THE DYNAMIC MODEL OF A SERVOVALVE SV60

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1. INTRODUCTION

The servovalve is essentially a regulating system. The output (flow, pressure) is controlled by the electric control input. There is a negative feedback. This feedback can be mechanical, hydraulic and electrical. The analysis is realized on linearising mathematical models. As modeling techniques there can be used transfer functions or state equations.
The paper presents the mathematical model for a SV 60 servovalve. The dynamic performances are influenced by the constructive parameters. The mathematical model permits the realisation of the block diagram of the servovalve and the use of the variable state method.

2. The servovalve mathematical model

In fig. 1 it is shown the simplified servovalve functional scheme in which: TM – torque motor, FN – flap nozzle, VS – slide valve and MF – mechanic feedback.

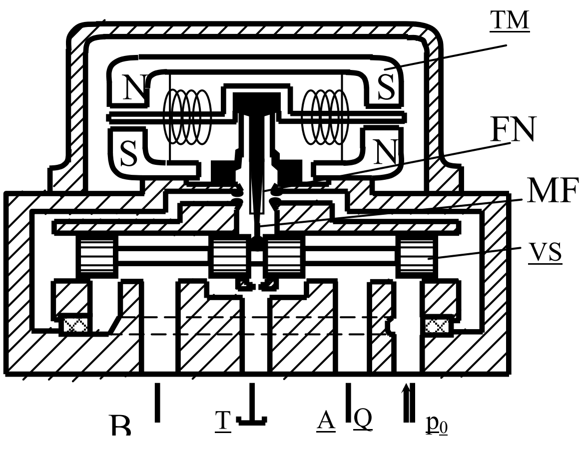


Figure 1. Servovalve functional scheme.

2.1. The torque motor mathematical model

The electrical circuit equation:

$$u = Ri + L\frac{di}{dt} + k_{u\theta}\frac{d\theta}{dt} \qquad (1)$$

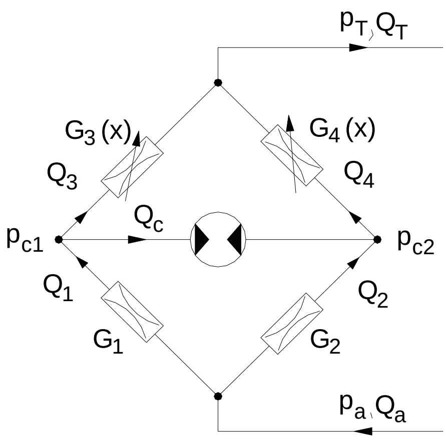
The dynamic equilibrium equation of the moments that operate on the blade:

$$k_m i = J_c\frac{d^2\theta}{dt^2} + c\frac{d\theta}{dt} + k_f\theta + M_h \qquad (2)$$

For $k_{u\theta}=0 M_h=0$ and applying the Laplace transformation it is obtained:

Figure 2. Hydraulic balance

3)



$$u(s) = R\cdot i(s) + L\cdot s\cdot i(s) + k_{u\theta}\cdot s\cdot\theta(s)$$

$$k_m\cdot i(s) = \left(J_c\cdot s^2 + c\cdot s + k_f\right)\cdot\theta(s) + M_h(s)$$

$$i(s) = \left[u(s) - k_{u\theta}\cdot s\cdot\theta(s)\right]\frac{1/R}{T_e s + 1}$$

$$\theta(s) = \left[k_m\cdot i(s) - M_h(s)\right]\frac{1/k_f}{T_m^2 s^2 + 2\xi_m T_m s + 1}$$

The transfer function is:

$$Y_{CE} = \frac{x(s)}{u(s)} = \frac{(l\cdot k_m)/(R\cdot k_f)}{(T_e s + 1)\left(T_m^2 s^2 + 2\xi_m T_m s + 1\right)}$$

2.2. The flap-nozzle amplifier mathematical model

The running of the flap-nozzle amplifier is of a hydraulic balance type, fig. 2.

