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CONSTRUCTIVE AND FUNCTIONAL PARAMETERS OF ROTATING PNEUMATIC MOTORS

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Abstract: *In modern pneumatic systems, besides classical linear motors that provide translational motion are found rotary air motors. The latter ones are designed to ensure rotation motion for angles between 1^0 and 360^0. An important strong role regarding the magnitude of these motors is represented by accurate determination of moments, speed and angular accelerations which they develop.*
Key words: *speed, acceleration, force, inertia momentum, theoretic momentum, effective momentum*

1. INTRODUCTION

Constructive parameters of pneumatic rotary actuators are closely interrelated with translational motion parameters and how the implemented mechanical systems convert speed, force and linear acceleration in time, angular acceleration.

For a better understanding of the motion parameters problem, are further presented an analogy between the sizes of rotation motion toward translational motion. If in the case of linear motors we are talking about pushing force, for the rotational motors we will find torque or momentum.

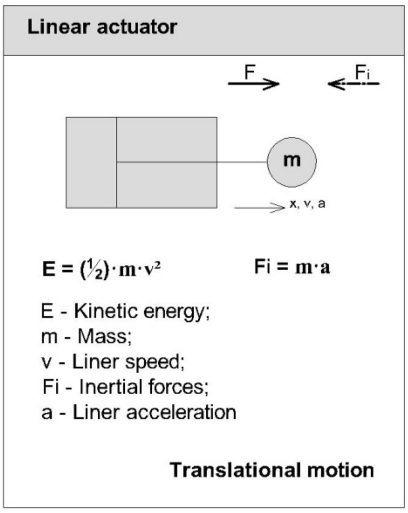

Fig.1. The parameters of translational motion

The correspondent of linear movement from the case of linear motors is found like angular displacement at rotated motors. If we derive these displacements we will obtain linear speed (for linear motors) respective angular speed (for rotational motors). The second derivative of the two displacements will provide linear acceleration for linear actuators and angular acceleration for rotational motors.

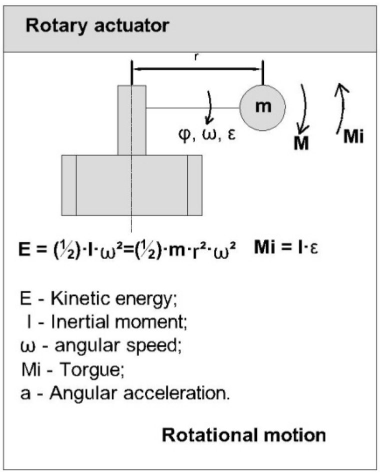

Fig.2. Parameters for rotation motion

In most cases, the constructive variants of the rotary motors have at the base rotational mechanisms. The most common mechanism used in the oscillating rotary motors is represented by the conversion mechanism pinion rack.

2. THE DETERMINATION OF INERTIA MOMENT FOR A ROTARY MOTOR

The moment of inertia is a physical quantity that expresses the resistance which opposes to the moving body rotating, in this case to the action of an external force or a moment. In the case of the rotary movement performed by rotary actuator, the moment of inertia will be:

$$I = m \cdot r^2 \qquad (1)$$

where: I – moment of inertia ;

m – the mass in rotary motion;

r – radius of gyration from the centre of rotation

In practice it has been established that the moment of inertia depends on the shape, dimensions, weight, the way of fastening and the center of gravity of the workpiece. In the figure below are some situations and calculation formulas of the moment of inertia for the handling of them with the rotary actuators.

