3. Determination of a piston compressor delivery

3.1 Introduction

A compressor is a good (basic) example of the open thermodynamics system. The main aims of use of it are as follows:

- to get drive medium for pneumatic devices,
- to increase temperature for coolant in refrigerators and heat pumps,
- to grow density for easy transport of medium.

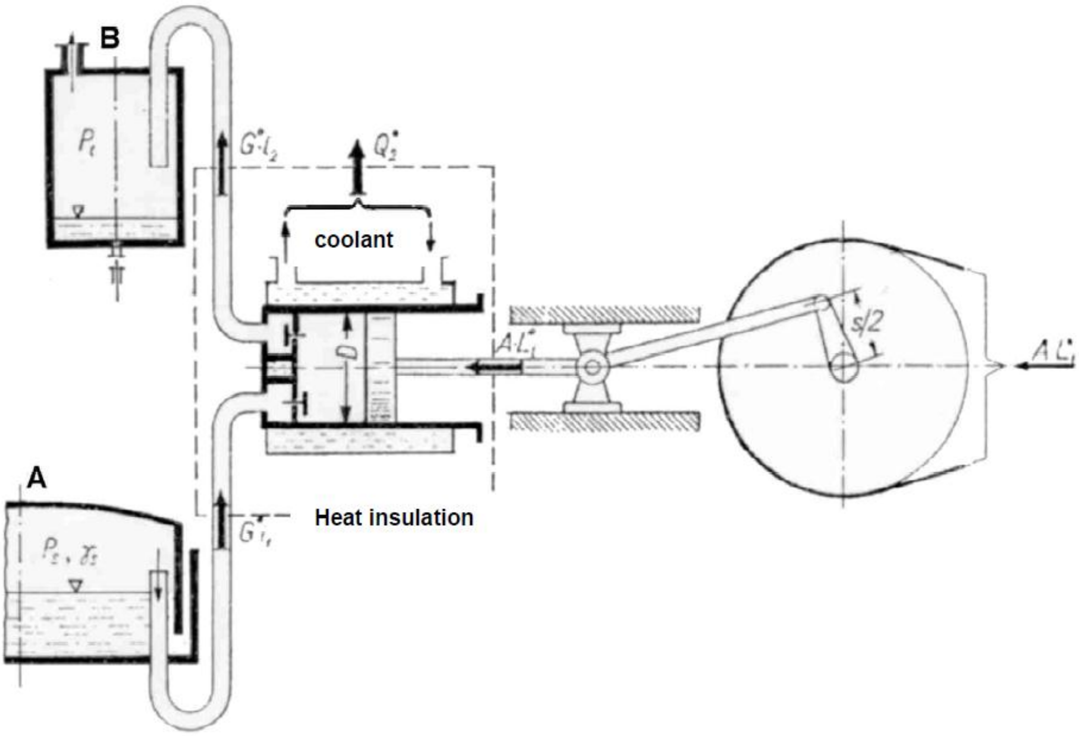

Fig 1 Scheme of piston compressor

Piston in compressor moves between two extreme positions called dead centres. Position closer to cylinder head (with valves) is called top dead centre TDC and the opposite one is the bottom dead centre – BTD. Considering construction of compressor and safety of piston operation, it is necessary that piston crown does not reach the head of compressor. Volume between piston and cylinder head, when piston is in TDC position, is called clearance space - V_{sz}.

It has a negative meaning. The compressor delivery is the highest for zero clearance space. Why? The clearance space is fill by gas after pressing (extrusion). It has pressure bigger than during the suction process. When piston starts filling tank with new portion of gas, pressure inside has to be reduced below or equal to suck pressure, first. It means piston stroke is used in part, only. On the another hand, the clearance space by used to control delivery in compressor powered by electrical motor with steady revolution (speed).
Compressor delivery depended on clearance space is determined by volumetric efficiency η_v.