The balance load is the four-way valve. Using the notation $\bar{x} = x/x_0$ it results $\bar{x}_1 = 1 - \bar{x}$ and $\bar{x}_2 = 1 + \bar{x}$. The flow equations are:

$$Q_1 = G_1\sqrt{p_a - p_{c1}}\ ; Q_3 = G_3(x)\sqrt{p_{c1} - p_T}$$
$$Q_2 = G_2\sqrt{p_a - p_{c2}}\ ; Q_4 = G_4(x)\sqrt{p_{c2} - p_T} \quad (4)$$

The hydraulic resistivity equations are:

$$G_1 = G_2 = G_{dr} = \mu_{dr} \cdot A_{dr} \cdot \sqrt{\frac{2}{\rho}}$$
$$G_3(x) = G_o \cdot \bar{x}_1 = G_o \cdot (1 - \bar{x}) \quad (5)$$
$$G_4(x) = G_o \cdot \bar{x}_2 = G_o \cdot (1 + \bar{x})$$

Using the notation $\alpha = G_0/G_{dr}$ it results:

$$\frac{p_{c1} - p_{c2}}{p_a - p_T} = \frac{4 \cdot \alpha^2 \cdot \bar{x}}{\left[1 + \alpha^2 \cdot (1 - \bar{x})^2\right] \cdot \left[1 + \alpha^2 \cdot (1 + \bar{x})^2\right]} \quad (6)$$

The characteristics $\Delta p = f(\bar{x})$ is linear for $\bar{x} \in [0; \bar{x}_m]$. It can be written:

$$\Delta p = K_{px} \cdot \bar{x} \quad (7)$$

2.3. The four-way valve mathematical model

The flow for a shifting y of the piston is:

$$Q = \mu \cdot \pi \cdot d_p \cdot y \cdot \sqrt{\frac{2}{\rho}} \cdot \sqrt{\Delta p} \quad (8)$$
$$Q = G(y) \cdot \sqrt{\Delta p}$$

The functional analysis of the four way valves leads to an equivalent scheme of a hydraulic balance type, fig. 3

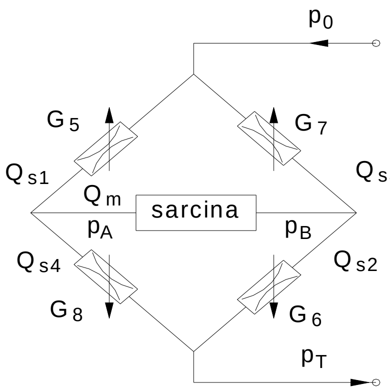
The equations of the flows

$$\begin{cases} Q_{s1} = G_5(y) \cdot \sqrt{p_0 - p_A} \\ Q_{s2} = G_6(y) \cdot \sqrt{p_B - p_T} \end{cases} \quad y>0 \quad (9)$$

$$\begin{cases} Q_{s3} = G_7(y) \cdot \sqrt{p_0 - p_B} \\ Q_{s4} = G_8(y) \cdot \sqrt{p_A - p_T} \end{cases} \quad y<0 \quad (10)$$

For the symmetrical distribution and $p_T=0$

Figure 3. Hydraulic balance



$$Q_{s1} = Q_{s2} = Q_{s3} = Q_{s4} = Q_L \quad (11)$$
$$G_1 = G_2 = G_3 = G_4 = G(y)$$

We put down $p_A+p_B=p_0$ and $p_A-p_B=p_L$ it results:

$$Q_L = G(y) \cdot \sqrt{\frac{p_0 - p_L}{2}}\ , \quad y > 0$$
$$Q_L = G(y) \cdot \sqrt{\frac{p_0 + p_L}{2}}, \quad y < 0 \quad (12)$$

$$Q_L = G_M \cdot \frac{y}{y_M} \cdot \sqrt{\frac{p_0 - p_L \cdot sgn(y)}{2}} \quad (13)$$

We put down $\bar{p}_L = p_L/p_0$; $\bar{y} = y/y_M$; $\bar{Q}_L = Q_L/Q_M$, $G = \bar{y} \cdot G_M$, and it is obtained:

$$\bar{Q}_L = \bar{y} \cdot \sqrt{\frac{1}{2} \cdot \left[1 - \bar{p}_L \cdot sgn(\bar{y})\right]} \quad (14)$$

Through linearisation it is obtained:

$$\Delta\bar{Q}_L = k_{qy} \cdot \Delta\bar{y} - k_{py} \cdot \Delta\bar{p}_L \quad (15)$$

$$k_{qy} = \frac{\partial Q_L}{\partial y} = \frac{G_M \cdot \sqrt{p_0}}{y_M} \cdot \sqrt{\frac{1}{2} \cdot \left[1 - \frac{\bar{p}_{Lo}}{p_0} sgn(\bar{y}_0)\right]}$$

$$k_{py} = \frac{\partial Q_L/\partial y}{\partial Q_L/\partial p_L} = \frac{k_{py}}{k_{qp}} = \frac{2p_0 \cdot \left[1 - \frac{\bar{p}_{Lo}}{p_0} \cdot sgn(\bar{y}_0)\right]}{\bar{y}_0\, sgn\, y_0}$$

are the flow α pressure gradients.

