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Study on the influence of supplying compressed air channels and evicting channels on pneumatical oscillation systems for vibromooshing

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Abstract. The paper presents a pneumatic system with two oscillating masses. The system is composed of a cylinder (framework) with mass m_1, which has a piston with mass m_2 inside.
The cylinder (framework system) has one supplying channel for compressed air and one evicting channel for each work chamber (left and right of the piston). Functionality of the piston position comparatively with the cylinder (framework) is possible through the supplying or evicting of compressed air. The variable force that keeps the movement depends on variation of the pressure that is changing depending on the piston position according to the cylinder (framework) and to the section form that is supplying and evicting channels with compressed air.
The paper presents the physical model/pattern, the mathematical model/pattern (differential equations) and numerical solution of the differential equations in hypothesis with the section form of supplying and evicting channels with compressed air is rectangular (variation linear) or circular (variation nonlinear).

1. Introduction
The mathematical modeling of the work of some mechanic systems, frequently used in the industry, such as the vibrosmoothing device with pneumatic operation, is very important, being the first condition in achievement of the mathematical model that will be used in computer simulation. The conditions for running, execution and functioning of this device allow the formulation of some simplifying hypothesis satisfying the design. These hypotheses are defined by the vibrosmoothing device and by the elastic elements.

The vibrosmoothing device represents a perfectly centered system, meaning that the result of perturbation (elastic and dissipative) forces is oriented through the mass center of system. Therefore, all the work organs make only translational movements;

The elastic elements are considered perfectly linear and the differences between their elastic characteristics are neglected. The whole system is moving around the stable equilibrium position.

2. The mathematical calculation models
The vibrosmoothing device is represented schematically in Figure 1.

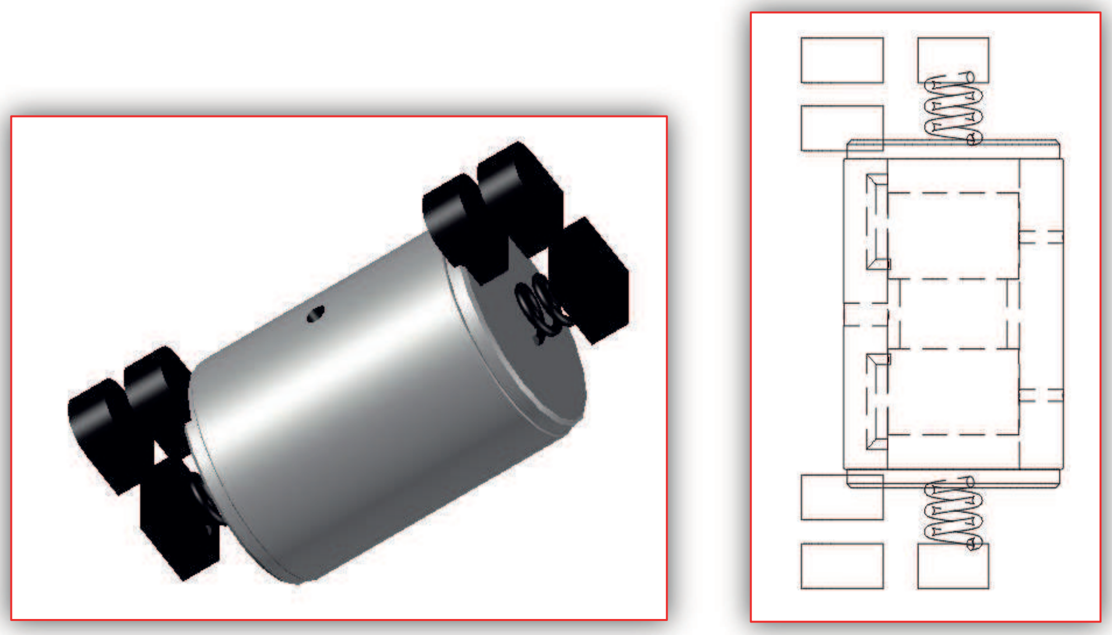

Figure 1. The classic vibrosmoothing device

The differential equations of the system movement for the pneumatical oscillation system are (Figure 2, 3 and 4):

