ON IMPROVING THE PERFORMANCES OF PNEUMATIC POSITIONING SYSTEMS

Mihai Avram[1], *Constantin Bucşan*[2]
[1,2]*"Politehnica" University of Bucharest, 313 Spl. Independentei, sector 6, Bucharest*
mavram02@yahoo.com

Abstract: The paper presents some solutions developed in order to improve the performances of the pneumatic positioning units and also the experimental models built to verify this methods. A pneumatic linear positioning system with piezoelectric compensation of the error is also presented.

Keywords: positioning system, pneutronic, piezoelectric actuator.

1. Introduction

Nowadays the pneumatic actuating is used for a large number of applications, due to its indubitable advantages: robustness, constructive simplicity, productivity, high reliability, low costs and environment friendliness. Although pneumatic actuating systems are used for precise positioning of the actuated loads, the increase of the positioning accuracy and especially its preservation in time are yet unsolved problems. Researchers must take into account the perturbation factors that limits the static and dynamic performances of the pneumatic positioning systems and analyse their influence.

Perspectives show that pneumatics will be one of the top positioning technologies, non polluting and with high performances. Well-known specialists argue the future development of pneumatics in [1]. Fundamental and applicative researches are performed in order to limit the negative effects of the working fluid properties: low viscosity and high compressibility.

More and more applications require accurate positioning of the actuated load in certain points of the stroke or in any point of the stroke. These are two different situations. Positioning the load in certain points of the stroke is a solved problem. The positioning points may be the ends of the stroke or some intermediate positions materialized by mechanical stoppers.

As the number of positioning points increases, the accurate positioning is harder to solve. Special motors were developed [2], but they are not yet largely used. Positioning the load in any point of the stroke is not yet an entirely solved problem. The first systems of this type were produced in 1985 and their accuracy was about ±1 mm. Increasing the accuracy of the pneumatic positioning systems was possible when proportional devices were used and especially when microcontrollers were implemented within their control systems structure. At the same time new control non linear innovative techniques were used: adaptive control, fuzzy, fuzzy – PWM, fuzzy – PID and neuronal control. Mathematical modelling of the systems was used in order to limit the nonlinear effects of friction and to improve the performances and so the accuracy of the positioning became ±0,1 mm up to ±0,05 mm.

"Pneutronic" concept appeared as a matter of course with the synergetic union of three domains: pneumatics, electronics and mechanics. So, pneumatic positioning systems were developed on the base of advanced control theories: the process parameters become data fluxes to be processed in real time using a control strategy established by modelling and simulating the process as a whole. The electronic control system, based on a controller or a microprocessor, processes and structures the data acquired from the sensors, makes decisions on the base of a working program and generates control signals for the electro-mechanical actuators of the proportional equipment. This way pressure, flow rate, displacement, speed, acceleration, force and torque developed by the motors within the system can be controlled.

In this configuration a pneutronic system becomes more stable, more accurate and quicker, being characterised by a certain level of intelligence.

2. Solutions for increasing the performances of the pneumatic positioning units

The static and dynamic performances of a pneumatic positioning system can be improved by using certain methods regarding both software and hardware structure of the system. The authors identified some of this methods, as following:

a. developing a performing control algorithm; this implies generating a control system for the proportional equipment that follows a certain law;

b. adapting the system to the current working conditions; this requires special subroutines as: determining the minimum control voltage, modifying the moment when the control signal is zeroed; determining the flow regime;
c. using a displacement transducer with the resolution correlated with the desired positioning accuracy;
d. using a control hydraulic circuit;
e. preserving the position: using one-way relievable controlled valves; using an independent braking system;
f. correcting the obtained position by using a supplementary actuator, as a piezoelectric one.

Some examples of pneutronic units implementing one or more of the above methods are further presented.

