5 - valve plate.

tion to the sleeve, can be described by the following expression:

$$\triangle C = \frac{\triangle h}{\frac{1}{2\pi \varepsilon_o \varepsilon_g} \ln \frac{d_1}{d_2}} \quad [pF] \ldots\ldots\ldots\ldots\ldots /1/$$

where:

ε_o = 0,0886 [pF/cm] - absolute permittivity of free space,

ε_g - coefficient of relative permittivity of compressed gas,

d_1 - inside sleeve diameter in [cm],

d_2 - mandrel diameter in [cm].

Having assumed that the value of the relative permittivity for gases is practically ε_g = 1, and replacing numerical value for ε_o, we obtain:

$$\triangle C = \frac{\triangle h}{1{,}8 \ln \frac{d_1}{d_2}} \quad [pF] \ldots\ldots\ldots\ldots\ldots\ldots /2/$$

Substituting expression /2/ by a concrete value of diameters relation, which is d_1/d_2 = 2, we can obtain:

$$\triangle C = \frac{\triangle h}{1{,}8 \ln 2} \quad [pF] \ldots\ldots\ldots\ldots\ldots\ldots /3/$$

Dependence /3/ allows to calculate a relation $\triangle C/\triangle h$ called the transducer sensitivity, the value of which is $\triangle C/\triangle h \approx 0{,}80$ [pF/cm] = 0,08 [pF/mm].

The interaction of the transducer on the valve is very slight. Small overall dimensions allow to install it in such a way that it hardly creates any disturbances in the flow of gas through the valve [3,4,7]. Being a non-contact transducer it does not create any additional deformations caused by friction. It is only a mandrel, fixed directly to the valve plate, that causes an increase of its mass. According to Söchting [6], the increase of the movable mass up to 10 % is of no importance because it does not change the character of the motion. The mandrel mass is essential in practice, when examining small compressors, the valve plates of which have small mass. That is why the mandrel in the discussed case has been produced from the aluminium, and its length has been limited to the necessary minimum.

The capacitance transducer can be a part of a measuring system with the carrier frequency, as well as an element of a measuring system fed with direct current. The author mostly uses a measuring system fed with direct current, which has been presented in Fig. 2. This system is based on the indication apparatus set produced by RFT firm and comprises: a cathode oscilloscope, capacitance transducer of the crank angle or the piston travel and dead centre signs, direct current amplifier for vertical deformations and an amplyfying set for horizontal deformations. The capacitance transducer has been fed with direct current of regulated voltage in the range of 100 - 180 V. By means of such a measuring system charts of valve plates displacement can be drafted as a function of the piston travel, crank angle or time. In order to analize the valve functioning, charts draf-

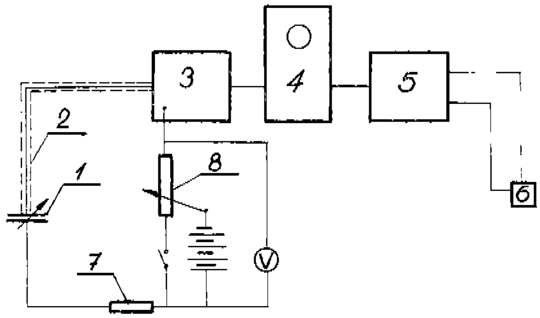

Fig. 2. A block scheme of a measuring system: 1 - capacitance transducer, 2 - coaxial cable of small capacitance, 3 - direct current amplifier, 4 - cathode oscilloscope, 5 - amplifying set for horizontal deformations, 6 - transducer of the crank angle and dead centre signs of the piston, 7 - cut-out, 8 - potentiometer.

ted as a function of the piston travel are the most advisable. According to the verifying examinations, angle steel deviations in that case do not go beyond 2^0. The measuring system with the capacitance transducer has a linear characteristic, if the mandrel is located centrally in the sleeve. The linearity of the characteristic is practically maintained when the eccentricity of the mandrel location in relation to the sleeve does not exceed 20 % of the distance $\frac{d_1 - d_2}{2}$ [4,6].