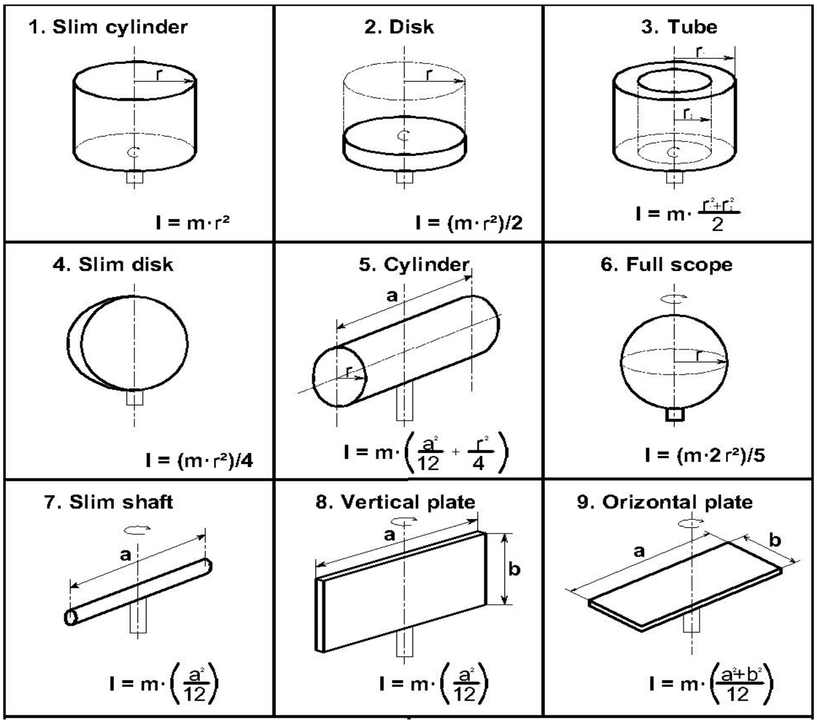

Fig. 3. Various situations for calculating the inertia

In case of rotary motion is observed that the kinetic energy is closely related to the moving mass and the square of the gyration radius. Can be seen that in the case of handling of small masses with an actuator which have big radius results very high kinetic energy. Because of the large kinetic energy stored by the mass during the movement can appear mechanic shocks at the end of the stroke, these shocks will be canceled/mitigated with the bumpers at the end of the stroke.

Starting from the situations described above, can be determined the moments of inertia for other complex structures, by breaking them in the basic elements presented.

2.1. Calculation example:

Determine the moment of inertia, developed the piece from the figure reported to the actuator shaft.

There are known the following values: m_1 = 5 kg, m_2 = 0.4 kg, L = 0,11 m, r_1 = 0.2 m, r_2 = 0.10 m and r_3 = 0.06 m.

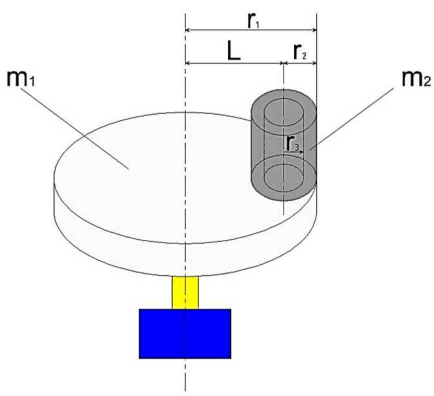

Fig. 4: Sketch of piece manipulating

Solving:

For calculation of the moment of inertia the system is breaking in the two components, disc and tube. The disc has the center of gravity on the rotation axis, so will have the moment of inertia:

$$I_1 = m_1 \cdot \frac{r_1^2}{2} \quad (2)$$

$$I_1 = 5[kg] \cdot \frac{0.2^2[m^2]}{2} = 10^{-1}[kg \cdot m^2] \quad (3)$$

The tube with mass m2 has the centre of gravity at distance L toward the rotation axis, so the moment of inertia will be:

$$I_2 = m_2 \cdot \frac{r_2^2 + r_3^2}{2} + m_2 \cdot L^2 \quad (4)$$

$$I_2 = 0.4 \cdot \frac{0.10^2 + 0.06^2}{2} + 0.4 \cdot 0.10^2 \quad (5)$$

$$I_2 = 6.72 \cdot 10^{-3}\ [kg \cdot m^2] \quad (6)$$

The total moment of inertia will be:

$$I_{tot} = I_1 + I_2 \quad (7)$$

$$I_{tot} = 10^{-1}[kg \cdot m^2] + 6.72 \cdot 10^{-3}[kg \cdot m^2] (8)$$

$$I_{tot} = 10.672 \cdot 10^{-2}[kg \cdot m^2] \quad (9)$$

So, in this case the manipulating system with rotary disc, exemplified, the total moment of inertia for which is subjected a pneumatic rotary motor is $10{,}672 \cdot 10^{-2}$ kg·m^2.

2.2. Theoretic driving moment

The theoretic driving moment is defined as the torque developed by an ideal rotary pneumatic motor, having the characteristics of a real rotary.

