On Plug Stroke Length Determination at Pneumatic Valve Distributors

PhD. Eng. **Hapenciuc A.**, PhD. eng. **Spânu C.**, PhD. eng. **Hapenciuc. M.**
"Dunărea de Jos" University of Galați

ABSTRACT

The values of operational distribution parameters for the usually pneumatic drive are very important for adequate function of these systems. The common approximations done in their calculus may generate errors. That is why for the situation when transit flow rate must be calculated with high precision; the real flow area has a major role for this. In this paper this area is compute as a function of stroke length for the valve distributors with truncated cone plug. The maximum stoke length for the two kinds of plugs (truncated cone and cone) were also calculated. The variation of maximum stroke length with cone angle was studied for cone plugs. Finally a comparison between the maximum stroke lengths for different cone angle was done.
Keywords*: valve distributors, conical plug, truncated cone plug, flow area, maximum stroke length.*

1. Generals

The determination of the operational distribution parameters for usually pneumatic drives is treated in literature [1, 2, 3, 4, 5] with adequate accuracy. For drives case at which transit flow rate must be calculated with high precision, the approximations can give erroneous data concerning the actual values. That's way these approximations are not satisfactory.

The can have flat, truncated cone or hemisphere surfaces for seat.

The presented calculus refers to valve distributors with truncated cone plug only. In figure 1 is shown a truncated cone plug fully opened, in other words after it carried out the maximum stroke length, noted here with c.

2. The flow area calculus

For the case of cone valve (fig.1) nominal section area is computed with relation:

$$A_N = \frac{\pi}{4}\left(d^2 - d_t^2\right) \tag{1}$$

and flow section area is identical with lateral area of the truncated cone defined by generating line a, large base diameter d and d_c the diameter that correspond to the small base determinate by the normal to truncated cone surface.

Lateral area of truncated cone is computed with:

$$A_c = \pi \cdot a \frac{d + d_c}{2} \tag{2}$$

where:

d is the nominal bore, identical with nominal diameter ($d = 2R$);

d_c is the diameter of the small base for the stroke length equal to c ($d_c = 2r$).

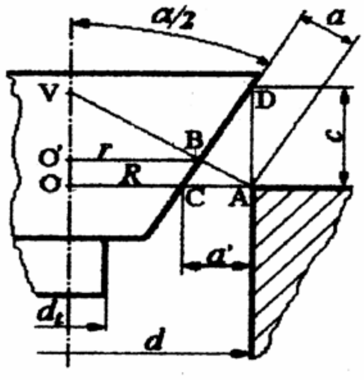

Fig.1. Truncated cone plug

It can be noticed that the nominal bore has a constant value while the diameter of the small base is variable depending on the valve stroke length.

Successively writing trigonometric functions for the right-angled triangles CAD and ABC it can be obtained:

$$a' = c \cdot tg\frac{\alpha}{2} \tag{3}$$

and respectively width of the clearance hole,

$$a = a' \cdot cos\frac{\alpha}{2} \tag{4}$$

Replacing relation (2) into relation (3) it can obtain:

$$a = c \cdot sin\frac{\alpha}{2} \tag{5}$$

Analogous to above it was obtained the width of the cone generating line:

$$VA = \frac{d}{2 \cdot cos\frac{\alpha}{2}} \tag{6}$$

From the congruence of the VO'B and VOA triangle it can be successively computed:

$$r = \frac{d}{2}\left(1 - \frac{a}{VA}\right) \tag{7}$$

Knowing that $d_c = 2r$ it can be found the relation for the small base calculus.

Making the replacements, the relation no. 2 becomes:

$$A_c = \frac{\pi}{2} \cdot c \cdot \left(2d - c \cdot sin\alpha\right) \cdot sin\frac{\alpha}{2} \tag{8}$$

3. The maximum stroke length calculus

For the complete raising of the valve above the seat level the section of the clearance hole is actually A_N. In this case $A_N = A_C$. Equalizing relation (1) and (2), it will be obtained a quadratic equation having stroke length c as variable:

$$2c^2 \, sin\alpha \cdot sin\frac{\alpha}{2} - 4cd \, sin\frac{\alpha}{2} + d^2 - d_t^2 = 0 \tag{9}$$

Resolving the equation and choosing the convenient solution, it can be inferred the maximum possible valve stroke length:

$$c = \frac{d + \sqrt{d^2 - \left(d^2 - d_t^2\right) \cdot cos\frac{\alpha}{2}}}{sin\alpha} \tag{10}$$

and if, the plug has not been fitted with a rod, for $d_t = 0$, the expression becomes:

$$c = \frac{d}{sin\alpha}\left(1 + \sqrt{1 - cos\frac{\alpha}{2}}\right) \tag{11}$$

In figure 2 the chart presents the maximum stroke length vs. con angle (usually between 30 and 45 degrees) for a 10 millimetres nominal bore, based on formula number (11). It can be observed that if the con angle increases the maximum stroke length decreases. The maximum value that take place for α = 30 it will be noted $c_{\max}$.

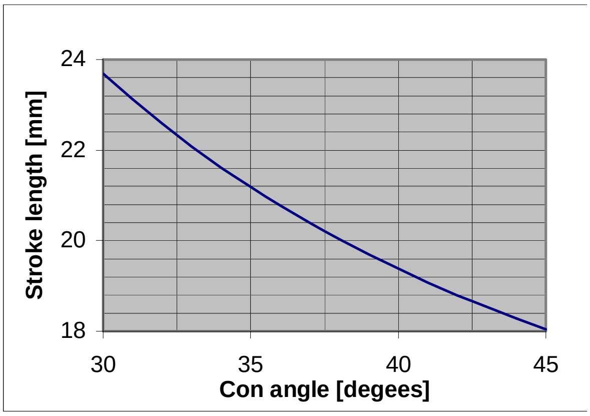

Fig.2. The stroke length vs. con angle.

