OPTIMIZING THE HYDRAULIC SYSTEMS USING THE SIMHYDRAULICS PROGRAMMING ENVIRONMENT

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***Abstract*:** This paper analyzes the simulation of a hydrostatic system using the Simhydraulics programme of the Matlab programming environment. The author intention is to underline the advantages of this programme offers in performing the functional tests of the complex hydraulic systems. The form of the characteristics resulting after the simulation indicates the precision of the model created and subsequently allows the choice of the optimum functional parameters. Using some specialized software, making models and simulations which can be realized using them, are necessary steps in the modern projecting of a hydrostatic system. The advantages in terms of time and costs offered by this method are also underlined here.

Keywords: Hydraulic systems, Simhydraulics, volume regulation, secondary regulation

1. INTRODUCTION

With fluctuations generated by the progress of science and technologies and by the worldwide usage trends, the hydraulic systems have known a considerable development, due to some major advantages those systems offer compared to the mechanical and even the electrical systems, since there are technical fields and areas in which they are irreplaceable. The hydraulic and pneumatic drive systems constitute means of transmitting the energy from the source to the working part; aside from the high and fully controllable value level of the energy, they also have the advantage of easily performing a continuous, accurate variation within the broad limits of the forces, couples, speed and position [1].

2. THE VOLUME REGULATION

One of the most important advantages of the hydraulic drive systems is the possibility of continuously modifying the rotation and translation speed of the burden, operated within a large range of values, in both direction and without any shocks. The engine power and thus the velocity are proportional to the output at constant burdens. Thus in the case of the linear engine we can get a constant force at the rod level, and for the rotative engine we can get a constant rotation couple [1].

The volume regulation is used especially when maximum force or couple is necessary during the start-up. The regulation of the hydrostatic systems can be achieved by regulating the pump output (volume regulation), by regulating the capacity of the hydraulic engine (secondary regulation), or using both methods (mixed regulation). The volume regulation of a system using a linear engine is presented in Figure 1a.

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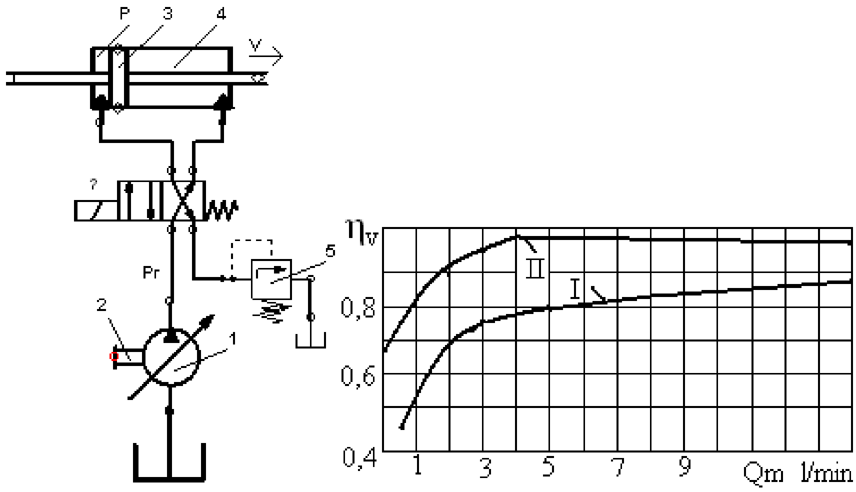

a b

Fig. 1. Hydraulic system with volume regulation [1]:
a) Linear engine system with volume regulation; b)The dependence of the volume efficiency of the pump (η_v) by engine demanding flow of (Q_M).

Acting on the capacity of pump 1, we regulate its output and thus the velocity of the piston in the linear hydraulic engine 3. By increasing the load on the piston rod, the pressure p in the chamber 4 of the hydraulic cylinder increases. The pressure p_r in the exhaust conduit of pump 1 also increases. The increase in pressure leads to volume losses in the pump, and decreases the output and thus the velocity.