The reference point is $\eta_v = 1$, of course. It is for ideal compressor where $V_{sz} = 0$ and compression
is adiabatic process – *fig. 2*. There are other assumptions, more:
- no friction between piston and cylinder,
- no hydraulic resistance around valves.

3.2 Indicator diagram

An indicator diagram is a graphical representation of the pressure change within the cylinder of the compressor with respect to the instantaneous piston location as well as instantaneous value of total volume of the gas.

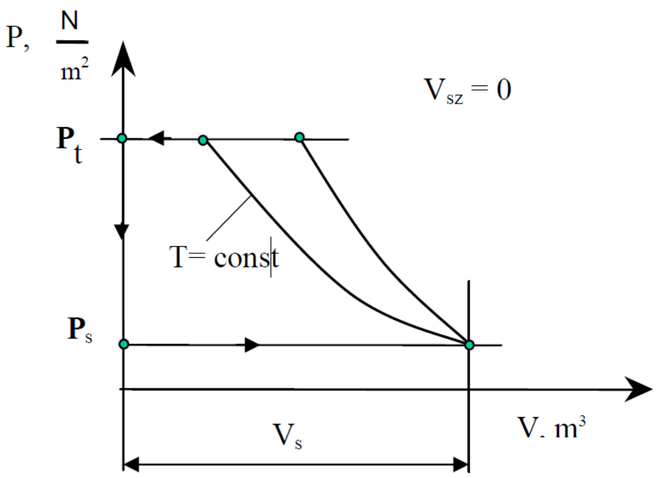

Fig 2. P-V diagram for ideal compressor. Pt – pressing (extrusion) pressure, Ps – suction pressure

The another standard (pattern) devices is called semi-ideal compressor – *fig. 3*.

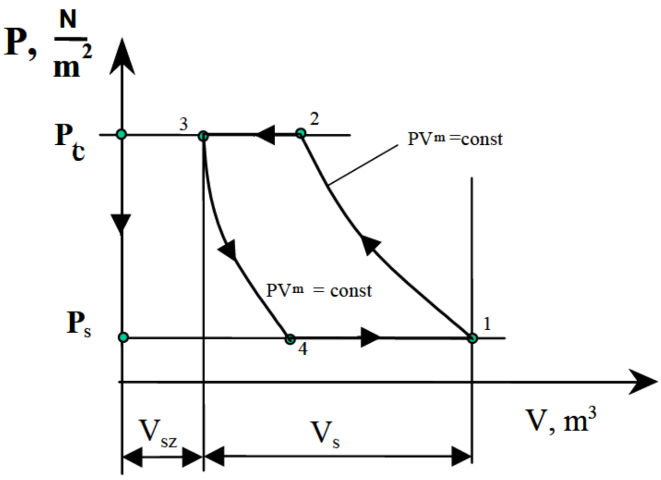

Fig 3. P-V diagram for semi-ideal compressor

For real compressor the P-V diagram is as in fig. 4.