SUBJECT OF INVESTIGATIONS AND METHOD OF THEIR REALIZATION

A subject of investigations was a suction valve in a small refrigerating compressor /cylindrical diameter D = 40 mm, piston travel S = 35 mm, rotational speed $\dot{n}$ = 970 r.p.m./. The compressor enters into the composition of a refrigerating machine working on freon 12, the nominal efficiency of which is about 2100 kJ/h at nominal parameters /+40 °C, -15 °C/. The compressor is equipped with a reed type suction valve of the following features:

number of orifices in the valve sizing	2
orifice diameter	d_o = 9 mm
sizing area	A_g = 1,272 cm^2
average speed in sizing	w_g = 11 m/s
depth of lift limiter	h = 2,1 mm

In the investigations two plates of 0,2 mm each have been used. Fig. 3 shows their shape and the place where the mandrel was attached to the plate. As formerly, the plates are called "a" and "b", according to the notation presented in Fig. 3. On the example of plate "a" an influence of a change of the lift limiter depth upon the valve functioning will beinvestigated.

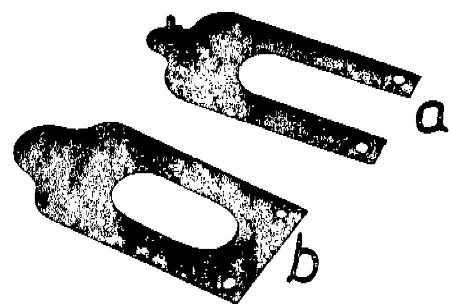

Fig. 3. Plates valve used in investigations.

Charts of the suction valve displacement have been drafted for different parameters of the refrigerating machine functioning on a research atand specially adapted for this purpose. Parameters of the refrigerating machine functioning have been established by regulating the expansion valve, regulated heating of evaporator and throttling of the air which refrigerates the condenser. A regularity of the required parameters establishing has been controlled on the grounds of pressure and temperature measurement in a suction connector

Table 1.

Temperature °C			Compression ratio
Condenser	Evaporator	Suction connector pipe	
+40	-25	+20	7,8
+40	-15	+20	5,3
+40	- 5	+20	3,7
+45	+ 5	+20	3,0
+60	+ 5	+20	4,0

pipe and the pressure measurement in the discharge connector pipe of the compressor. During the investigations precision of pressures was ±0,1 at and precision of temperature was ±1 °C. Table 1 shows a set of parameters of the refrigerating machine functioning during a record of charts of the valve plates displacement.

RESULTS

Fig. 4 presents oscillograms of charts of "a" and "b" plates displacement, drafted at different parameters of refrigerating machine functioning, when the lift limiter depth was 2,1 mm. Fig. 5 describes oscillograms of charts of the "a" plate displacement, drafted at the same parameters of the refrigerating machine functioning, when the depth of lift limiter was 3 mm. A set of charts in the figures corresponds with a set of parameters in Table 1.

Analysis of the chart shape of the plates displacement allows to state that it is favourable except cases /+40 °C, -25 °C/ and /+40 °C, -15 °C/. At the same time in all cases appear oscillations of the plate in the phase of opening. Angles of the valve opening change continuously together with a change of the compression ratio. However, absolute values of the valve opening delay are relatively high. Valve closure happens without a reflection about 25° after the outer deap centre. Charts of the plate displacement at two greatest investigated compression ratios gives evidence of an unfavourable valve functioning. In those cases the valve opens at a relatively high speed of the valve, then occur strong valve impacts against the limiter and a new almost complete closure of the valve. In the course of the opening phase the plate oscillations decrease and the phase of closing takes a normal course. A comparison of charts of plates "a" and "b" proves that the compression ratio is the greatest, plate "b" ensures a more favourable valve functioning. In the other cases any greater differences do not occur.