The volume losses also appear in the case of a constant burden due to the modification of the fluid viscosity when heated. In Figure 1b is presented the dependence of the volume efficiency of the pump (η_v) upon the output necessary for the hydraulic engine Q_M, for pumps with maximum output of 8-12 (l/min) and a pressure of $40 \cdot 10^5$ Pa. Curve 1 is specific for the impeller pumps, and curve 2 for the piston pumps [2].

The primary regulation offers essential, constructive and functional advantages for driving the mechanic loads characterized by high values of insertion and resistant couple. The rotation speed regulation system is in fact a fast electro-hydraulic servomechanism by means of which is modified the output of the volume pump according to the command signal sent by an electronic regulator. The basic diagram of an analogical variant of the regulation system is presented in Figure 2.

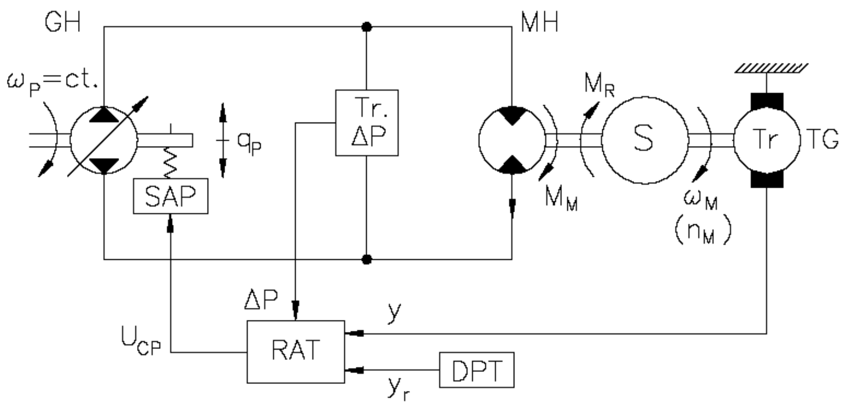

Fig. 2. The basic diagram of the rotation speed primary regulation system [2].

The automatic rotation speed regulator (RAT) has as external measurements the reference value of the rotation speed (y_r) as an analogue signal sent by the rotation speed control block (BMT), actual rotation speed (y), measured using a „tahogenerator" rotation speed transducer (T_r) and a differential pressure signal (ΔP) which is a measure of the couple performed by the hydraulic engine. After developing and processing the error signal $e=y_r-y$, the rotation speed regulator sends out a command signal (U_{cp}) which is the reference signal for the regulation servomechanism of the pump capacity (SAP), which has as exit volume the variable q_p.

The transfer function of this servomechanism considered as a tracking system is [2]:

$$H_{smp}(s) = \frac{q_p(s)}{U_{cp}(s)} = \frac{K_{smp}}{T_{smp} \cdot s + 1} \tag{1}$$

where K_{smp} is the amplification factor, and T_{smp} is the time constant. Since the quality measure of the regulation system is the rotation speed of the hydraulic system and of the load ($z=\omega_M$), the transducer used is defined by the relation [2]:

$$y = K_t \cdot \omega_M \tag{2}$$

where K_t (V_s/rad) is the transfer constant. Considering the fact that the hydrostatic transmissions usually activate great loads which can accumulate a large quantity of kinetic energy, the recovery of the breaking mechanical energy is possible either by restoration of the primary energy source or by storage in hydraulic accumulators.

3. MODELLING AND SIMULATING A HYDROSTATIC SYSTEM USING THE SIMHYDRAULICS PROGRAMME

3.1. Drafting the hydrostatic model

When projecting technical systems in general and especially the hydrostatic systems, detailed knowledge concerning the phenomena taking place during the real static and dynamic states is necessary. Especially here, the simulation tests are extremely useful, being considerably cheaper and faster than the experimental ones [2].

The availability and existence of several hardware devices, computers and mathematical simulation software, allows the testing and performance of simulation operations even for very complicated systems. The programming environment Matlab-Simulink is frequently used in such applications [2], offering the following advantages:

- the designer doesn't have to create a programme for solving the system equations and the mathematical model adopted;
- a quick simulation, due to the fast and efficient computing system and of the algorithm included in the kit;
- it ensures an easy method for creating the block diagram using a graphical editor;
- the possibility to visualize the results of the calculation an its results for future applications;
- the easiness of modifying the coefficients of the mathematical model.