Figure 1 shows the principle scheme of a positioning system [3] where methods "a", "b" and "e" were used. The following algorithms were developed and implemented within the working program of the system [4]:

- the *Control* algorithm: it is used to assure the positioning with a desired error; a certain variation low is imposed the control signal *u*;
- the *Sonic Regime* algorithm: it is used to determine experimentally the control voltage values for which the flowing regime is a sonic one, in order to eliminate the influence of the actuated load variations upon the positioning accuracy;
- the *Calibration* algorithm: it is used to determine experimentally the smallest value of the control signal that assures the movement of the mobile assembly with the minimum speed, in order to choose the control voltage value in the braking phase.

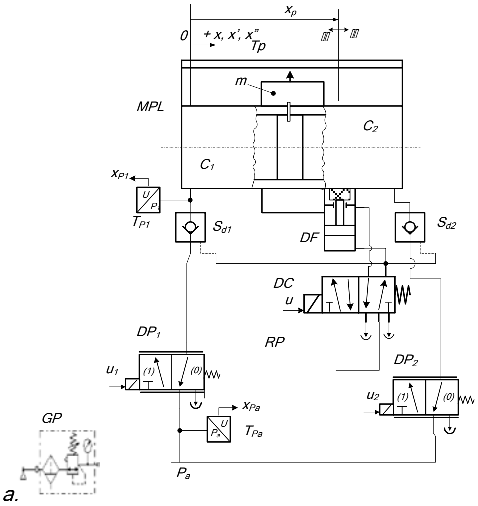

Figure 1: The principle scheme of a positioning system

The experimental model of the unit is shown in Figure 2 and it features the following characteristics:

- the pneumatic linear motor *MPL*, with an integrated position transducer T_p and also a braking system *DF*;
- two one-way valves, relievable, S_{d1} and S_{d2}, pneumatically controlled, one for each circuit of the motor; when the distributor *DC* is not commanded the mobile assembly of the motor is firmly stopped, both by blocking the rod of the motor with the braking system and by blocking the active chambers of the motor C_1 and C_2.

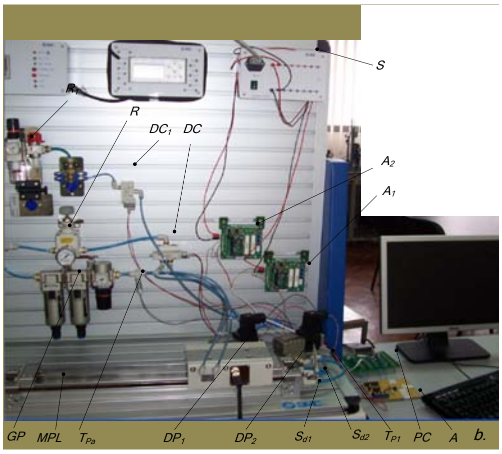

Figure 2: The experimental model of the unit

Figure 3 shows the principle scheme of a positioning system [5] where the "d" method was applied.

A hydraulic circuit is used to control the position, containing a proportional distributor *DHP* which assures a rigorous control of the flow rate of the working fluid; so the speed of the load is precise controlled and the load is firmly stopped by blocking the hydraulic circuit. The control algorithms are presented in [6] and the developed working program is presented in [7].

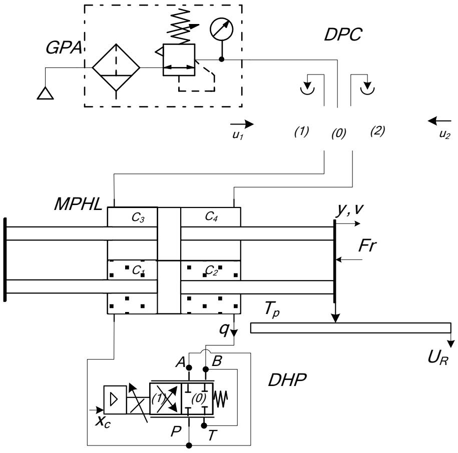

Figure 3: The principle scheme of a positioning system using a control hydraulic circuit

A view of the built experimental model is shown in Figure 4.

