EXPERIMENTAL DETERMINATION OF PARAMETERS DESCRIPTIVE OF MAGNETO-RHEOLOGICAL VALVE

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Abstract **In this paper is presented an experimental test stand of rheological stop-valves. Rheological stop-valve structures are robust, simple in terms of constructive and easy to control. However, due to non-Newtonian fluid flow rheological, are difficult to model mathematically. Since many parameters of these valves are determined empirically, and depend very much on the constructive parameters, it is necessary to determine them experimentally. The paper also presents a stand designed, developed and tested for magneto-rheological stop valves. This is shown schematically speaking, constructive and programming. The stand allows the experimental determination of parameters valves, their dependence on the type of fluid used and the type rheological field excitation applied to the fluid. Determination of valve parameters can be made for any type of field excitation. Applied voltage generator may be continuous, can be generated with a constant frequency or a frequency dictated by the law of order. Applied voltage generator can also generated signal and PWM. It can be controlled manually or automatically, in terms of amplitude, pulse width and frequency. Although experimental work stand is used to determine parameters for magneto-rheological stop valve and test it allowed electro-rheological valves stop by changing the generator field excitation. At the end of the paper is presented an example set of results acquired for one of the valves tested.**

Keywords: *rheologic, magnetorheological, valve-stop, experimental-parameters*

1. INTRODUCTION

Magneto-rheological (MR) fluids, generally consisting of small magnetic particles dispersed in a liquid, are material systems whose rheological properties are controllable through the application of an external magnetic field.
Under a high magnetic field, the magnetic particles have been observed to aggregate into elongated clusters aligned along the magnetic field direction. This macro-structure is responsible for the solid like rheological characteristics and is hereby denoted the ground state of the MR fluids at the high field limit. The structure of the MR fluid ground state(s) has been the subject of prior experimental and theoretical studies, but with conflicting conclusions in regard to both the observations and the governing physics.
We recall that the magneto-rheological stop-valve is a simple construction that allows magneto-rheological fluid flow through a channel inside, and its exposure to a magnetic field (fig.1).
Channel flow may have different forms of construction section of the route and the magnetic field.
To a strong magnetic field solid particles from liquid are oriented field entered chains of particles between magnetic poles NS. We assume that magnetic field lines are perpendicular to the flow direction of these chains of particles practically blocking the flow.
Due to stress exerted by liquid flow these chains break allowing particles to flow. However due to the magnetic field they are recovering. The field intensity is higher with both the speed of recovery / training is higher, leading ultimately to block fluid flow: [2], [5], [10].

2. PROBLEM FORMULATION

Since the phenomena occurring during flow of viscous rheological fluids are very complex and difficult mathematical modeling is necessary to determine the experimental parameters, global descriptive rheological stop-valve.
Mathematical models proposed for fluids, applied to rheological systems goes from ideal operating premises and therefore cannot fully describe a real system. Thus part of the system parameters must be approximated on the basis of preliminary experiments.

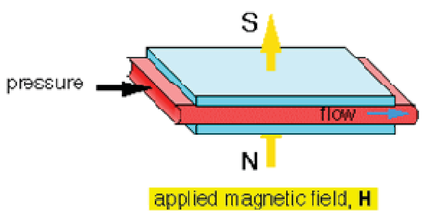

Figure 1: The MR Valve Stop structure

Thus for a system with valve-stop depending on the type and size of valve the constructive rheological parameters are determined experimentally, on the basis of which can mathematically model the behavior of the energy in magnetic field and electric: [1], [6], [7], [9].

3. PROBLEM SOLUTION

It created a mathematic model for applications and a physical platform for determining stop-valve parameters (fig.2, fig.3).

3.1. Mathematical model of a valve application

Considering that the fluid is a one-dimensional and that the strength of body and convection effects is negligible, when applying conservation, obtain a differential equation of order one between viscosity gradient and axial pressure gradient.
The solution of this equation leads to a linear distribution of viscosity, independent of the type of material existing between the poles. When the material has a characteristic viscosity gradient, such as MR fluid, will flow until the resulting pressure gradient will increase to a level that becomes dynamic viscosity greater than resistant. In this case, the critical pressure gradient, amplitude, for fluid flow is [4]:

$$\left|\left(\frac{dp}{dx}\right)_c\right| = \frac{2\tau_y}{h} \tag{1}$$

If the pressure gradient is equal to or greater than this critical value, and the fluid in the immediate vicinity of the stimulant poles, where the apparent viscosity maximum, we will have all conditions for the fluid to flow. Near the center, where the apparent viscosity is identical to zero, will be an area not active material characterized by a uniform axial velocity similar to

