INFLUENCE OF TERMS T_1 AND T_2 FROM THE EQUILIBRIUM EQUATION FOR PRESSURE REDUCERS

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Abstract: *Experimental sets the percentage that each time the equation has to balance, influencing the final value of the output pressure of pressure reducers.*

Keywords: *pressure reducers, equilibrium equation, flow.*

1. INTRODUCTION

The gas pressure reducers so-called “*after self*” regulators unlike the safety valves that also can be called “*before self*” regulators that decrease the value of pressure p_1 of gas to their input at a value of pressure p_2 to output that is held constantly automatically. They can be classified as follows [1]:

- pressure reducers with the balanced adjusting member or balanced reducers;
- pressure reducers with the unbalanced adjusting member or unbalanced reducers;

The equilibrium equation for the unbalanced reducers is given by the relation:

$$p_2 = \underbrace{\frac{F_1^0 - F_{2.0} + F_{e.0} + p_a \cdot S_{m_{ef}} - c_1 \cdot p \cdot n}{S_{m_{ef}} \mp S_0}}_{T_1} \mp \underbrace{\frac{s_0}{S_{m_{ef}} \mp S_0}}_{T_2} \cdot p_1 - \underbrace{\frac{c \cdot C \cdot Q_m \sqrt{T_1 \cdot R \cdot A^*}}{\left(S_{m_{ef}} \mp s_0\right) \cdot \varepsilon \cdot \Psi \cdot \sqrt{s_0} \cdot p_1 \cdot \sin\theta}}_{T_3} - \delta \cdot \mu_s \cdot \underbrace{\frac{N}{S_{m_{ef}} \mp S_0}}_{T_4} \quad (1)$$

where:

p_2 – the output pressure from reducer (the reduced pressure);

F_1^0 - the force given by the initial contraction of adjusting spring; if the initial contraction misses $F_1^0 = 0$;

$F_{2,0}$ – the force given by valve spring when this is sat on its seat;

$F_{e,0}$ – the force given by elasticity of sensitive element (diaphragm) when valve is on seat;

p_a – the atmospheric pressure;

$S_{m_{ef}}$ - the effective surface of sensitive element;

c_1 – the stiffness of adjusting spring;

p – the pitch of adjusting screw;

n – the rotations number of adjusting screw;

s_0 – the seat surface (the unbalanced surface);

p_1 – the input pressure into reducer;

c – constant, $c = c_1 + c_2 + c_3$;

c_2 – the stiffness of valve spring;

c_3 – the diaphragm stiffness:

C = constant; $C = \frac{2}{\sqrt{\pi}}$

Q_m – the mass flow of gas;

T_1 – the gas temperature to input reducer;

R - the gas constant per mole;

ε - constant; for the flat valve ε = 1;

ψ - the flow coefficient;

θ - the semi angle from top of valve cone; for the flat valve $\theta = 90^{0,}$ so sin θ = 1;

δ - the over unitary coefficient;

μ - the static friction coefficient;

N – the normal force on the surface of valve guide;

$$A^* = \frac{1}{\sqrt{\frac{2\chi}{\chi-1}\left(\frac{p_2}{p_1}\right)^{\frac{2}{\chi}}\left[\left(1-\frac{p_2}{p_1}\right)^{\frac{\chi-1}{\chi}}\right]}} \quad (2)$$

In the case of sub critical flow A* increases together with the increasing of ratio $\frac{p_2}{p_1}$, [2].

When $\frac{p_2}{p_1}$ = β the minimum size has a minimum value, constant and equal to A.

$$A = \sqrt{\frac{1}{\chi\left(\frac{2}{\chi+1}\right)^{\frac{\chi+1}{\chi-1}}}} \quad (3)$$

χ - The adiabatic exponent of gas.

The first term of right side has the highest influence for the output pressure valve from reducer. The value of term T_1 is determined by adjusting reducer and does not depend on the pressure value to input of reducer.

This fact leads to the increase of pressure p_2 for the reducers with inverse stroke and at the decrease of pressure p_2 for the reducer with direct stroke.

The term T_3 unlike the first two ones, depends in a great measure on the mass flow Q_m of consumed gas.

