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APPLICATION OF HYDRAULIC CIRCUIT IN MECHATRONIC SYSTEMS

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ABSTRACT
This paper focuses on the calculations of basic variables of the hydrostatic circuits in the mechatronic systems. These calculations are important for machines used for forming materials by means of great forces, e.g. hydraulic press. Due to differences in equipment design, lack of a universal method of calculation is noticeable. It is necessary to determine the coefficients required for the calculations in an experimental way.
KEYWORDS: hydraulic circuit, MATLAB, simulation

STOSOWANIE OBWODU HYDRAULICZNEGO W SYSTEMACH MECHATRONICZNYCH

STRESZCZENIE
Tematem niniejszego artykułu jest obliczanie zmiennych podstawowych w obwodach hydrostatycznych w systemach mechatronicznych. Obliczenia te są wykonywane w mechatronice i wykorzystywane w maszynach do formowania materiałów za pomocą wielkich sił (prasa hydrauliczna). Zauważalny jest brak uniwersalnej metody obliczeń ze względu na różnice w konstrukcji urządzeń, stąd też konieczne jest wyznaczanie potrzebnych do obliczeń współczynników w sposób eksperymentalny.
SŁOWA KLUCZOWE: obwód hydrauliczny, symulacje, MATLAB

1. Introduction

The subject matter of the article is a calculation of basic variables in hydrostatic circuit used in the mechatronic systems. These calculations are important for mechatronic machines used for forming materials by means of great forces (hydraulic press) [1, 2]. Working medium of those machines is in the majority hydraulic fluid – hydraulic oil. To obtain or convert the energy involved in the process of any form, it is necessary to transform energy delivered by the working fluid. Energy transfer through hydrostatic transmission has several advantages in opposite to the transfer through mechanical transmission [3]. One of the biggest advantages is a smooth transition of power; what is more, the lack of clutch, full process control and absence of shocks in the transmission structure are also considered as benefits. Whereas complex design and lower overall efficiency of the machine should be enumerated as the disadvantages.

2. Hydrostatic unit model

Energy has to be delivered hydrostatically to an actuator. For such a change the hydraulic pump is needed. There is a high amount of hydraulic generators on the market offered by worldwide manufacturers, which operate on different principles [4].

Determining parameters of all hydraulic units are: pressure, displacement and speed. Hydraulic pumps and motors operate according to the same physical principle – the only difference is the direction of transfer of mechanical and hydraulic energy.

Basic parameters of hydraulic pumps are working geometrical volume V and pressure (pressure gradient) Δp. Revolutions n, or angular speed ω, flow rate $Q = n \cdot V$, torque $M = V \cdot (\Delta p/2p)$, power $P = Q \cdot \Delta p$ and control parameter β can be qualified as ancillary parameters. Using the basic and ancillary parameters, it is possible to calculate the flow - η_Q, pressure (mechanical-hydraulic) - η_p and total efficiency η_c of hydrostatic converters (e.g. pumps) and hydrostatic transmissions [5].

A mathematical model of hydrostatic unit in generator mode was formulated by Schlösser as the equations [6, 7]:

$$Q_G = \beta_G A_G \omega_G - \frac{\beta_G \Delta p_G A_G}{\eta} + C_{st}\sqrt{2\Delta p} \tag{1}$$

$$M_G = \beta_G A_G \Delta p_G + C_{fG} \Delta p_G + C_{\eta G} \eta A_G \omega_G + C_{hG} \rho A_G^{5/3} \omega_G^2 \tag{2}$$

The Schlösser`s mathematical model later modified by Thomasin can be expressed in the form of equations:

$$Q_G = \beta_G A_G \omega_G - \frac{\beta_G \Delta p_G A_G}{\eta} \tag{3}$$

$$M_G = \beta_G A_G \Delta p_G + C_{fG} \Delta p_G + C_{\eta G} \eta A_G \omega_G + C_{hG} \rho A_G^{5/3} \beta_G^3 \omega_G^2 \tag{4}$$

Where: Q_G .... *effective flow rate of the pump*

M_G .... *effective torque at the shaft of the pump*

A_G .... *volume parameter of the pump*

ω_G .... *angular speed of the pump shaft*

β_G .... *control parameter of the pump,*

η .... *dynamic viscosity of working fluid*

C_{sG} .... *coefficient of flow resistance in the pump*

Q_{fG} .... *coefficient of loss caused by dry friction in the pump*

$C_{\eta G}$ .... *coefficient of loss caused by viscous friction in the pump*

$C_{\eta G}$ .... *coefficient of hydrodynamic loss in pump*

3. Model and simulation results

The possible structure of a mathematical model of a hydrostatic circuit providing the movement of the part of forming mechatronic system by the double-acting hydrostatic cylinder is shown in fig. 1.