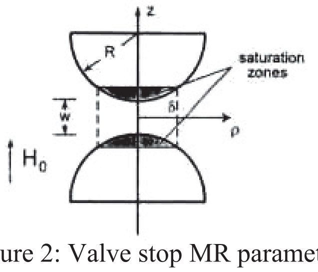

Figure 2: Valve stop MR parameters

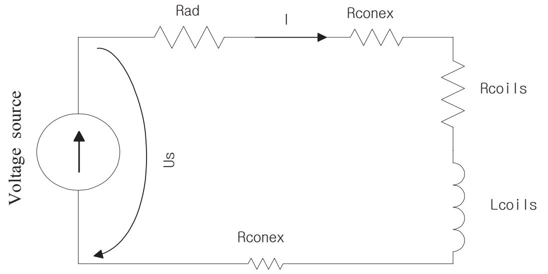

Figure 3: Simple control circuit

that of free flow. It changes in pressure tubes (based on the formula of d'Arcy for circular tube) is (fig. 4):

$$\Delta P_{short\_pipes} = f\frac{l}{d}\frac{\rho}{2A^2}Q^2 = \frac{64}{\mathrm{Re}}\frac{l}{d}\frac{\rho}{2A^2}Q^2 = \frac{K}{K_1}Q^2 \approx K_{\Delta P}Q^2 \tag{2}$$

l - length of tube [m] d - inside diameter of tube [m] - fluid density [kg/m3], A - area of the tube section [m2]; Q - flow rate [m3/sec] f - friction factor ; Re - Reynolds number or the form used most frequently (mean change nozzle or valve):

$$Q = \pi d\Delta x\sqrt{\frac{2}{\rho}}\sqrt{\Delta P} \tag{3}$$

Using the previous equations results (fig.5),

$$\Delta P_{short\_pipes} = \Delta P_\eta + \Delta P_\tau \Leftrightarrow$$

$$\frac{K}{K_1}Q^2 = \frac{12\eta QL}{g^3 w} + \frac{cL}{g}\tau \Leftrightarrow K_{\Delta P}Q^2 = \frac{12\eta L}{g^3 w}Q + \frac{cL}{g}\alpha H^m \tag{4}$$

In equilibrium, the last equation becomes:

$$K_{\Delta P}Q_0^2 = \frac{12\eta L}{g^3 w}Q_0 + \frac{cL}{g}\alpha H_0{}^m \tag{5}$$

Expressing these elements under the following form: $H = H_0 + \Delta H$ and $Q = Q_0 + \Delta Q$, can write that (neglecting terms of higher order):

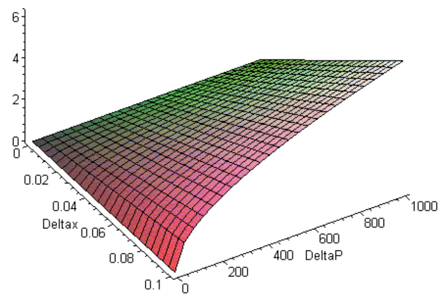

Figure 4: Changes in pressure tubes

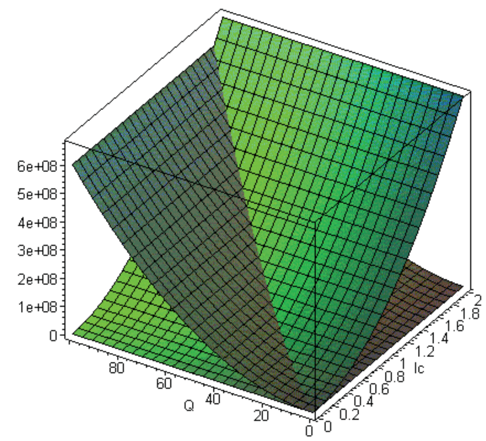

Figure 5: Dependent flow of intensity magnetic field

$$\frac{d}{dt}(\frac{\Delta Q}{Q_0}) + a_1 \frac{\Delta Q}{Q_0} = a_2 \frac{\Delta H}{H_0} \tag{6}$$

where,

$$a_1 = \frac{12\eta}{g^3 w\rho} - \frac{Q_0}{A^2 wgL}; \quad a_2 = \frac{\alpha cm}{g\rho Q_0} H_0^m$$