The convenient characteristics of the Simhydraulics programme in the Matlab Simulink programming environment make this kit become a necessary soft for performing the simulation tests for the complex hydraulic systems [4]. Within this simulation programme, a fundamental role is that of the block diagram which is a graphical model that substitutes the equation system describing the mathematical model associated to the process. The block diagram includes a series of symbols named blocks, connected by interconnecting lines.
Each block represents an elementary dynamic system which, according to the input size the initial state and the specific parameters produces a continuous exit size for the continual blocks or values of the exit size in the case

of discrete systems. The connection lines are oriented segments which connect an exit size of a block and an input size of another block [3].

After drafting the block diagram corresponding to the mathematical model, the visualization blocks are placed (most frequently Scope - oscilloscope in the Sinks library). They must be activated by double click, thus opening the window containing the oscilloscope screen, and at this moment we are able to modify the oscilloscope configuration [3].

The diagram of the hydrostatic drive system suggested for testing is presented in Figure 3. The hydraulic engine 7 with adjustable capacity activates the loading system 9 by means of a certain coupler, the necessary hydraulic energy being ensured by the pump with adjustable cylinders 2.

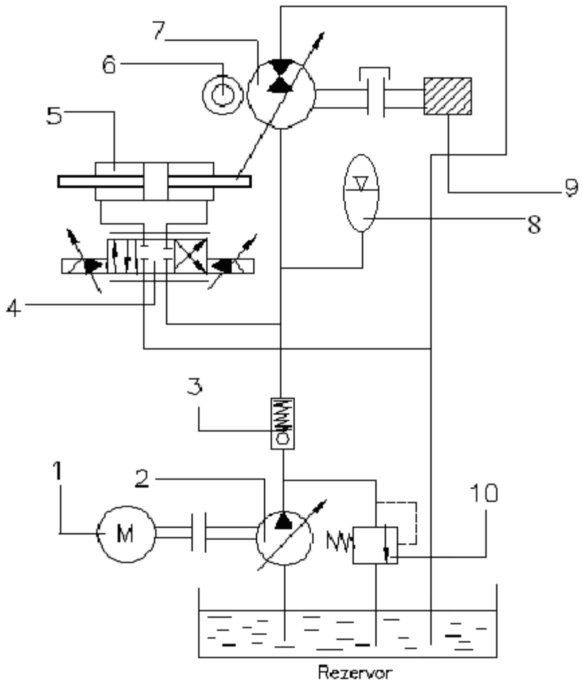

Fig. 3. Hydrostatic drive system suggested for simulation in Simhydraulics.

The regulation of the hydraulic engine capacity and its direction of rotation is ensured by means of cylinder 5 commanded by the servovalve 4. The electrical signal for the servovalve 4 is sent by the tahogenerator 6, connected to the hydraulic engine. The accumulator 8 in the hydraulic diagram helps maintaining an approximately constant value for the pressure within the circuit. It will get loaded when the hydraulic unit 7 works using the pump and it will ensure the necessary pressure for lifting the load 9. The mechanical system 9 for loading the hydraulic engine is simulated, as we will see in the Simhydraulics representation, by means of a board suspended by a winch, the corresponding inertia force, buffer.

The testing of the hydraulic system can be performed after building the diagram in the specific programming environment. Having predefined the main hydraulic elements, the model building is only a matter of looking for symbols in different symbol libraries and drawing the connections between the elements. Figure 4 presents the hydrostatic system in Figure 3. In order to simplify the representation of a diagram in Simhydraulics, we can work with blocks representing subsystems. The secondary regulation unit of the hydraulic engine 7 is presented in Figure 4 as a subsystem chosen from the ones predefined in the programming environment used, Figure 5.