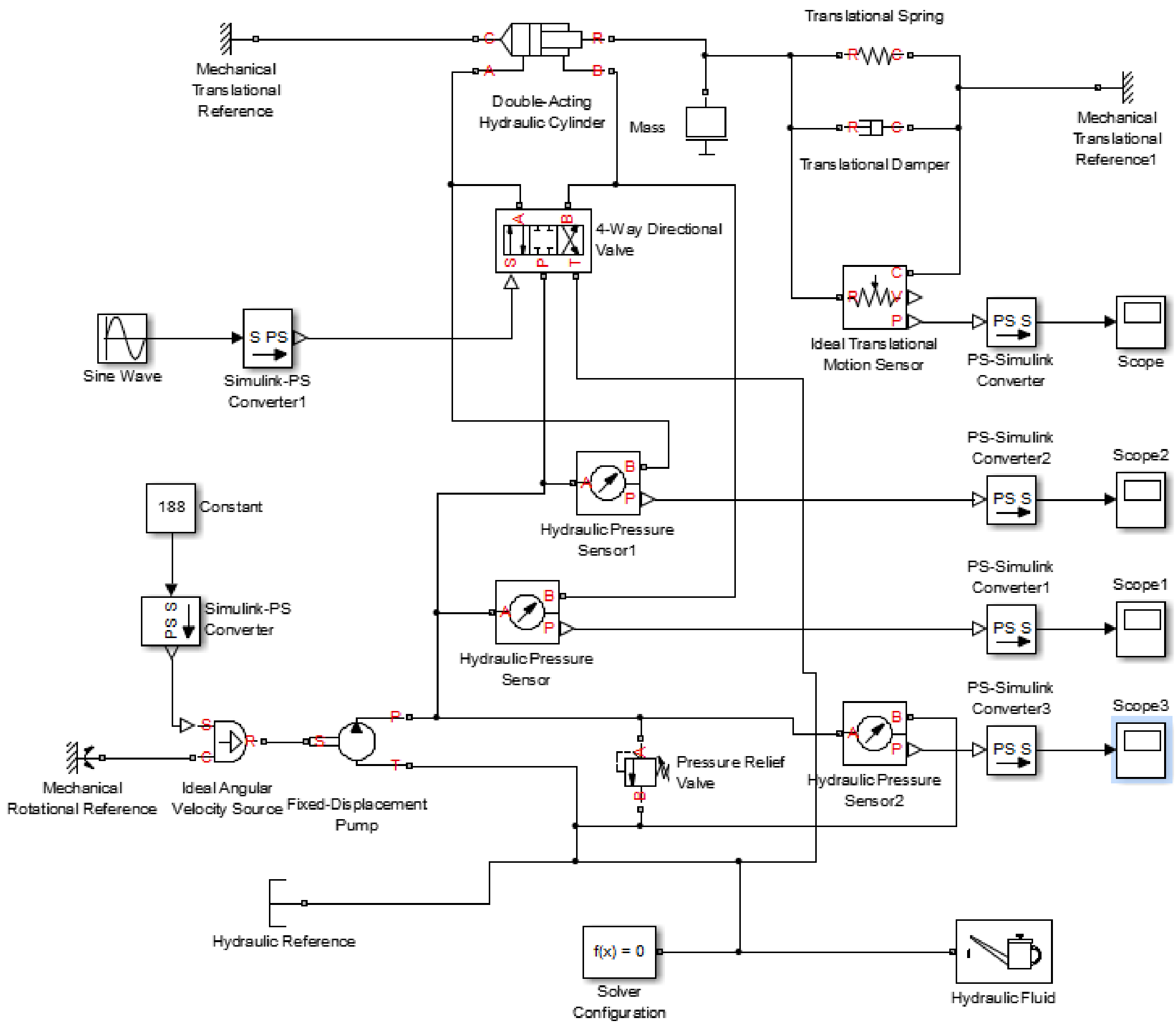

Fig. 1. The block model of hydraulic circuit including rotary hydraulic pump with 4-way directional valve and double acting hydraulic cylinder

The progress of the relative position of the cylinder piston rod, the pressure difference between the A and B cylinder input and the pump output, and the pressure difference between the pump input and output were observed. The results of the simulation are presented in fig. 2 to fig. 5.