Between the magnetic field intensity and number of spiral coil following relationship exists [8]:

$$H = \frac{N}{l} I, \tag{7}$$

where N - number of spirit; l - length of the spire N, I - current amplitude. Using these notation equations (7) becomes:

$$\frac{d}{dt}(\frac{\Delta Q}{Q_0}) + a_1 \frac{\Delta Q}{Q_0} = a_2 \frac{\Delta I}{I_0} \tag{8}$$

Structure of the most simple control circuit includes a source of current / voltage with additional resistors and coils:

$$\left(R_{ad} + R_{conex} + R_{coils}\right) I + L_{coils} \frac{d}{dt} I = U_s \tag{9}$$

Power source is not ideal (the resistance of its output has a finite value) and can be approximated by a voltage source with a resistor in series with a resistor of a limited value Rad. To simplify the electrical circuit, resistance winding with the auxiliary connections can be neglected in comparison with Rad. Using the same technique, with the equivalent circuit that has a dynamic system of order I:

$$\frac{d}{dt}(\frac{\Delta I}{I_0}) + a_3 \frac{\Delta I}{I_0} = a_4 \frac{\Delta U_s}{U_{S0}} \tag{10}$$

where

$$a_4 = \frac{U_{S0}}{I_0 L_{coils}}$$

$$a_3 = \frac{R_{ad} + R_{conex} + R_{coils}}{L_{coils}} \approx \frac{R_{ad}}{L_{coils}}$$

3.2. Experimental platform for determining the parameters stop-valve MR

Presented platform is designed to determine the experimental parameters of magneto-rheological electro-valves.

As a concept, the platform is composed of a block which moves rheological fluid, the block which generate the excitation field and electro-valve MR (fig. 6) [12].

The experimental stand is shown in figure 7.

Block 1 has sharing two pistons and the first and the second piston with the shaft, a pneumatic piston and a hydraulic. The pneumatic plunger it has the role of a generator of motion, while the other piston train the magneto-rheological liquid [13].

The second block have a similar construction and operations to. I have to mention that the movement is generated only in one of the blocks 1 or 2 at a time. So a block has the role of motor, the other having the role of the generator. These are in series to the block 3 - the magneto-rheological stop-valve.

Depending on the direction of travel of the pistons from block 1 the magneto-rheological fluid is trained by the electro-valve and determines the movement of the pistons from block 2. Similar to the movement of pistons from block 2 the ones from block 1 generate the movement of pistons in block 1 [14].

Electro-valve energy may be influenced by using an electromagnetic element composed of a framework for ferrite winder - block 4. The command is given for the both pistons in a positive or negative direction of the axis.

By applying magnetic field to the electro-valve MR we control the speed of MR fluid. The final result is dependent of the speed of movement of the rheological fluid, which is also dependent on the power energy which also generate the magnetic field.

Order of displaced pistons from blocks 1 and 2 is being done by the electro-valve with pneumatic drawer - block 5. Depending on supply voltage thereof (0V and 24V) is generated movement for pistons from block 1 and block 2).

By using PC with a Simulink algorithm command and interfacing with the computer platform is used the acquisition board from Quanser [11].

In figure 8 is presented the model as Simulink model. Order stand is made by Quanser acquisition system using a PC. Control laws are implemented through a custom Simulink model Quanser system. This model allows modeling of the voltage generator excitation control according to a law implemented and the process repeated a sufficient number of times to obtain average values of the parameters real valve. Simulink model contains the following modules: Module for acquisition of input signals that command, control module deneratorului field excitation, race heads detection module (used for automatic repeated measurements), measurements processing the acquired parameters, etc.

3.3 Experimental results

Since the shape and dimensions of the channel through which fluid flows in magnetic field is decisive for the effectiveness of stop-valve MR valves we have experimented with different and representative forms and materials. We can see a stop-valve as an application specific. There is an ideal stop-valve which is compatible with all applications.