Building a subsystem requires attention in establishing the functions that define it and in converting the physical measurement units. The command for the movement of the servo-cylinder is sent by the corresponding servovalve by means of a 4/3 servo-distributor. The input signal for the secondary regulation block can be of different types, and the one chosen is presented in from Figure 6.

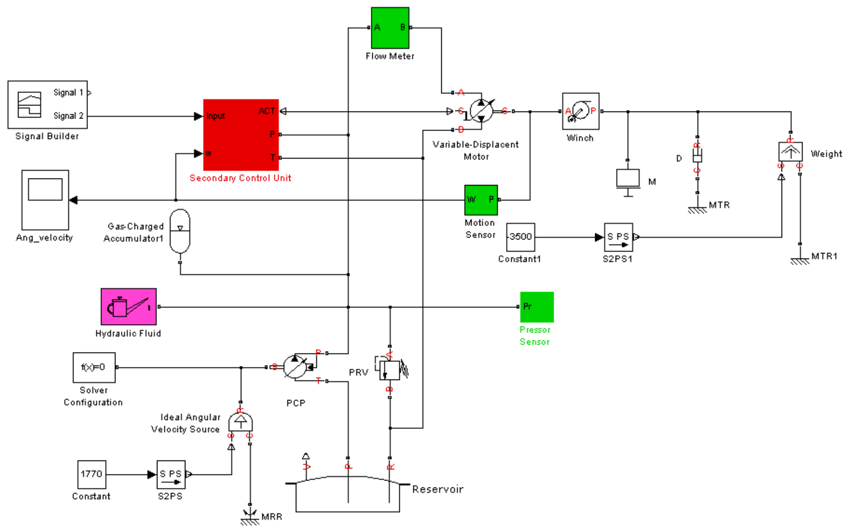

Fig. 4. Modelling the hydrostatic system in Simhydraulics.

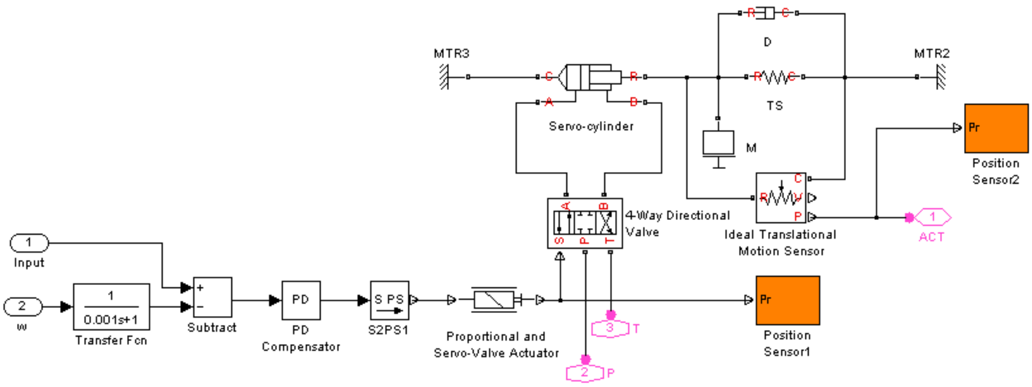

Fig. 5. Modelling the secondary regulation unit.

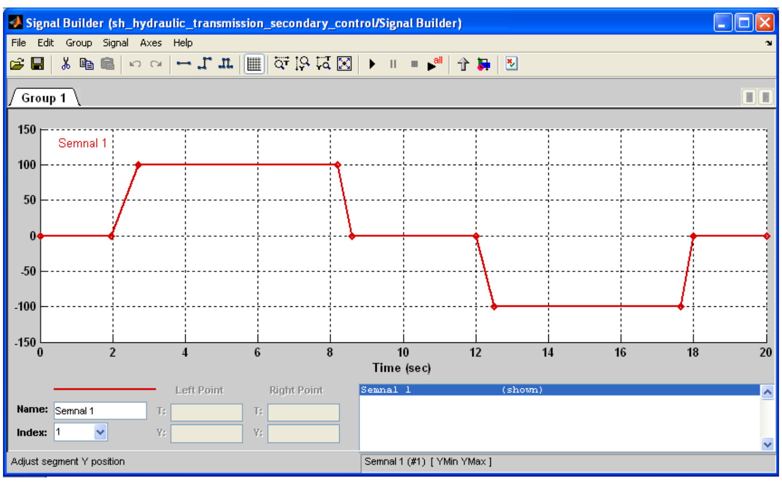

Fig. 6. Input signal for the secondary regulation unit.