4. Conclusion

There is a possibility of a calculation of all basic characteristics of the hydrostatic circuits by using presented equations. It is difficult to set the right coefficients of resistance and losses in hydraulic units; they are different for each unit and depend on construction of the device and the principle of its operation. The coefficients can be established by laboratory tests of every explored unit [8, 9].

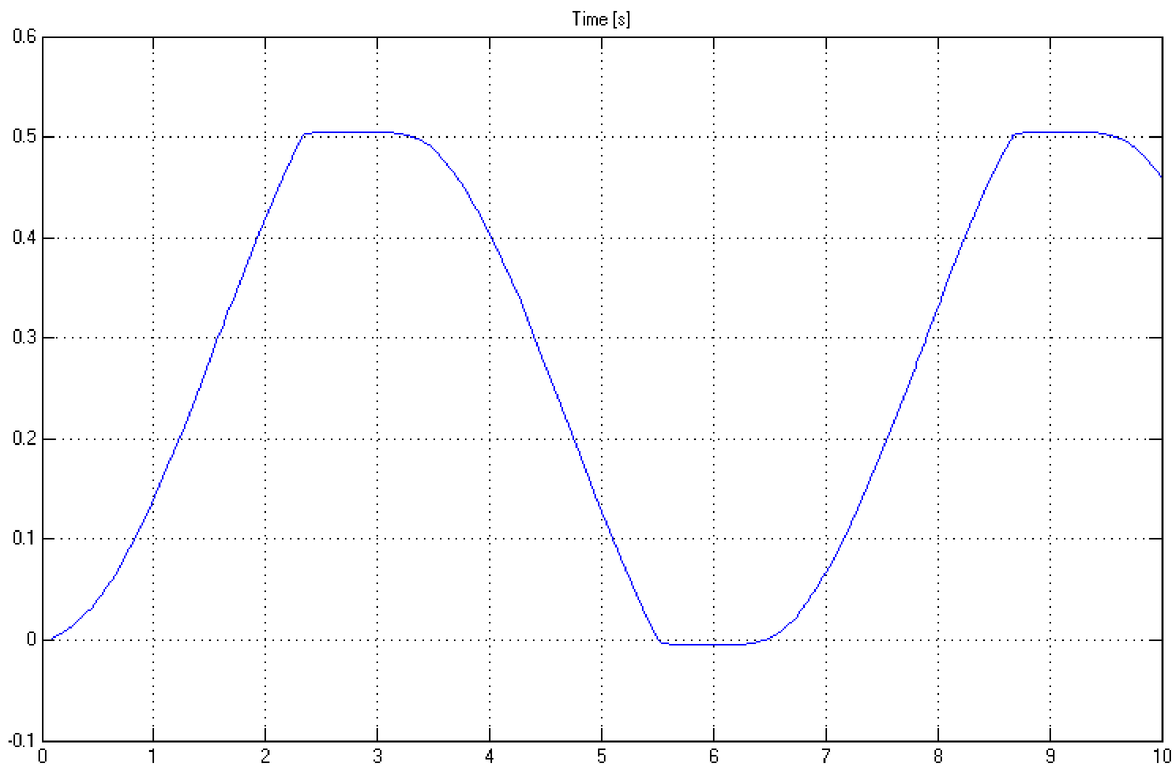

Fig. 2. The time progress of the relative hydraulic cylinder piston rod distance (m)