The value of this term always increases non – linear together with the decrease of pressure p_1 from input into pressure reducer. In the case of sub critical flow through throttle slot, this increasing is more marked because the size A* suddenly increases due to fast decrease of ratio p_2 / p_1.

The value of term T_4 from the right side of relation (1) depends in a great measure on the value of pressure p_1 to input into reducer included into the size N. The general curves of variation of the four components from the right side of relation (1) for the case of reducers with inverse and direct stroke are presented in Fig. 1 and Fig. 2 respectively.

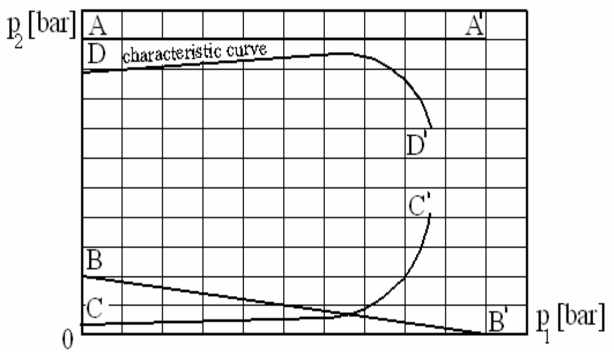

Fig. 1. General curves of variation for the terms from the right side of equilibrium equation for unbalanced reducers and inverse stroke

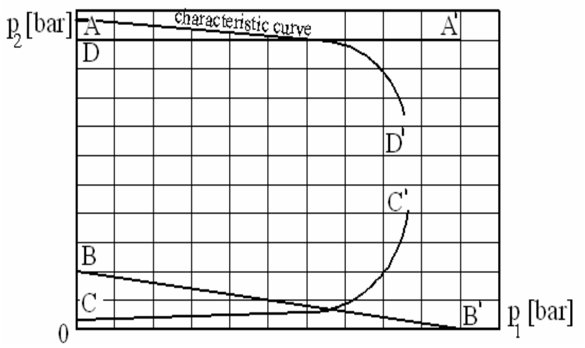

Fig. 2. General curves of variation for the terms from the right side of equilibrium equation for an unbalanced reducer with spring and direct stroke

In Fig. 1 the segment AA′ represents the component T_1, the segment BB′ represents the component T_2 and the curve CC′ represents the component T_3. The curve DD′ represents the characteristic curve (general) of pressure for an unbalanced reducer with spring and inverse stroke. In Fig.1.2, the segments AA′, BB′ and CC′ represent the terms T_1, T_2 and T_3 and the curve DD′ represents the characteristic curve (general) of pressure for an unbalanced reducer with the spring and direct stroke [2].

2. THEORETICAL EVALUATION OF TERMS OF EQUILIBRIUM EQUATION

The terms T_1, end T_2 will be evaluated for a reducer of class 5 with the working parameters under S.R. – EN 585.

2.1. Evaluation of term T_1

The term T_1 that depends only on the adjusting of reducer for the gas pressure can be expressed as T_1 = ct and is defined by the relation:

$$T_1 = \frac{F_1^0 - F_{2.0} + F_{e.0} + p_a \cdot S_{mef} + c_1 \cdot p \cdot n}{S_{mef} \mp s_0} \quad (4)$$

All sizes from relation (1) are explained in the introduction of present paper so that it does not come back on them for some absolutely necessary explanatory notes only. So:

$F_1^0 = 0.$

The initial contraction missing of main spring;

$F_{2,0} = c_2\, h$.

where :

c_2 - constant of valve spring;

h – compression stroke for carrying out sealing of throttle slot;

c_2 = 6 [N/mm] for all classes of reducers;

h = 5 [mm] for all classes of reducers;

$F_{c,0}$ = 0 due to the adopted technical solution and will be present in the claims chapter;

p_a = 0,098 [N/mm^2] ;

S_{mef} - the effective surface of diaphragm and has the value:

S_{mef} = 86 [mm^2] ;

c_1 - the constant of main spring under Table 1.

Table 1

Reducer class	0	1	2	3	4	5
c_1 [N/mm]	80,10		209,60		329	

The product $c_1 \cdot p \cdot n$ gives the value of forces developed by the mean spring, to limit, when the valve is still sited on the seat.

p = 1,5 [mm] for all classes of reducers

The number n of screw rotations necessary to compress of mean spring has been experimentally determined for each reducer class and is given in Table 2.