The input system, processed using a proportional derivative PD controller and an S-PS convertor activate the servovalve, whose reaction in moving the mobile element is registered by a movement sensor 1. The reaction of the servo cylinder is, in its turn, monitored using the movement sensor 2.

3.2. Results achieved after the simulation

The reaction of the output parameters after applying the input signal of the type presented above is shown in Figure 7 and Figure 8 for the secondary regulation subsystem and in Figure 9, Figure 10 and Figure 11 for the secondary regulation system of the hydraulic engine capacity.

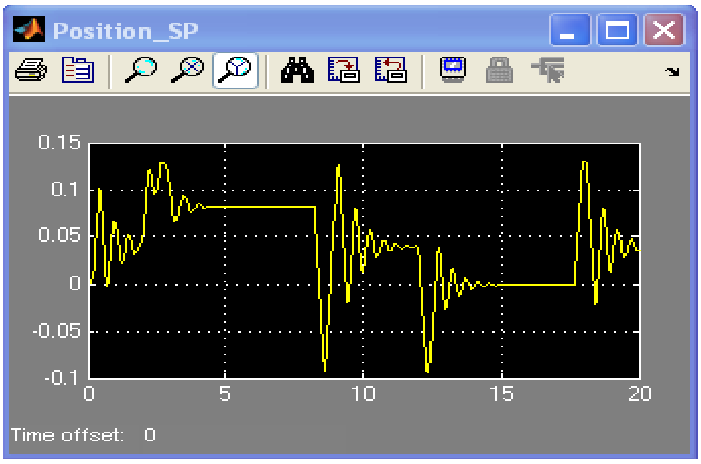

Fig. 7. Reaction of the servo-cylinder.

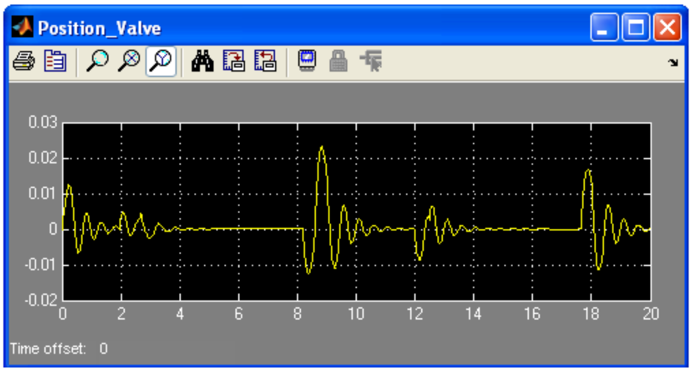

Fig. 8. Position of servovalve.

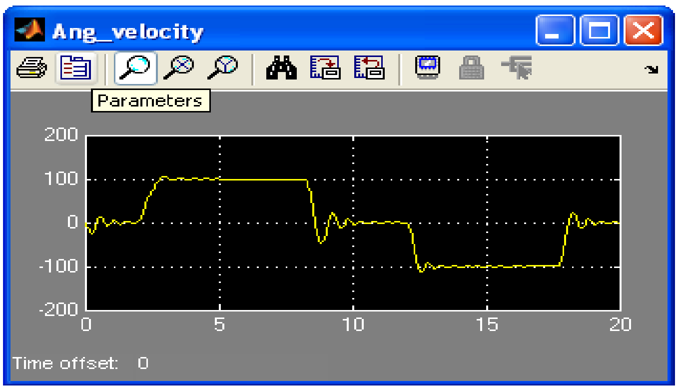

Fig. 9. Angular velocity of the hydraulic engine.