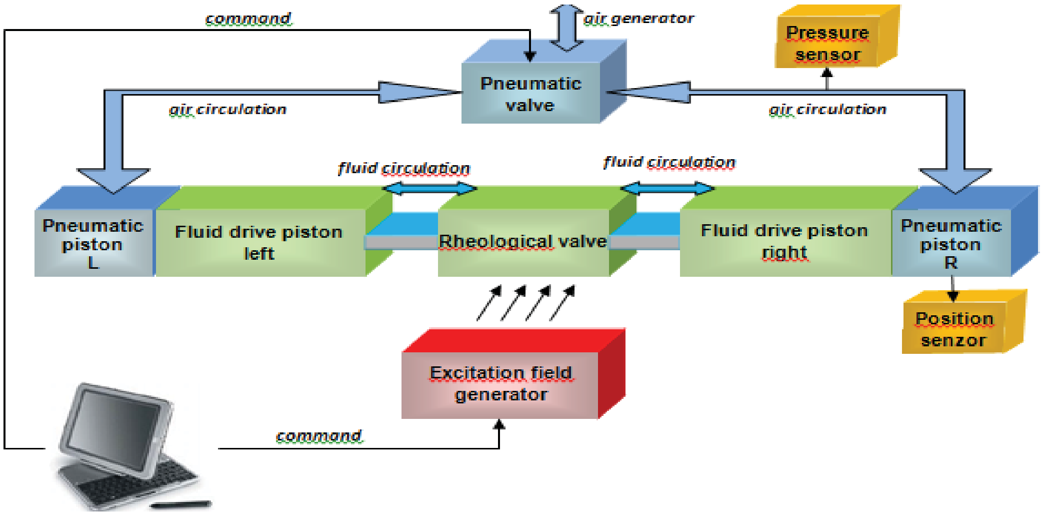

Figure 6: General scheme of the platform

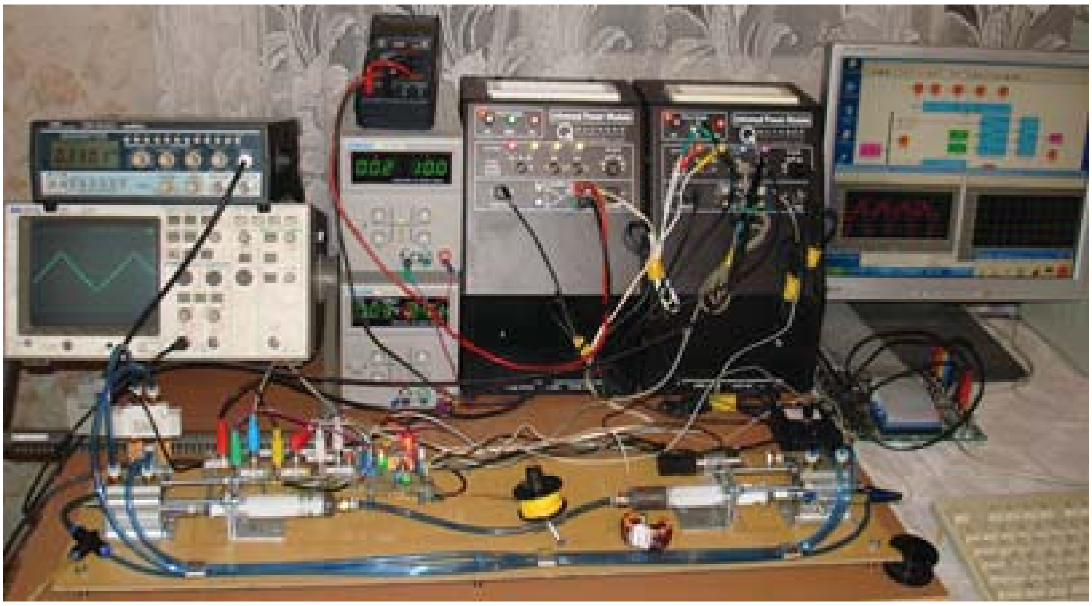

Figure 7: The experimental stand

From the constructive variant each have advantages and disadvantages.

Parameters determining the performance of stop-valves are:

- geometric parameters;
- shape and dimensions of the channel section to browse;
- factor of wall roughness;
- form of the active route;
- size of the active route;
- parameters of the material that is built;
- geometric parameters (volume of material interpose between fluid and the magnetic field);
- parameters of diamagnetic material that is built;
- factor of material strength;
- magneto-rheological fluid characteristics;
- the viscosity of the magnetic field;
- sedimentation rate;
- factor of strength fluid;
- viscosity speed variation;
- parameters of the magnetic field
- direction of the magnetic field applied;
- frequency voltage to generate the magnetic field;
- magnetic field intensity.