On the grounds of results of plate "a" investigations, it is easy to see that the increase of the lift limiter depth causes a considerable deterioration of the valve functioning at the greatest compression ratio. In the limiting investigated case, when the lift limiter depth was 3,0 mm /Fig. 5/ for the greatest compression ratio, strong plate oscillations are observed in the opening phase, which cause triple and almost complete closing of the val-

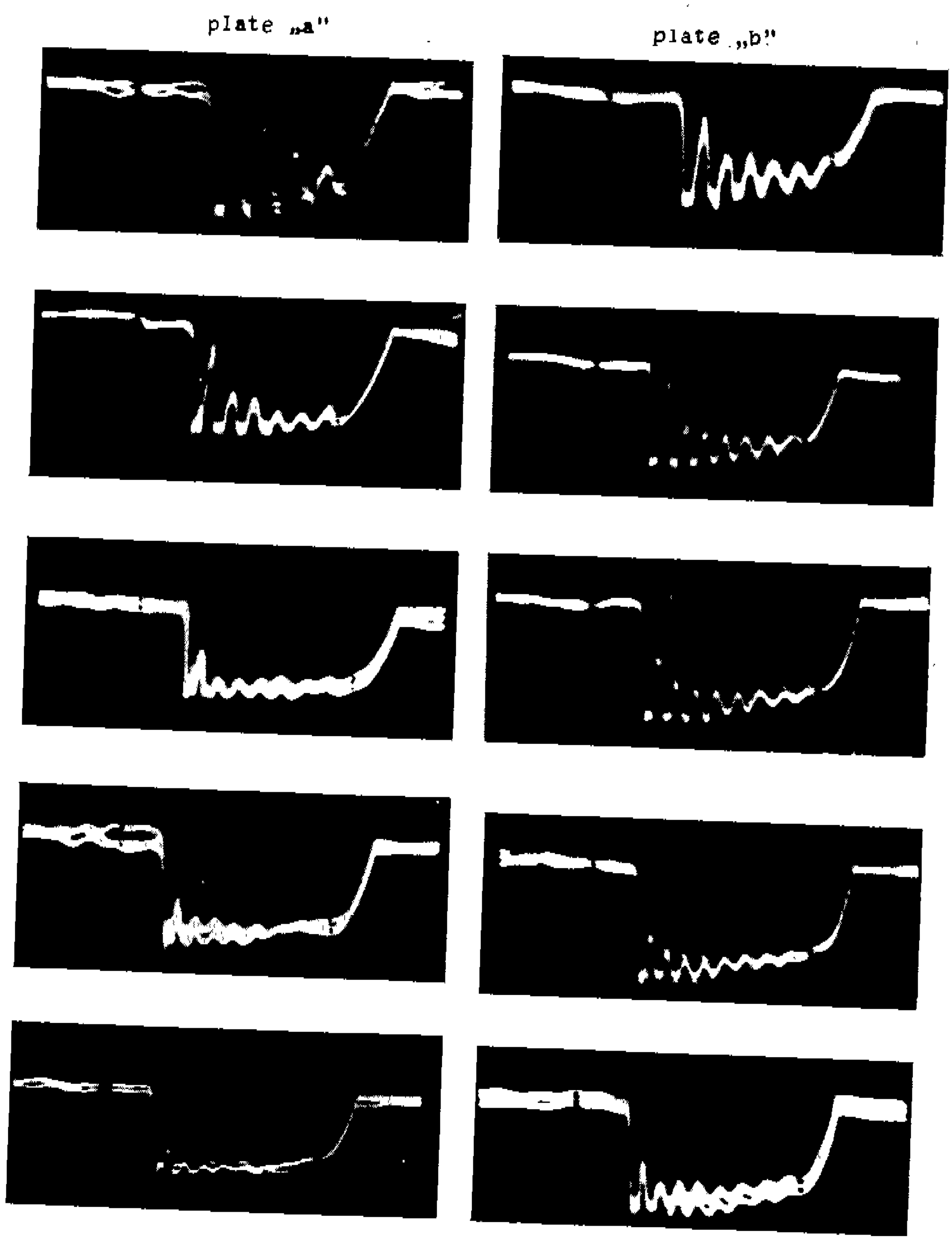

Fig. 4. Oscillograms of charts of "a" and "b" plates displacement when the lift limiter depth is 2,1 mm.