$$\ddot{x} = \frac{K_e}{m_1} \cdot x - \frac{A}{m_1}(P_1 - P_4) - \frac{F_a}{m_1} \cdot sign\left(\dot{x}\right) \quad (1)$$

$$\ddot{u} = \frac{K_e}{m_1} \cdot x + \frac{F_a}{m_1} \cdot sign\left(\dot{x}\right) + A(P_1 - P_4) \cdot \left(\frac{1}{m_1} + \frac{1}{m_2}\right) \quad (2)$$

where:
m_1 is the framework mass;
m_2 is the piston mass;
K_e is the elastic constant of the springs mounted in parallel;
F_a is the constant horizontal force;
P_1 is the pressure on the left frontal surface;
P_4 is the pressure on the right frontal surface;
P_r is the pressure for compressed air supplying;
A is the supplying channel for compressed air;

It is imperative to take into consideration each type of production program (range), to restrain as much as possible the area that we are using and to minimize the time of execution, all of these in order to satisfy the client's needs, to try to classify them in order to be able to define a global software (with general rules) that is expect to fulfill each client's needs (Figure 5) [1-6].

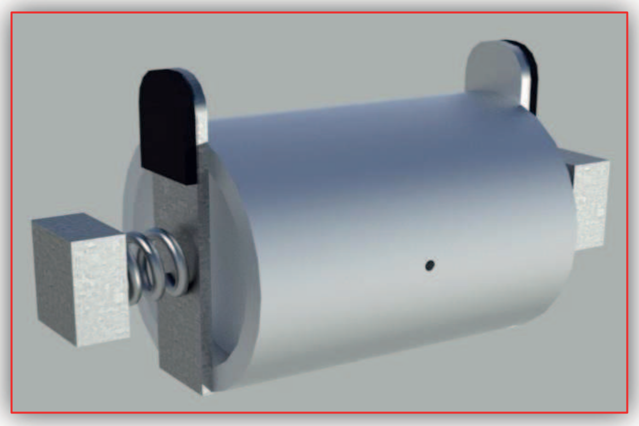

Figure 2. The vibrosmoothing device

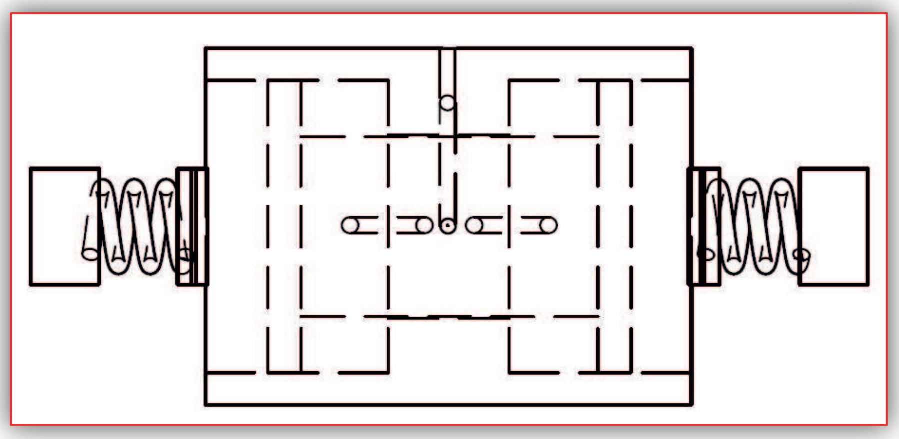

Figure 3. The upper view of vibrosmoothing device

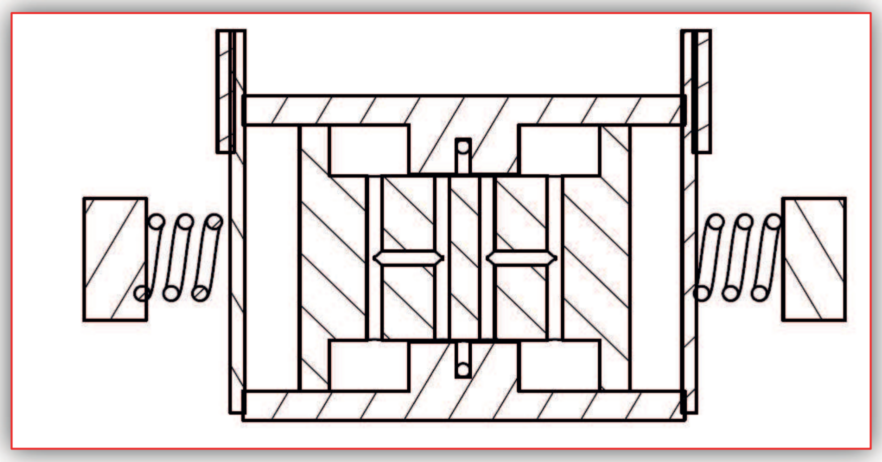

Figure 4. The front view of vibrosmoothing device

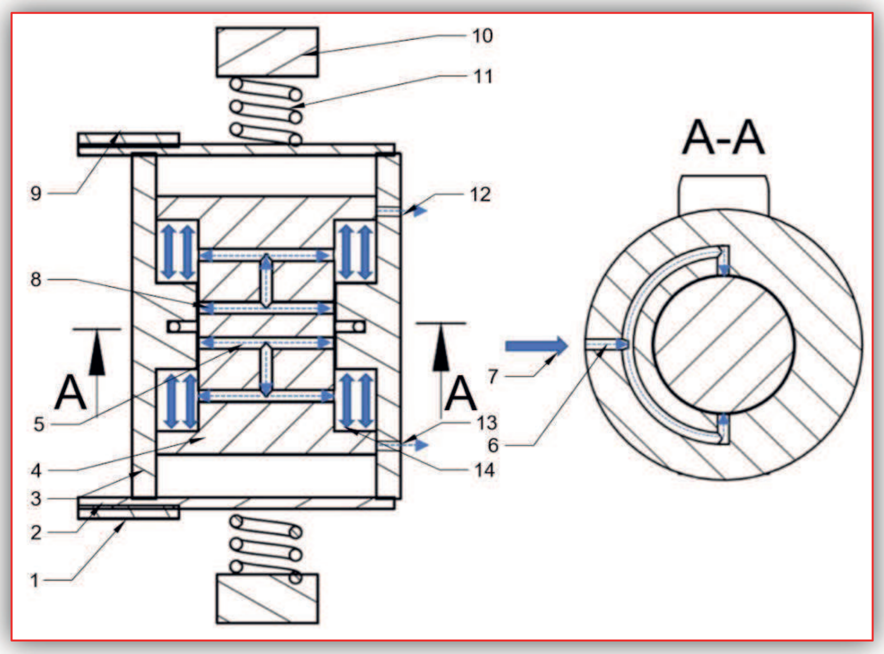

Figure 5. Schematically principle of pneumatically oscillation system

where:

1. Electromagnet
2. Cover frame of pneumatical system
3. Framework mass (m_1)
4. Piston mass (m_2), with diameter D and length l
5. The supplying channel for compressed air to the right chamber of the piston