If we calculate the ratio $c / c_{\max}$, where c is the values for α between 30 and 45 degrees, its representation is like in figure 3.

According to (11) the ratio is not depending on d. The maximum stroke length decrease is for 45 degree and is about 0.75.

Usually, the air flow resistance of the element is determined, a parameter for that has not a measurement unit in pneumatics. The concept used in this case is called equivalent clearance section A_e, which is opposite to resistance.

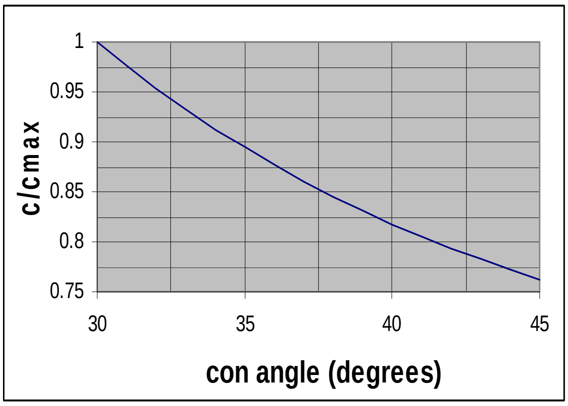

Fig.3. The ratio $c/c_{\max}$ vs. con angle.

The measurement unit for equivalent flow section is mm^2 and it is the area of an aperture, mounted perpendicular to the air flow direction and which determines the same pressure drop and the same air leakage as with real situation, when air flows through the considered element.

Accordingly, the pressure drop depends on the ratio between flow rate and flow section.

For considered situation $A_e = A_c$, and on the basis of these equality, it can be inferred the relation between flow rate and pressure.

The relation between these variable it is a directly proportional one, but it is a more complex relation because pressure drop is depending on the intake pressure and temperature, as a result of the compressibility of air.

If the pneumatic drive equipment needs a more rigorous computation of the flow rate, than this is made on the basis of a specific formula depending on the type of flow (subsonic or sonic). The conditions of sonic flow are fulfilled if the ratio between the absolute pressures from input and output apertures is greater, or equal, to 1.896, or is a function of relative pressure as follows:

if

$$p_i + 1.013 \prec 1.896(p_e + 1.013) \qquad (12a)$$

the flow is subsonic;

or if

$$p_i + 1.013 \geq 1.896(p_e + 1.013) \qquad (12b)$$

the flow is sonic.

If the influence of the temperature on the flow process is ignored, then the flow rate can be accurately computed into subsonic regime with the relation:

$$Q = 22.2 \cdot A_e \cdot \sqrt{(p_e + 1.013)(p_i - p_e)} \qquad (13)$$

For a sonic flow regime, the following relation it will be used:

$$Q = 11.1 \cdot A_e \cdot (p_e + 1.013) \qquad (14)$$

4. Conclusions

The real flow area is very important when transit flow rate must be calculated with high precision. In the paper for the valve distributors with truncated cone plug this area is compute like a function of stroke length.

Into the paper the maximum stoke for the two kinds of plugs it is also calculated.

From the calculus results that maximum stroke length decreases if the con angle increases.

References:

1. **Avram, M**., *Acţionări hidraulice şi pneumatice. Vol. I şi II.* Editura Printech, Bucureşti, 1999;

2. **Cosoroabă, V. et. al.,** *Acţionări pneumatice*. Editura tehnică, Bucureşti, 1971;

3. **Cosoroabă, V. et. al.,** *Acţionări pneumatice*. Editura tehnică, Bucureşti, 1974;

4. **Dies, J.,** *Introduction à l`automatisation pneumatique.* Edité par la Société FRANTEC, Paris, 1980;

5. **Hapenciuc, A., Constantin, V**., *Acţionări pneumatice. Elemente componente.* Editura fundaţiei universitare „Dunărea de Jos" Galaţi, 2005.

Rezumat

Valorile parametrilor operaționali de distribuție pentru acționările pneumatice uzuale sunt foarte importante pentru funcționarea adecvată a acestor sisteme. Aproximațiile comune făcute în calculul lor pot genera erori. Din această cauză, pentru situația când debitul de tranzit trebuie calculat cu mare precizie, aria reală de curgere are un rol major. In lucrare, această arie, este calculată funcție de lungimea cursei pentru distribuitoarele cu ventil tronconic. Se calculează, de asemenea, lungimea maximă a cursei pentru două tipuri de ventil: tronconic şi conic. Pentru ventilele conice se studiază variația lungimii maxime a cursei cu unghiul conului ventilului. In final, se face o comparaţie între lungimile maxime ale cursei pentru diferite valori ale unghiului conului.

Résumé

Les valeurs des paramètres opérationnels de distribution pour l'entraînement par commande pneumatique sont très importantes pour le fonctionnement adéquat de ces systèmes. Les approximations habituelles faites pour les calculer peuvent générer des erreurs. Ainsi, la surface réelle du flux de fluide a un rôle principal dans le calcule très précis du débit de transit. Dans l'article, cette surface a été calculée en fonction de la longueur de la course pour les distributeurs à valves en forme de cône tronquée. Le calcul de la longueur maximale de la course a été calculé pour deux types de valves: en forme de cône et de cône tronqué. Pour les valves coniques, la variation de la longueur maximale de la course a été étudiée en fonction de l'angle du con de la valve. A la fin, une comparaison a été faite entre les longueurs maximales de la course, pour plusieurs valeurs de l'angle du cône.