Are presented in order of developments the following:

- voltage of electro-valve for pneumatic pistons which control the movement;
- displacement, calculated according to the voltage supplied by the displacement sensor;
- speed, acceleration and shock obtained by repeated derivation of the position function of time;
- voltage supplied by the pressure sensor, because the size of the reservoir pressure compressor is quite small pressure varies from moving pistons, so the interpretation of this signal is useful to correct results.

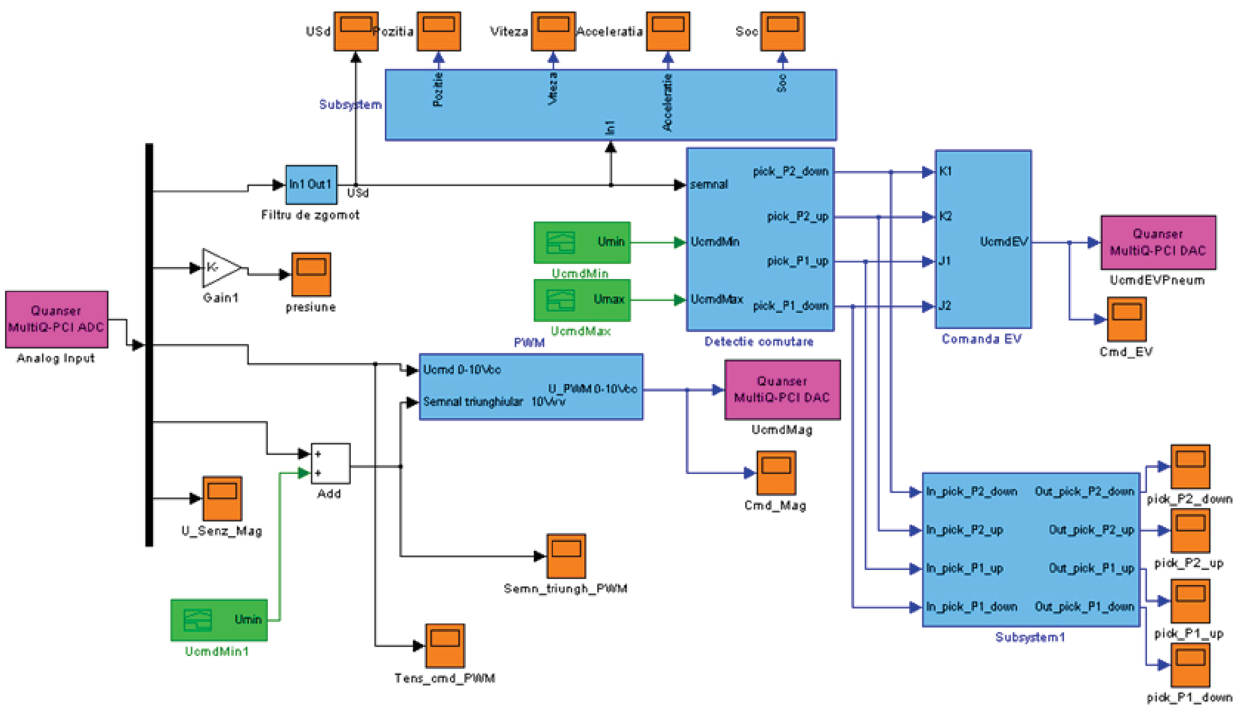

Figure 8: Simulink general model

Data acquisition is over 20 s. During this time pistons running repeatedly travel between the position of minimum and maximum position. Generating the magnetic field is approximately 10 seconds after.
Position has negative values because the command is given when arriving at a minimum which corresponds to the head of the race pistons. For this reason once an order is delayed until the actual change of direction of travel delays due to data switching electro-valve and inertial moments of the system and creates pressure in one cylinder and removing pressure from other cylinder. For this reason, although the command has been leading the movement continues at a negative position. Position calculation is done according to prescribed values.
These times can be eliminated through a correlation calculation of delay times with experimental measurement of these times (depending on system). And may delay your order to the electro-valve, such as pistons to make the race complete.
For magneto-rheological valve-stop from acrylic material with 2 mm section diameter of cylindrical channel flow is presented the evolution of main parameters measured by the platform (fig. 9). Capture is performed for a step signal of 6V applied after approximately 1 seconds from the start capture measurements, the parameters measured were: pneumatic valve power voltage, position, speed, accelerator, sock and pressure.
Can see a significant variation of measured parameters to the appearance of signal step. For a higher signal can be applied effectively stop the flow. Required value of the signal depends on the constructive parameters of the valve.