There are two situations depending by the constructive form of rotary actuator:

a) Actuator type pinion rack – theoretic driving moment in this case is equal with the product between divider radius of the piston and the theoretic force developed by the linear pneumatic cylinder.

$$M = F \cdot R \cdot n \quad (10)$$

where: R – divider radius of the piston;
m – tooth module;
z – number of teeth;
F – theoretical force of the linear cylinder;
n – number of racks.

b) Actuator with blades – Theoretic driving moment in this case will be:

$$M = F \cdot R_m \cdot n = p \cdot S \cdot R_m \cdot n \quad (11)$$

where: S – blade surface;
Rm – average radius of blade;
n – number of blades;
p – working pressure.

2.3. Effective driving moment

The effective driving momentum is obtained by multiplying the theoretic driving moment with the yield of rotary actuator.
As to the linear actuators, also in the case of the rotary ones, the yield depends by a lot of factors like: lubrication, inner surface quality, working pressure, mechanical yield of the conversion mechanism, and so on.

Below is a table which lists values of torque developed by a rotary actuator with pinion and rack for different working pressures.

Air consumption

In the case of rotary pneumatic actuators is used the following formula of calculation for the average flow of consumed air:

$$Q = k \cdot n_c \cdot [V_g \cdot (p+1) + V_t \cdot p] \quad \left[\frac{l}{min}\right] (12)$$

where:Q – average air flow [l/min];
k – correction coefficient;
nc – number of double strokes per minute [stroke/min];
Vg – geometric volume of the actuator [cm3/cycle];
Vt – total volume of the link pipes [cm3];
p – working pressure [bar].

Geometric volume is calculating for each stroke, because is a linear actuator with bilateral rod, and wil be obtained by summing the geometrical volumes of the two chambers, like this:

$$V_g = V_A + V_B \quad (13)$$

$$V_A = \frac{\pi \cdot D^2}{4} \quad (14)$$

$$V_B = \frac{\pi \cdot (D^2 - d^2)}{4} \quad (15)$$

The volume of connecting pipes will be obtained by multiplying the section area of the pipe with the length of this ($l = l_1 + l_2$). If pipe section is circular, then the pipes volume will be:

$$V_t = \frac{\pi \cdot d_i}{4} \cdot (l_1 + l_2) \cdot 10^{-3}\ [cm^3] \quad (16)$$

Maximum flow for a rotary actuator can be calculated dividing the required air volume for performing a stroke in the time of the performing a rotation, thus obtaining the relation:

$Q_{max} = \frac{\Delta v}{t} = [V \cdot (p+1) \cdot 10^{-3} + a \cdot l \cdot \frac{60}{t}$ [l/min] (17)

where: t – time for performing a rotation [s];

V – maximum volume between V_A and V_B.

Table 1.

Effective driving moment depending by the pressure

Diametru piston	Presiunea de lucru (MPa)									
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
30	0.38	0.76	1.14	1.53	1.91	2.29	2.67	3.05	3.44	3.82
50	1.85	3.71	5.57	7.43	9.27	11.2	13.0	14.9	16.7	18.5
63	3.44	6.88	10.4	13.8	17.2	20.6	24.0	27.5	31.0	34.4
80	6.34	12.7	19.0	25.3	31.7	38.0	44.4	50.7	57.0	63.4
100	14.9	29.7	44.6	59.4	74.3	89.1	104	119	133	149

3. CONCLUSION

In the case of pneumatic rotary motors, the moment of inertia which has to be beat such a motor, in the situation of manipulating some parts, dictates the geometric dimensions and constructive form of this. To reduce the gauge dimensions of this type of motors is recommended to be used some clamping sketches through the moment of inertia of the motion to be minimum.

Also, to increase the reliability of the whole system and to increase the efficiency will take into account a series of factors like: working pressure, quality of inner surfaces, lubrication, and mechanical efficiency of the conversion mechanism and so on.

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PARAMETRII CONSTRUCTIVI ȘI FUNCȚIONALI AI MOTOARELOR PNEUMATICE ROTATIVE

Rezumat: *In sistemele pneumatice moderne, pe langa clasicele motoare liniare care asigura miscarea de translatie se regasesc si motoarele pneumatice rotative. Acestea din urma au rolul de a asigura miscarea de rotatie pentru unghiuri cuprinse intre 1^0 si 360^0. Un rol forte important in ceea ce priveste dimensionarea acestor motoare il reprezinta determinarea exacta a momentelor, turatiilor si acceleratiilor unghiulare pe care acestea le dezvolta.*

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