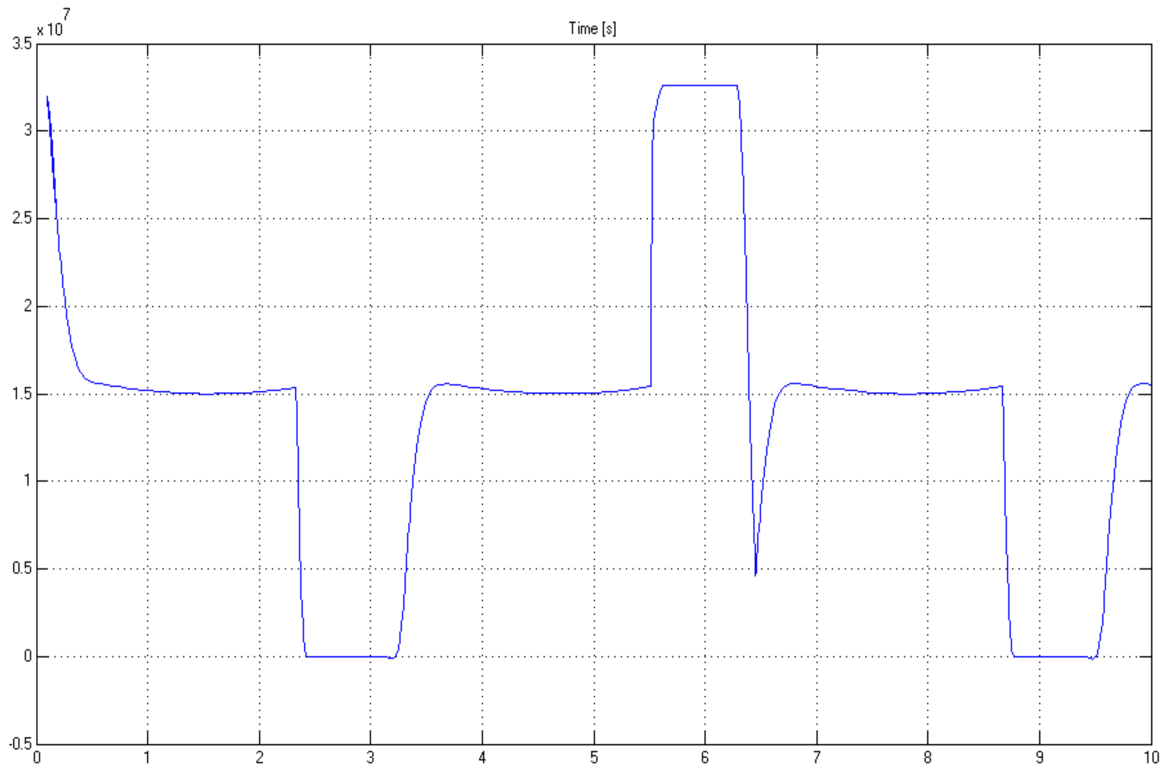

Fig. 3. The time progress of the pressure difference (Pa) between the A hydraulic cylinder input and the pump output