6. The principal supplying channel for compressed air
7. Pressure for compressed air supplying mass (P_r)
8. The supplying channel for compressed air to the left chamber of the piston
9. Electromagnet
10. Fixed mass
11. Spring, u compressed distance
12. Evicting channel for compressed air from the left chamber of the piston
13. Evicting channel for compressed air from the right chamber of the piston
14. Pressure compartment (P_1, P_2)

3. The mathematical calculation model

The framework of mass m1 is executing an absolute movement in comparison with the fixed system Oxy. The relative movement of the piston of mass, m_2 is described in comparison with the system O_1uv.

The differential equations of the system movement are [1-3]:

$$\ddot{u} = \frac{K_e}{m_1} \cdot x + \frac{F_a}{m_1} \cdot \sin g(\dot{x}) + A(P_1 - P_2) \cdot \left(\frac{1}{m_1} + \frac{1}{m_2}\right) \tag{3}$$

We can see that m_1, m_2, A, K_e, F_a remain constant during the movement, but the pressures P_1 and P_2 are changing in function of the piston position in comparison with the framework.

3.1. The variation of the pressures P_1 and P_2

The variable pressures P_1 and P_2 are determined by studying the system as a pneumatical cylinder with double effect. Considering the transformation process as an adiabatic process the pressures P_1 and P_2 alternating linearly in hypothesis with the section form of supplying and evicting channels with compressed air is rectangular and the pressures P_1 and P_2 alternating nonlinearly in hypothesis with the section form of supplying and evicting channels with compressed air is circular, Figures 6 and 7 [2-5].