4. CONCLUSIONS

Some main characteristics of the ideal stop-valve may be:

- adherence material stop valve and rheological fluid should be directly proportional to the intensity of the magnetic field (zero in the absence of the magnetic field and maximum magnetic field intensity maximum);
- sedimentation rate must be zero;
- the magnetic field must be transverse to the direction of flow;
- rate of change of viscosity must be infinite
- geometric shape of the channel flow should allow freezing at a nominal flow of the magnetic field and does not introduce losses in the absence of the magnetic field;
- frequency of the magnetic field must be equal to the form of hysteresis of the fluid (for saving).

It is apparently a contradiction of these ideal conditions. In the design of a practical stop-valve determinants are general operating parameters, which require also the determination of all parameters of construction.
Although the platform was designed and used for magneto-rheological valves by changing the field excitation of the magnetic field in electric field can cause and descriptive parameters for electro-rheological valve.

Acknowledgment

This work was (partially) supported by the strategic grant POSDRU/CPP107/DMI1.5/S/78421, Project ID

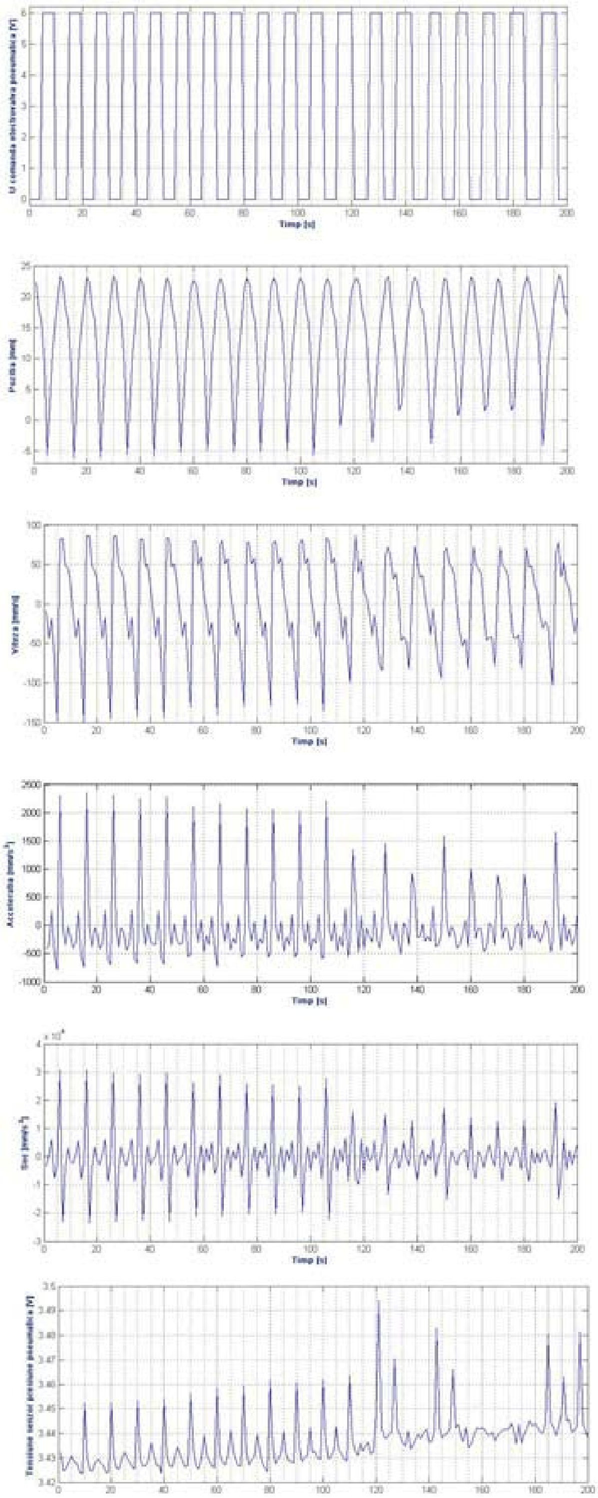

Figure 9: Time variations of: pneumatic valve power voltage, position, speed, accelerator, sock and pressure

78421 (2010), co-financed by the European Social Fund – Investing in People, within the Sectorial Operational Programme Human Resources Development 2007 – 2013."

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