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ASPECTS REGARDING INTEGRATED DESIGN OF PNEUMATIC ACTUATORS BASED SYSTEMS

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Abstract: *The paper proposes a large approach to pneumatic systems starting from the mathematical laws, written in the form of differential equations, which govern the operation of pneumatic systems and continuing with the simulation model. The concept of integrated design includes all approaches, needed for an optimal and deep system understanding, such as modeling, simulation and control. Pneumatic actuators have a nonlinear functionality because of air compressibility, the existing frictions and the valves nonlinearities. Because of these, they are used in high speed applications and simple positioning systems. Thus, the mathematical analyses of pneumatic systems have received a special attention. Aspects concerning mathematical modeling using Bond Graph method are presented in the paper too. Bond graph method is an alternative to mathematical "traditional" modeling and like any alternative method may be used to verify the calculations and how the approaches were designed in the mathematical system. Another advantage would be the electronic similarity with the introduction of the three passive elements: resistance, condenser and coil, proposed to be the basic elements in the phenomenology in this method. The differential equations were implemented in Matlab Simulink..*
Keywords: *fuidtronic, mechatronic, pneumatic, bond graph, dynamic, simulation*

1. INTRODUCTION

Mechatronics design involves, besides the conceptual stage, the parallel development of virtual and effective prototyping processes, which can confirm the veracity of approaches. The design based on analytic model is an approach which reduces time and costs of the design, allowing engineers to analyze and test a model to be equated to the actual behavior. The result of this way of working is a fully optimized and tested without the risk that some components will not function optimally in the system.
The pneumatic systems have a nonlinear function, because of the air compressibility, the friction forces and the valve's non-linearities. Because of these, they are used in high speed applications and simple positioning systems. The model studied proposes the analysis of the nonlinear characteristics, so the residual volume and uneven distribution of the friction forces were integrated

2. PNEUMATIC SYSTEM MODEL

The mathematical analysis of pneumatic systems has received an important attention. The model studied, proposes nonlinear characteristics analysis and for that were integrated into calculations the residual volume and uneven distribution of friction forces. Analysis of dynamic behavior of the pneumatic system requires relationships that characterize the dynamic features of 3 elements: the valve, the pneumatic actuator and the load.

$$\dot{P}_a = -\frac{k\dot{V}_a}{V_a}P_a + \frac{k}{V_a}RT_sC_dC_0w_aX_af\left(P_a,P_s,P_e\right) \quad \textbf{(1)}$$

$$\dot{P}_b = -\frac{k\dot{V}_b}{V_b}P_b + \frac{k}{V_b}RT_sC_dC_0w_aX_bf\left(P_b,P_s,P_e\right) \quad \textbf{(2)}$$

$$A_aP_a - A_bP_b - K_f\dot{x} - K_{s-c}(x)S(\dot{x},P_a,P_b) = M\ddot{x} \quad \textbf{(3)}$$

Flow mass "m" relationship between the two ports of the valve, is written according to the movement of the drawer and the chamber pressure. It can be written relations for mass flow that supplies the cylinder based on the energy conservation principle applied to the cylinder of limited volume.

Where $\dot{x}$ represents speed, $\ddot{x}$ acceleration, K_f viscous friction coefficient and $K_{s-c}(x)$ is the combination of static and coulombian frictions.