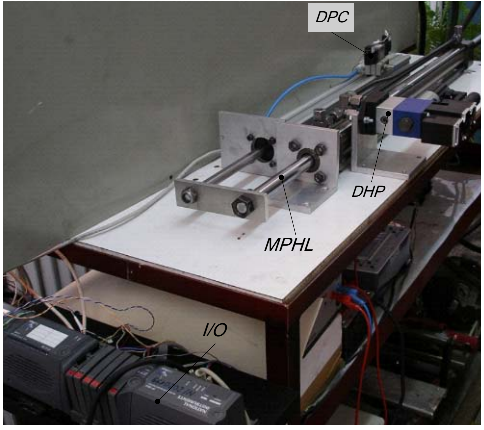

Figure 4: A view of the experimental model

Very good results were obtained with hybrid actuating systems, as pneumatic-piezoelectric. The pneumatic component assures a high speed of the actuated load and long strokes and the piezoelectric component assures a higher positioning accuracy and high forces.

An example is the system obtained by placing a piezoelectric actuator subassembly on the mobile subassembly *m* of the linear pneumtatic motor *MPL* (Figure 1). The principle scheme of the piezoelectric actuator is shown in Figure 5:

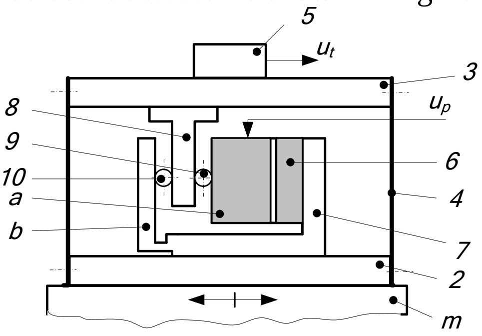

Figure 5: The principle scheme of the piezoelectric actuator

The piezoelectric actuator subassembly consists of:

- the base plate 2 fastened to the mobile subassembly m;
- the mobile plate 3 carries the actuated load 5 and is guided on four lamellar springs 4 fastened to the base plate;
- the piezoelectric actuator with mechanical amplification 6, fastened to the part 7 which is mounted on the base plate; the actuator acts upon the table 3 by means of the part 8 and of the bearing balls 9 and 10; the contact between the the part 8, the balls and the mobile sector "a" of the actuator is assured by the elasticity of the sector "b" of the part 7.

Figure 6 shows the functioning diagram of the pneumatic actuator with piezoelectric compensation.

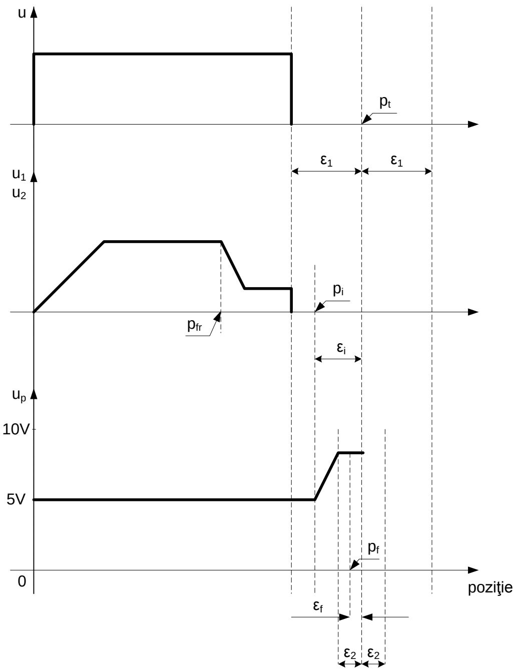

Figure 6: The functioning diagram of the pneumatic actuator with piezoelectric compensation

In the initial state a command voltage *u* is applied to the distributor *DC* and so the braking system *DF* is deactivated; a command voltage u_p=5V is also applied to the piezoelectric actuator, which is so positioned to the half of the maximum stroke; in this case the plate *3* is practically fastened to the base plate *2* and to the slide *m*.

