UDC 621, 629 531

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IMPROVEMENT OF THE FRICTION MODEL IN THE AILERON CONTROL SYSTEM

The power element for controlling the ailerons is a hydraulic actuator, and to improve the efficiency of these hydraulic actuators, a more accurate calculation model than that available in the literature is provided.

The accuracy is improved by using nonlinear friction in the model, which is given in the work [1].

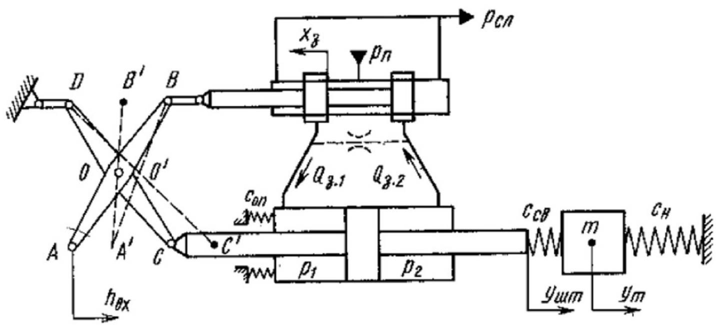

Figure 1 – Diagram of a hydromechanical drive [2].

Analytical model

The operation of this drive is described by Newton's second law:

$$c_{cv}(y_{sht} - y_m) - c_H y_m - P_{fri} = m\frac{(d^2 y_m)}{(dt^2)}, \quad (1)$$

where y_{sht} and y_m are displacement of the hydraulic cylinder rod by mass m.

In literature, P_{fri} is approximated by a linear function. To improve the accuracy of calculations, it is proposed to approximate friction by a nonlinear model according to formula [1]:

$$P_{fri} = P_c\left[\left(P_{br} - P_c\right)\cdot\exp\left(-\upsilon_{\text{piston}} / \upsilon_L\right) + k_v\left|\upsilon_{\text{piston}}\right|\right] \quad (2)$$

Instead of the characteristic, one takes an approximate characteristic that will have the following form:

$$Q_v = K_{Qx}x_v - K_{Qp}x_H \quad (3)$$

Comparing expressions (1) and (3), together with taking into account nonlinear friction (2), results into the equation of motion of the cylinder rod:

$$m\frac{d^2 y_m}{dt^2} + P_c\left[\left(P_{br} - P_c\right)\cdot\exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v\left|\upsilon_{piston}\right|\right] + \quad (4)$$

$$+(c_{cv} - c_H)y_m = c_{cv}y_{sht}$$

Instead of the equation of motion of the output link of the hydraulic actuator, an equilibrium equation will be used. It looks like

$$F_c p_H - c_{cv}\left(y_{sht} - y_m\right) = 0 \quad (5)$$

The motion of the hydraulic cylinder piston around the middle position is described by equation:

$$Q_v = F_c P_c\left[\left(P_{br} - P_c\right)\cdot\exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v\left|\upsilon_{piston}\right|\right] + \frac{V_O + V_L}{B_{zh}}\frac{dp_1}{dt}$$

$$Q_v = F_c P_c\left[\left(P_{br} - P_c\right)\cdot\exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v\left|\upsilon_{piston}\right|\right] + \frac{V_O + V_L}{B_{zh}}\frac{dp_2}{dt}$$

After transformations, such the equation is obtained:

$$Q_v = F_c P_c\left[\left(P_{br} - P_c\right)\cdot\exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v\left|\upsilon_{piston}\right|\right] + \frac{V_O + V_L}{2B_{zh}}\frac{dp_H}{dt}$$

Usually the mass is neglected and left P_{fri} for a more accurate calculation of the hydraulic cylinder.

$$F_c p_H - P_{fri} - c_O y_C = 0 \quad (6)$$

$$y_c = \frac{F_c p_H - P_{fri}}{c_o} \quad F_c \cdot; \frac{d}{dt}\left(\frac{F_c p_H - P_{fri}}{c_o}\right)$$

$$Q_v = F_c P_c \left[\left(P_{br} - P_c\right) \cdot \exp\left(\frac{-\upsilon_{piston}}{\upsilon_L}\right) + k_v \left|\upsilon_{piston}\right| \right] + F_c$$

$$\cdot \frac{d}{dt}\left(\frac{F_c p_H - P_{fri}}{c_o}\right) + \frac{V_0}{2E_c}\frac{dp_H}{dt}$$

where E_c – the given modulus of elasticity of the hydraulic cylinder, which is in the following relation.

$$E_c = \frac{B_{zh}}{1 + \frac{V_L}{V_o} + \frac{2F_c^2 B_{zh}}{V_o c_o}}$$

Equations (3), (4), (5), (6) mathematical model of a hydraulic servo–actuator with throttle control.

$$\left(1 + \frac{2E_c F_c^2}{V_o c_{cv}}\right) \frac{V_o m}{2E_c F_c K_{Qx}} \frac{d^3 y_m}{dt^3} \frac{F_c}{K_{Qx}}$$

$$\left(\frac{K_{Qp} m}{F_c^2} + \frac{P_c \left[\left(P_{br} - P_c\right) \cdot \exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v \left|\upsilon_{piston}\right| \right] V_o}{2E_c F_c^2} + \right.$$

$$\frac{P_c \left[\left(P_{br} - P_c\right) \cdot \exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v \left|\upsilon_{piston}\right| \right] V_o}{c_{cv}} +$$

$$\left. \frac{K_{Qx} m \frac{F_c P_H - P_{fri}}{c_o}}{F_c c_{cv}} \right) \frac{d^2 y_m}{dt^2} + \frac{F_c}{K_{Qx}} \left(\frac{c_H}{c_{cv}} + \frac{V_o c_H}{2E_c F_c^2} + \right.$$

$$+ \frac{K_{Qp} P_c \left[\left(P_{br} - P_c\right) \cdot \exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v \left|\upsilon_{piston}\right| \right]}{F_c^2} +$$

$$\left. \frac{K_{Qx} \left(\frac{F_c P_H - P_{fri}}{c_o}\right) P_c \left[\left(P_{br} - P_c\right) \cdot \exp\left(-\upsilon_{piston} / \upsilon_L\right) + k_v \left|\upsilon_{piston}\right| \right]}{F_c c_{cv}} + 1 \right) \frac{dy_m}{dt}$$

$$+ \left(\left(\frac{F_c P_H - P_{fri}}{c_o}\right) + \frac{\left(\frac{F_c P_H - P_{fri}}{c_o}\right) c_H}{c_{cv}} + \frac{K_{Qp} c_H}{K_{Qx} F_c} \right) y_m = K_{xh} h_{Bx}$$

References

1. Lukianov P.V., Pavlova K.S. Neliniina dynamika v modeli systemy pervynnoho kontroliu polotom. Mekhanika hiroskopichnykh system, Kyiv, 2024. №47, S. 17–27C. 17–27 https://doi.org/10.20535/0203–3771472024307719.

2. Utiuhov Ye.V. Rozrobka ta doslidzhennia systemy keruvannia vazhkoho transportnoho litaka. – Kvalifikatsiina robota na zdobuttia osvitnoho stupenia mahistra zi spetsialnosti 134 «Aviatsiina ta raketno–kosmichna tekhnika» osvitno–profesiinoi prohramy «Litaky i vertoloty». – Derzhavnyi universytet «Kyivskyi aviatsiinyi instytut». Kyiv, 2024. – 79 c.