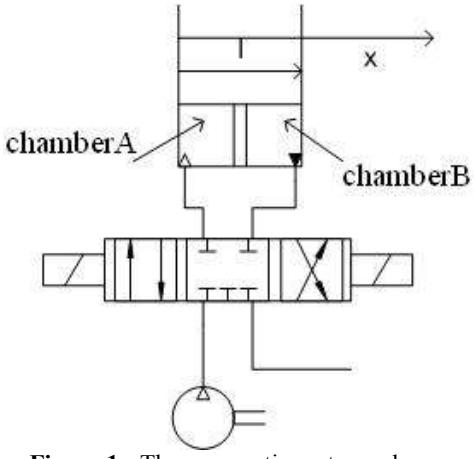

Figure 1: The pneumatic system scheme

3. BOND GRAPH MODEL

Bond Graph modelling method is based the energy flow method. Energy is the basic element in a system regardless of his type. A system can be powered from one or more sources, the energy that flows through the system elements can be stored in certain components or partial dissipated trough resistances as heat, and then transmitted to the effectors. The essential advantage brought by this relatively new method is the unitary treating of systems, regardless of the type: electrical, mechanical, hydraulic etc., by introducing some principles to which all systems can join. This advantage can extend also to the mechatronic systems, knowing that they have a strong interdisciplinary character, and the integration principle represents a basic component that exists in all mechatronic systems. Bond Graph method is a less used and studied method that represents an alternative concept to the "traditional" modelling and can be used for checking the calculations and to check how the approach in mathematical terms was thought. Another advantage would be the correspondence with electronic science by introducing three passive components: resistance, coil and condenser as basic components in the phenomenology proposed by this method. In figure 2 is shown the bond graph model for a pneumatic cylinder with a proportional valve.

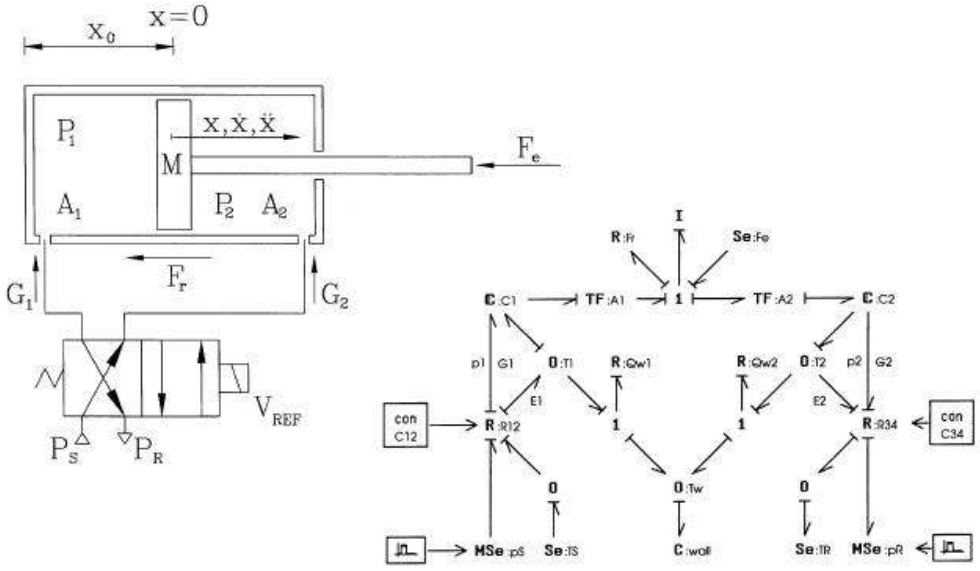

Figure 2: Pneumatic actuator**'s** bond graph model

4. NUMERICAL RESULTS

The equations used in developing the model based on which the simulation was done, are (1), (2) and (3) and of course the mathematical relations that describes the functions' in these equations. These are first and second order differential equations that characterize the phenomena which stand for the functionality of the actuator, the valve and the load dynamics.