- if: $$u_{\min} \le u \le u_1 \Rightarrow P_1 = P_0\left(\frac{u_7-u_1}{u_7-u}\right)^{\chi};\ P_4 = P_r\left(\frac{l-l_1-u_7+u_1}{l-l_1-u_7+u}\right)^{\chi} \quad (4)$$

- if: $$u_1 \le u \le u_2 \Rightarrow P_1 = P_0;\ P_4 = P_r \quad (5)$$

- if: $$u_2 \le u \le u_3 \Rightarrow P_1 = P_0 + \left[\frac{3}{4}P_r\left(\frac{u_7-u_4}{u_7-u_3}\right)^{\chi} - P_0\right]\frac{u-u_2}{u_3-u_2};\ P_4 = P_r - \frac{1}{4}P_r\left(\frac{u-u_2}{u_3-u_2}\right) \quad (6)$$

- if: $$u_3 \le u \le u_4 \Rightarrow P_1 = \frac{3}{4}P_r\left(\frac{u_7-u_4}{u_7-u}\right)^{\chi};P_4 = \frac{3}{4}P_r\left(\frac{l-l_1-u_7+u_3}{l-l_1-u_7+u}\right)^{\chi} \quad (7)$$

- if: $$u_4 \le \ u \ \le u_5 \Rightarrow P_1 = P_r\left[\frac{3}{4}+\frac{1}{4}\left(\frac{u-u_4}{u_5-u_4}\right)^{\chi}\right];\ P_4 = \frac{3}{4}P_r\left[\left(\frac{l-l_1+u_3-u_7}{l-l_1+u_4+u_7}\right)^{\chi} + P_0\right]\frac{u-u_4}{u_5-u_4} \quad (8)$$

- if: $$u_5 \le u \le u_6 \Rightarrow P_1 = P_r;\ P_4 = P_0 \quad (9)$$

- if: $$u_4 \le \ u \ \le u_5 \Rightarrow P_1 = P_r\left[\frac{3}{4}+\frac{1}{4}\left(\frac{u-u_4}{u_5-u_4}\right)^{\chi}\right];\ P_4 = \frac{3}{4}P_r\left[\left(\frac{l-l_1+u_3-u_7}{l-l_1+u_4+u_7}\right)^{\chi} + P_0\right]\frac{u-u_4}{u_5-u_4} \quad (10)$$