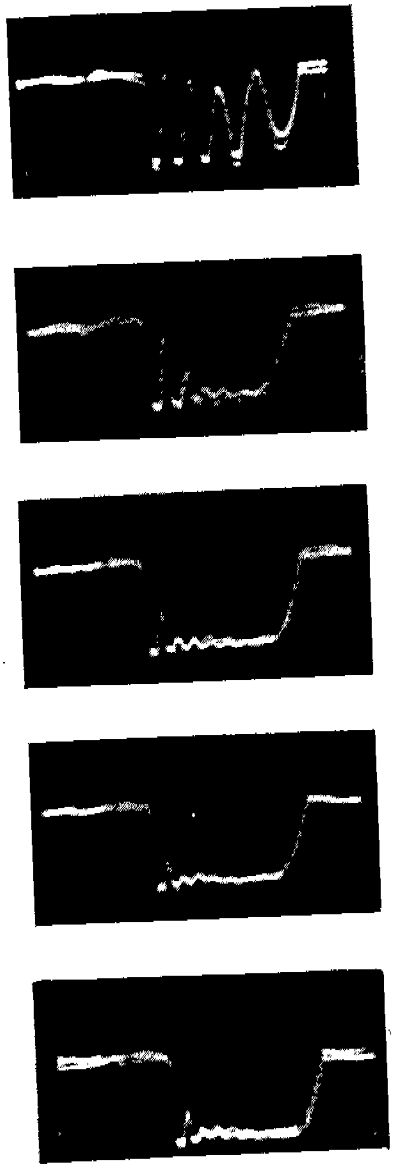

Fig. 5. Oscillograms of charts of plate "a" displacement when the lift limiter depth is 3,0 mm.

ve and its final closure with a strong reflection. When the compression ratios are smaller, a shape of the plate displacement charts is favourable and similar to the charts of the plate when the lift limiter depth is 2,1 mm.

CONCLUSIONS

On the grounds of the investigations it can be stated that the suction valve functioning is correct except two highest compression ratios. If we consider the whole range of the investigated compression ratios, it should be noted that the use of plate "b" ensures a more profitable valve functioning. The increase of the lift limiter depth over 2,5 mm is useless because it causes a considerable deterioration of the valve functioning at the greatest compression ratios.

REFERENCES

1. G.W. Gatecliff, H.S. Henry "Simulation of the Dynamic Performance of a Variable Width Cantilever Suction Valve Using Computer Graphics", Proceedings of 1976 Purdue Compressor Technology Conference, West Lafayette, Indiana, 6-9 July 1976, pp. 189-193.

2. H.K. Reddy, J.F. Hamilton "Accurate Experimental Determination of Frequencies, Mode Shapes, and Dynamic Strains in Plate Valves of Reciprocating Compressors", Proceedings of 1976 Purdue Compressor Technology Conference, West Lafayette, Indiana, 6-9 July 1976, pp. 290-294.

3. M. Łuszczycki "Badanie dynamiczne samoczynnych zaworów sprężarki SAF-23", Czasopismo Techniczne, nr 8/63/, 1963, pp. 9-15.

4. M. Łuszczycki "Czujnik pojemnościowy do zdejmowania wykresów drogi płytek samoczynnych zaworów sprężarkowych", Czasopismo Techniczne, nr 12/88/, 1965, pp. 35-37.

5. W. Soedel "Introduction to Computer Simulation of Positive Displacement Tape Compressors", Purdue University, West Lafayette, 1972,

6. F. Söchting "Huboszillogramme von Ventilen raschlaufender Verdichter", VDI-Z. Bd. 97, nr 3, 1955

7. St. Steindel " Wpływ charakterystyki sprężyn na działanie zaworów płytkowych i na wskaźniki ekonomiczne sprężarki", Archiwum Budowy Maszyn, tom XI, z. 2, 1964, pp. 311-344.