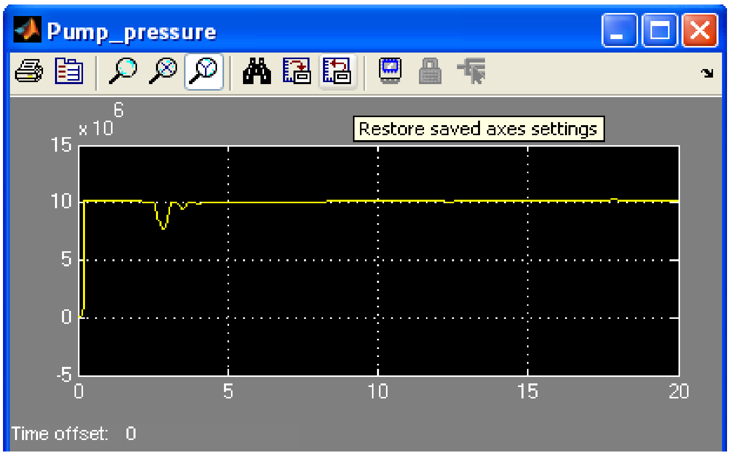

Fig. 10. Pomp pressure.

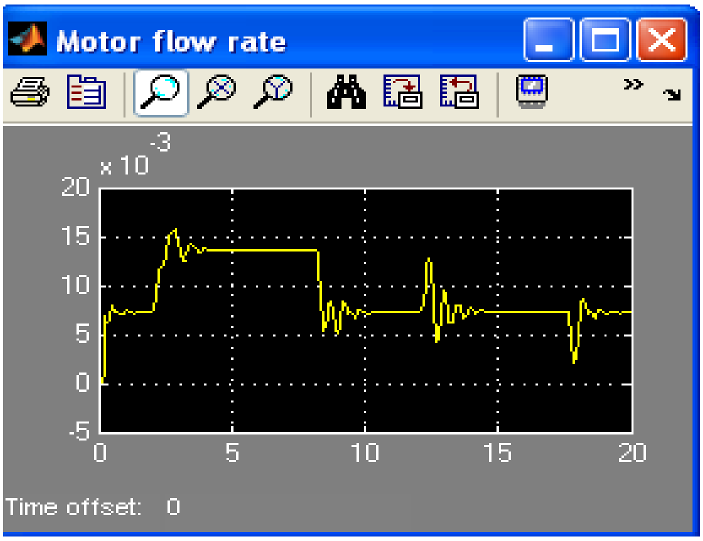

Fig. 11. Variation of the engine flow.

4. CONCLUSIONS

The modelling and simulation of the hydrostatic systems has been performed using the Matlab Simulink programming environment, the Simhydraulics kit. This method allows us to select the regulation variant for the system parameters within the primary as well as the secondary regulation range. The model presented in this paper illustrates the case of a secondary regulation.

The results achieved underlined the following dynamic performance of the regulation system suggested:

- any variation in the input size leads to a variation of the output size by the variation of the coefficient for capacity regulation;
- any variation of the resistant couple leads to a short transient variation of the angular velocity which can be attenuated by modifying the engine capacity at a constant pressure;
- the high sensitivity of the secondary regulation subassembly (Figure 7 and 8) and the variation in the servovalve position cause a reaction of the same type on the servo cylinder level.

- the variation diagram for the hydraulic engine rotation speed follows the aspect of the diagram for the servo cylinder position, thus validating the correct connection of the secondary regulation subsystem within the hydraulic system.

It is important to adjust the hydraulic parameters of the pump according to the engine load in order to avoid any transient pressure oscillations (Figure 10). For a correct value of the pump pressure according to the loading of the system, the engine input and the angular velocity have a stable and obvious similar diagram.

The use of the programming environments of the same category as Symhidraulics simplifies the designer's work starting from the designing stage, allowing him to improve the hydraulic diagram from the point of view of its design, as well as to choose the functional parameters and the component parts so as the energetic efficiency of the assembly should be as high as possible.

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