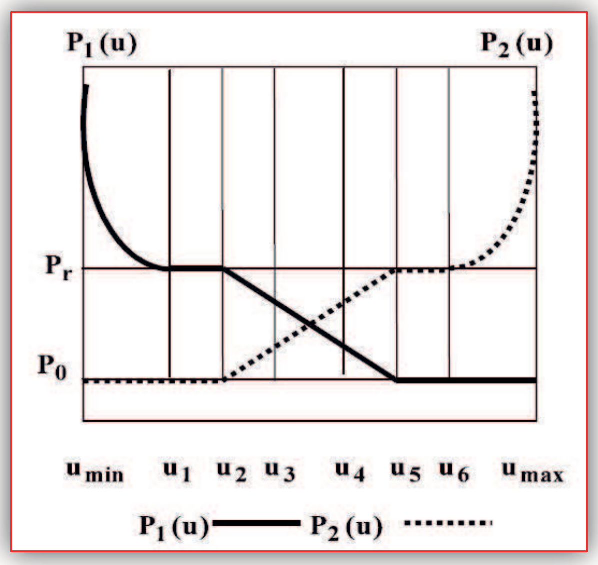

Figure 6. The resultant in a transversal cross section

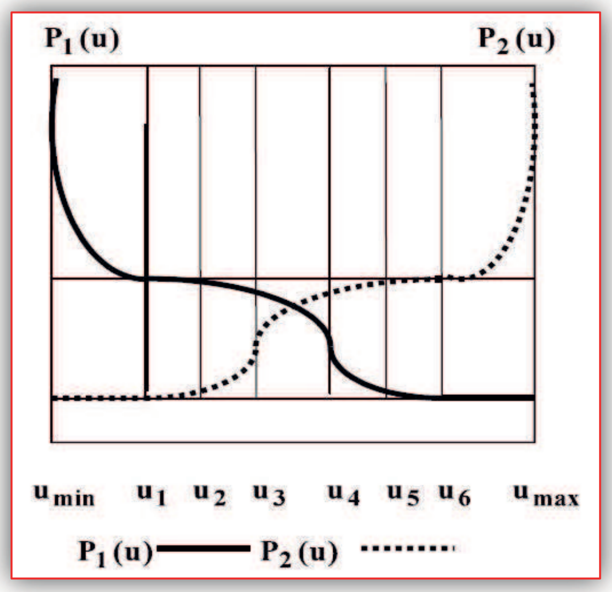

Figure 7. The resultant in a transversal cross section

4. Numerical solution of the differential equations

The differential equations system was solved numerically using the Runge-Kutta method with the use of utilitarian MathCAD. Introducing the following initial values [7-9]:

- $u_1 = 0.014$ m;
- $u_2 = 0.018$ m;
- $u_3 = 0.022$ m;
- $u_4 = 0.032$ m;
- $u_5 = 0.036$ m;
- $u_6 = 0.040$ m;
- $U_{min} = 0$ m;
- $U_{max} = 0.054$ m;
- D = 0.050 m;
- l = 0.102 m;
- X = 1.4;
- $P_r = 4 \cdot 10^5$ N /m^2;
- $P_0 = 1 \cdot 10^5$ N/ m^2;
- $m_1 =$ 4,5 kg;
- m_2 = 2,5 kg;
- K_e = 80-104 N/ m;
- F_a = 25 N

We obtained the graphics of the framework displacement (Figure 8) in hypothesis with the section form of supplying and evicting channels with compressed air is rectangular and the graphics of the framework displacement (Figure 9) in hypothesis with the section form of supplying and evicting channels with compressed air is circular [10-12].

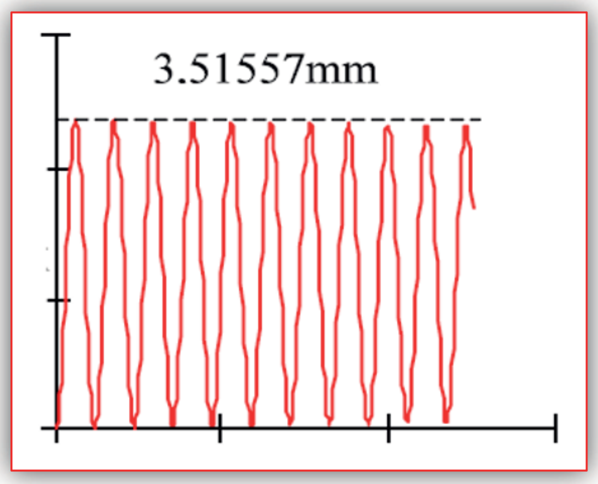

Figure 8. The graphics of the framework displacement in rectangular section

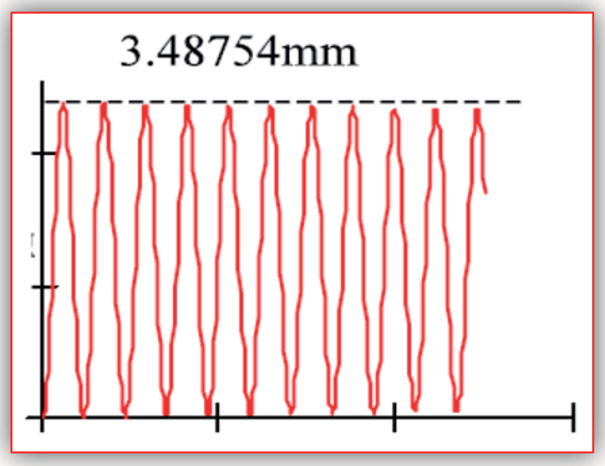

Figure 9. The graphics of the framework displacement in circular section

5. Conclusion

The physical model of the oscillation system pneumatical is used for constructing the vibrosmoothing device with pneumatical actioning of the movement. The mathematical modelling allows us to choose the constructing and running optimal parameters in order to obtain a movement with desired amplitude and frequency for the framework, satisfying the technological process demands.

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