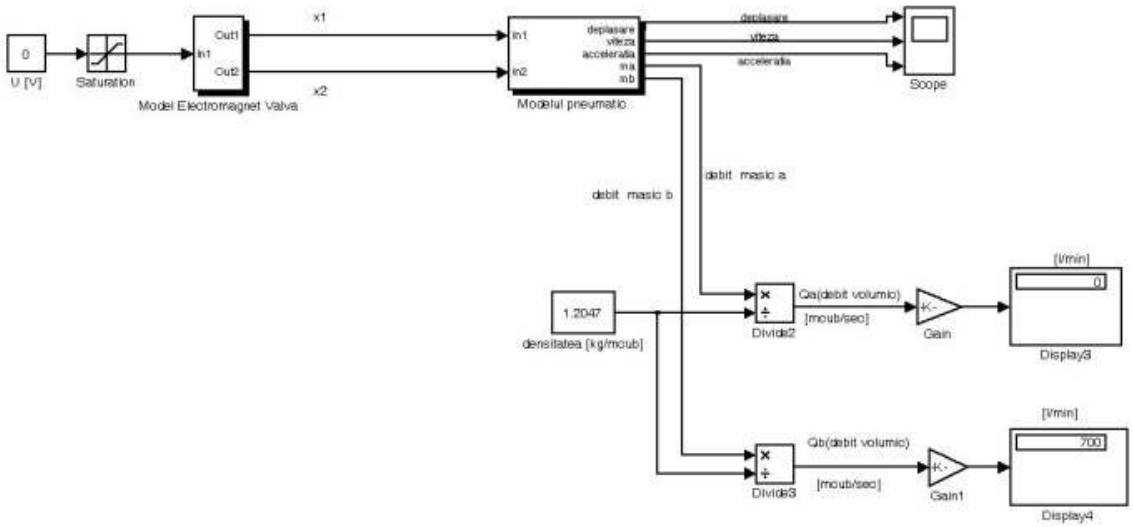

Figure 3: Pneumatic model

In figure 3 is shown the pneumatic model, described with differential equations in the previous chapters, implemented in Matlab-Simulink.

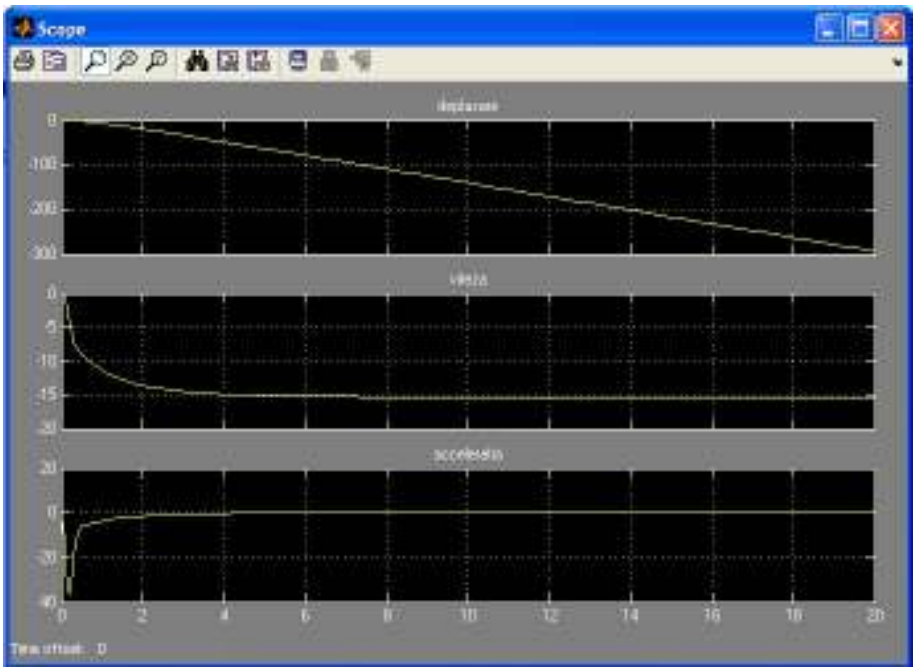

Figure 4: Model outputs

It is possible to view, in figure 4, the system's response materialized in the displacement, speed and acceleration of the axis piston to a maximum valve's opening obtained by applying 0 V to the valve's coil. It is very important to specify how the proportional valve works, so the range of voltage that can be applied to the coil is between 0 and 10 V, 0 V representing the maximum displacement of the valve's drawer in a giving direction, and 10 V represents the maximum displacement in the opposite direction.

5. CONCLUSION

The concept of integrated design includes all approaches, needed for an optimal and deep system understanding, such as modeling, simulation and control. Like hydraulic elements, pneumatic based systems are characterized by resistance, inertia and capacity. These three main components are well described in bond graph modeling, a less used method of modeling complex systems. Accentuating the limits of fragmentation approach and the necessity of an overall vision, the science of integration tries to avoid such situations, pointing out even more strongly the need to take into account not only the subsystem on which we must act, but also for his connections with other subsystems and in fact the suprasystem they belong. The integration science subscribes within the context of modern thinking.

The concept of integration is one of the great gains of mankind due to information revolution and mechatronics is an integrative vision technology.

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