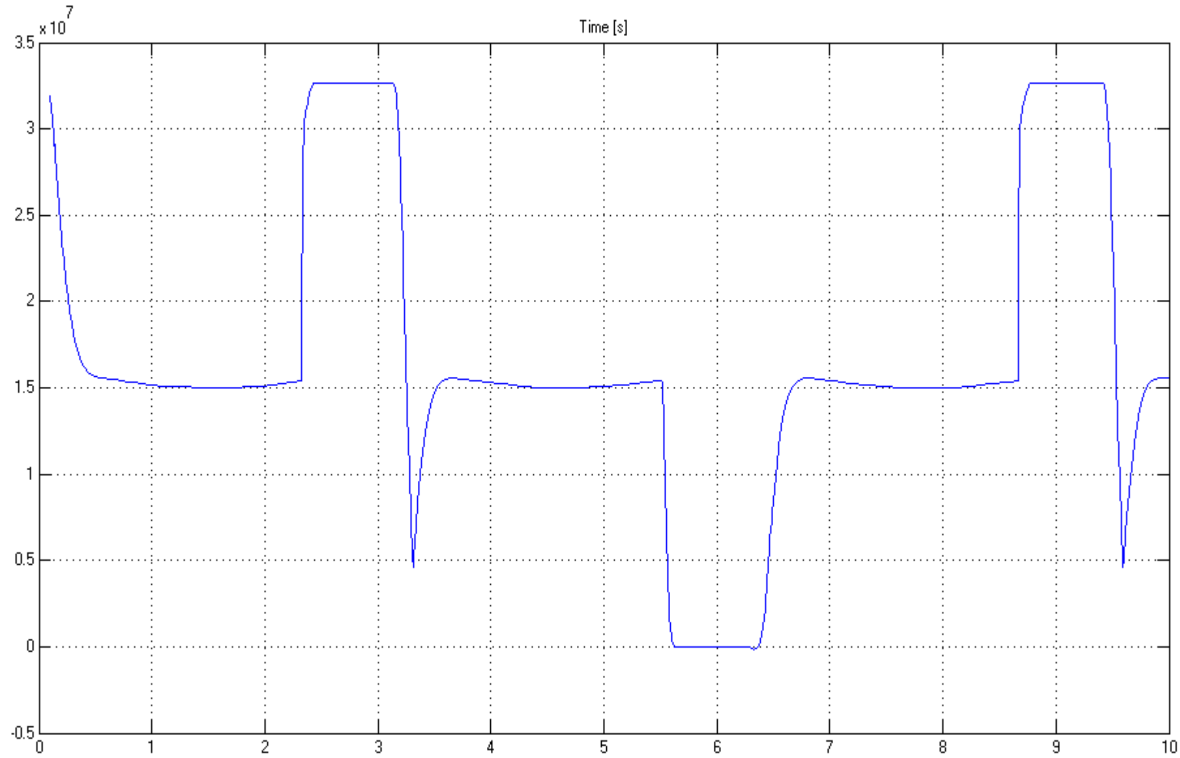

Fig. 4. The time progress of the pressure difference (Pa) between the B hydraulic cylinder input and the pump output

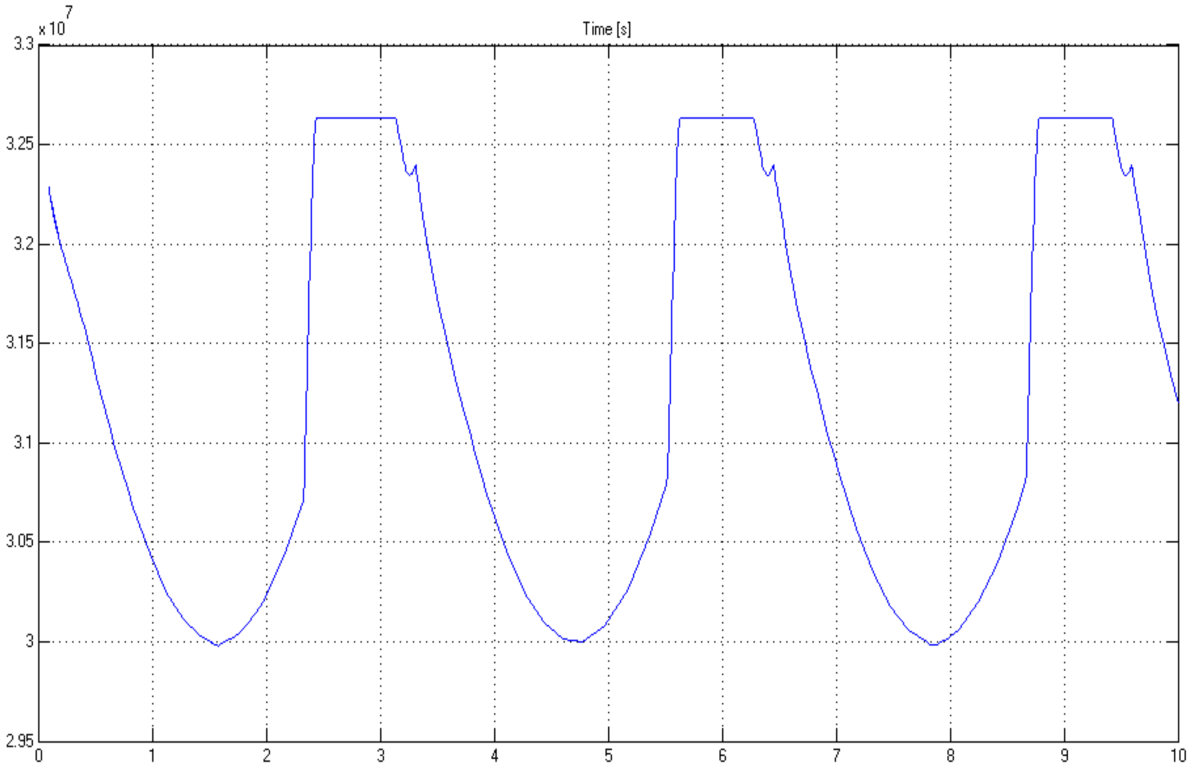

Fig. 5. The time progress of the pressure difference (Pa) between the pump input and output

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