When the load must be moved to a target position p_t, a command voltage u_1 is applied to the proportional distributor DP_1 for movement in one way, respectively a command voltage u_2 is applied to the distributor DP_2 for movement in the opposite way; this voltage increases from zero to the regime value, when the slide *m* moves with the regime speed. The displacement of the load is measured by means of the relative movement between the reading head of the position transducer T_p and the incremental rule fastened to the pneumatic cylinder MPL, when the signal u_t is generated.

When the load reaches the position p_{fr}, the value of the voltage u_1 is lowered in order to reduce the speed of the load; when the position p_t-ε_1 is reached (where ε_1 is the positioning error of the system without the piezoelectric actuator) the voltage u_1 is zeroed and the voltage *u* is also zeroed in order to activate the braking system *DF*. The mobile system continues the movement because of the inertia and stops in the point p_i, with an initial positioning error ε_i in respect to the target position p_t.

In order to lower the positioning error, the command voltage u_p of the piezoelectric actuator is modified so the part *8* moves, together with the table *3*, until the load reaches the position $p_f - \varepsilon_2$ (where ε_2 is the positioning error of the system with piezoelectric compensation), and from this moment the voltage is maintained constant. The table *3* continues the movement because of the inertia and stops in the point p_f, with a final positioning error ε_f in respect to the target position p_t.

Figure 7 shows a view of the built experimental model of the actuating system.

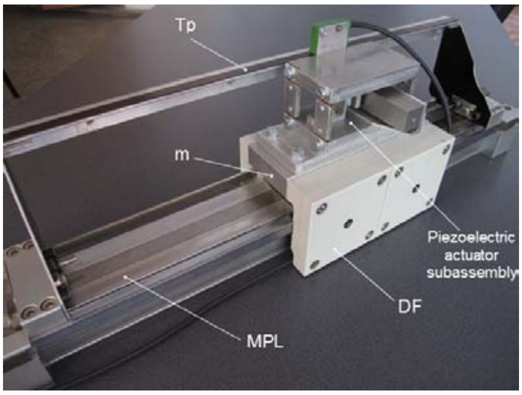

Figure 7: A view of the built experimental model

3. Conclusions

Using a hybrid actuating system as presented, the final error ε_f is much smaller then the initial positioning error ε_i of the system without piezoelectric compensation and it mainly depends on the resolution of the position transducer T_p.

The experimental results will be the subject of a further paper.

4. Bibliography

[1] Vogel G., Mühlberger E., L'univers fascinant de la pneumatique, Editura Hope International Communications, Freiburg, 2003;

[2] Avram M., Acţionări hidraulice şi pneumatice – Echipamente şi sisteme clasice şi mecatronice, Editura Universitară, Bucureşti, 2005;

[3] Avram M., Bucşan C., Constantin V., Hardware and Software Development of a Pneutronic Positioning Unit, Buletinul Institutului Politehnic din Iaşi, Tomul LVI (LX), Fasc.4, Secţia Construcţii de Maşini, 2010;

[4] Avram M., Constantin V., Constantin B., Pneutornic Positioning Unit, Part 2: The control algorithms, Romanian Review of Precision Mechanics, Optics and Mecatronics, 2010 (20), No.37, pag.39…42;

[5] Avram M., Bucşan C., Bogatu L., Duminică D., Pneumo-hydraulic Positioning Unit, Part I: Construction and Operation, Romanian Review of Precision Mechanics, Optics and Mecatronics 2009 (19), No.35, pag.39…42;

[6] Avram M., Bucşan C., Constantin V., Pneumo-Hydraulic Positioning Unit. Part II: The Control Algorithm, Romanian Review of Precision Mechanics, Optics and Mecatronics, 2010 (20), No.38, pag.15…20;

[7] Constantin V., Avram M., Bucşan C., Pneumohydraulic Positioning Unit Control Software, Mecatronica, nr.1, 2010, pag.19...23.