Table 2

Class reducer	0	1	2	3	4	5
n	5	6,5	3	4,75	3,5	4,75

The value of surface s_0 = 20 mm^2 for reducers from classes 0, 1 and s_0 = 30 mm^2 for reducers from classes 2, 4 and 5. The values obtained for term T_1 for the six classes if educes are given in Table 3 and graph from Fig. 3 [3].

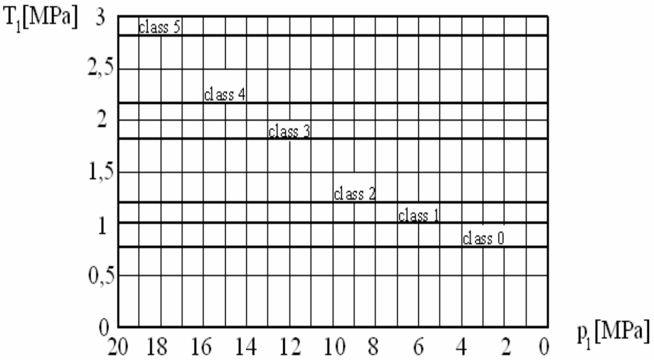

Fig. 3. Graph of term T_1

Table 3.

Reducer class	0	1	2	3	4	5
T_1 [MPa]	0,781	0,995	1,188	1,865	2,146	2,889

2.2 Evaluation of term T_2

The term T_2 that apparently does not depend on the adjusting reducer but only on pressure p_1 to input into reducer, can be expressed as $T = B \cdot p_1$ in which b is a constant and is given by the relation:

$$T_2 = \frac{s_0}{S_{mef} \mp s_0} \cdot p_1 \qquad (5)$$

During the adjusting of reducer but the value modification of valve lift h_v leads to the modification of unbalanced surface s_0 by increase of high of throttling slot.

The departures of the two sizes being very small it is considered $\frac{s_0}{S_{mef} \mp s_0} = B = ct \cdot$

The values calculated for the term T_2 when the pressure p_1 modifies its value between 20 ÷ 0 [MPa] are given in Table 4 for all reducer's classes and graphs for the functions expressed by the relation (5) in Fig. 4 [3].

Table 4

[MPa] Reducer class	20	18	16	14	12	10
0, 1, 2	0,476	0,428	0,380	0,333	0,285	0,238
3, 4, 5	0,722	0,649	0,578	0,505	0,433	0,361

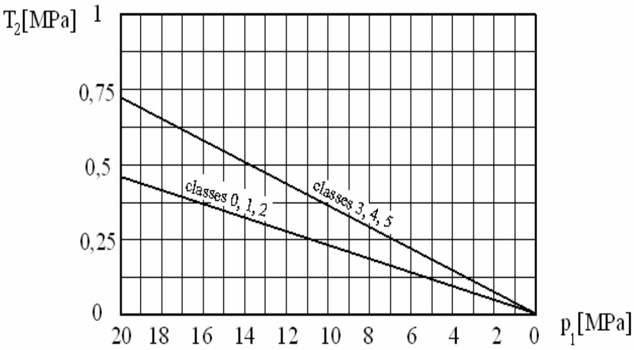

Fig. 4 Graph of term T_2

3. CONCLUSIONS

Following the values from Table 3 (end 4) and the curves from Fig. 3 (end 4) the importance and influence on which the terms T_1 and T_2 from the right side of equilibrium equation of a reducer with unbalanced adjusting member (valve) and inverse stroke (direction of gas jet between the chamber of high and low pressure is inverse of valve opening direction to increase the flow) have on sensibility and stability of adjusting can be evaluated.

Therefore, it may be seen that the prevalent during the operating for pressures p_1 higher than p_{1cr} the term T_2 has and from the moment when p_1 becomes lower than p_{1cr} the influence of term T_3 is overwhelming.

The influence of friction becomes even more obviously when the reducers of small classes that for a reducer of class 0 it represents barely 7,5% from p_1. As a conclusion, the done study helps the sphere experts to come at some noticeable and technological decisions to increase or decrease the influences of terms T_1 end T_2, so that the sensibility and stability desired to be obtained.

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