Through linearisation and the application of Laplace transformation it is obtained:

$$Q_L(s) = k_{qy} \cdot y(s) - k_{py} \cdot p_L(s) \quad (16)$$

The dynamic equilibrium equation of the forces is.

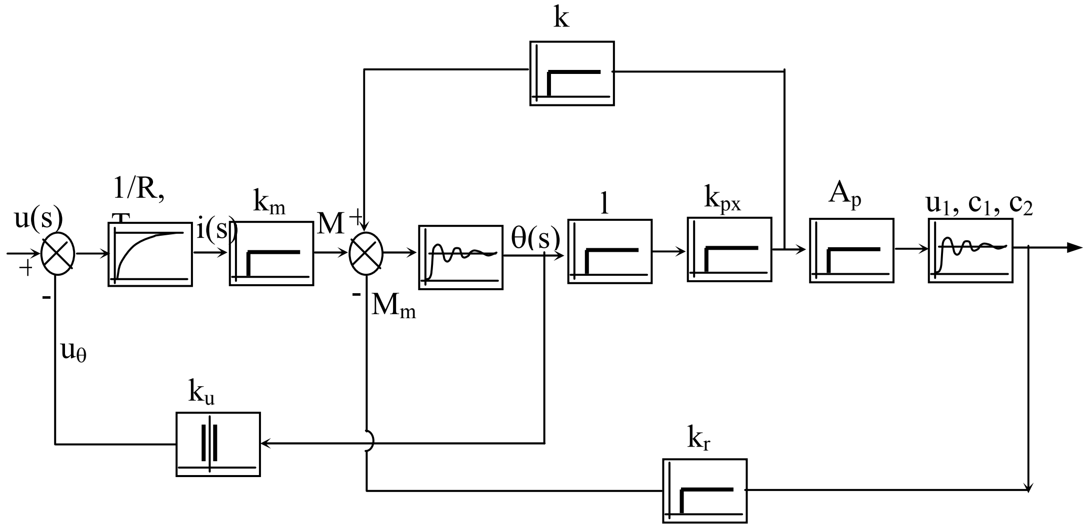


Figure 4. Servovalve block scheme

$$A_p \cdot (p_{c1} - p_{c2}) = m_1 \frac{d^2 y}{dt^2} + c_1 \frac{dy}{dt} + c_2 \cdot y$$

Through the application of Laplace transformation it is obtained:

$$(m_1 \cdot s^2 + c_1 \cdot s + c_2) \cdot y(s) = A_p \cdot \Delta p(s) \quad (18)$$

The servovalve mathematical models results from the composing of the subassemblies.

$$i(s) = [u(s) - k_{u\theta} \cdot s \cdot \theta(s)] \frac{1/R}{T_e s + 1}$$

$$T_m^2 s^2 \cdot \theta(s) + 2 \cdot \xi_m T_m s \cdot \theta(s) + \theta(s) = k_{m\theta} \Delta M$$

$$(m_1 \cdot s^2 + c_1 \cdot s + c_2) \cdot y(s) = A_p \cdot \Delta p(s)$$

$$u_r(s) = k_\theta s \cdot \theta(s)$$

$$x_p(s) = l \cdot \theta(s)$$

$$\Delta p(s) = k_{px} \cdot x_p(s)$$

$$\Delta M = M_e - M_h - M_r$$

The block scheme is shown in fig. 4

4. CONCLUSIONS

The mathematical model of the servovalve is obtained by means of the adequate assembling of the mathematical models of the elements that constitute the regulating loop of the system.

On the bases of the block scheme, using the method of the state variables, there can be realized the numerical simulation on the computer.

References

1. *Călăraşu D.*, ***Reglarea secundară a sistemelor de acționare hidrostatică în regim de presiune cvasiconstantă, Ed. Media-Tech, Iaşi, 1999***
2. ***Chirita C**, Actionari electrohidraulice, Ed. Satya, Iasi, 2000*
3. ***Gamînin M.S**. ş.a., Gidravličesie sledâŝie privody sistem upravleniâ, Mašinostroenie, Moskva, 1972.*
4. ***Livinț Gh.**, Teoria sistemelor automate, Editura Gama, Iaşi, 1996.*
5. ***Mazilu I., Marin V.**, Sisteme hidraulice automate, Editura Academiei, Bucureşti, 1982.*