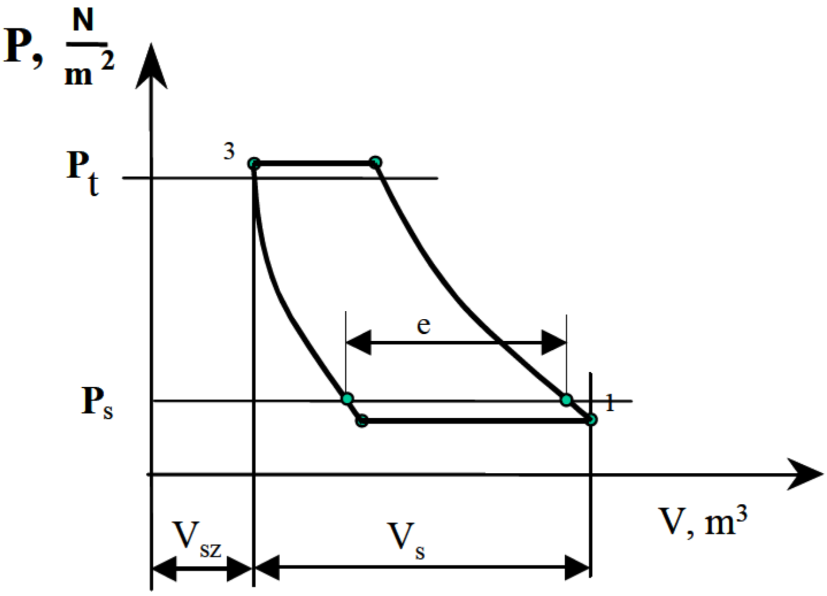

Fig 4 Fig. 4 P-V diagram for real compressor

3.3. Volumetric efficiency

Decrease of the compressor's efficiency caused by the clearance volume is determined by an indicator called volumetric efficiency η_V.

For the an ideal compressor $\eta_V = 1$; for semi-ideal compressor (see fig 3) the volumetric efficiency is given by:

$$\eta_V = \frac{V_1 - V_4}{V_S}$$

For real compressor the efficiency is:

$$\eta_V = \frac{a}{V_S}$$

Factor "a" from the denominator have to be determined using the diagram obtained experimentally

3.4 Filling the cylinder

The time of the ambient air compression from ambient pressure p_0 up to final pressure p_k inside the tank with volume of V_Z is strongly dependent on the swept volume V_S and the clearance V_{SZ}

During inflation of the tank the pressure changes along with change of the cycles number (i_{ki})

The value of (i_{ki}) changes with respect to the time of compressor operation (τ_{ki}), and the rotational speed of the compressor (n) expressed in [rpm] units. Thus:

$$i_{ki} = \frac{n \cdot \tau_{ki}}{60}$$

3.5 Experiment description

Fig 5 Compressor installation as a measurement position

Experiment is made for some clearance spaces V_{sz}. The test starts from the smallest one (as in design).
The following steps have to be realized:

- check the pressure in tank – should be equal to ambient one P_0,
- turn on the compressor and stop watch at the same moment,
- record the time values when the defined pressures will be reached P_j (i.e. each step 0,05 MPa between one to another),
- record the final time – time for final pressure (at the end of pressing) τ_k.

3.6. Elaboration of test data

To fulfil the objective of this experiments it is necessary:

3.6.1 To calculate Δm – the amount of air collected inside of the tank, after reaching pressures pk:

$$p_k V_Z = m_k R_{air} T_0$$

$$p_0 V_Z = m_0 R_{air} T_0$$

$$\Delta m = m_k - m_0$$

3.6.2 To compute m_{av} for each clearance space:

$$\dot{m}_{av} = \frac{\Delta m}{\tau_k}$$

3.6.3 To draw diagram V_{sz}, versus m_{av}.

An example of test table

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Group …………………..date: …………………. hour:…………………….

p_0=............................hPa to=................ °C T_0= ....K φ= .... %				
V_s = 107 cm^3 V_z = 100 000 cm^3 n = 1200 rpm				
$V_{sz1} = 30\ cm^3$				
$\Delta p_{ki}, MPa$	0,05	0,10	0,15	0,20
τ_{ki}, s				
i_{ki}				
p_{ki}, MPa				
$\dot{m}_{av}, {}^{kg}/_{s}$				
$V_{sz2} = 60\ cm^3$				
$\Delta p_{ki}, MPa$	0,05	0,10	0,15	0,20
τ_{ki}, s				
i_{ki}				
p_{ki}, MPa				
$\dot{m}_{av}, {}^{kg}/_{s}$				
$V_{sz3} = 90\ cm^3$				
$\Delta p_{ki}, MPa$	0,05	0,10	0,15	0,20
τ_{ki}, s				
i_{ki}				
p_{ki}, MPa				
$\dot{m}_{av}, {}^{kg}/_{s}$				