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ASPECTS OF THE DYNAMIC BEHAVIOUR OF PRESSURE VALVES

Lecturer PhD. Eng. Adrian-Sorin AXINTI
University “Dunarea de Jos” of Galati
The research Center of Machines, Mechanics and Technological Equipments

ABSTRACT

The present work is a synthesis of the research carried out in the years of exploration and research of hydraulic components in order to understand and evaluate dynamic behaviour. In particular, it tries to detect links between the dynamic response of a valve and constructive characteristics, in functional and dynamic environment. It is put forward the analytical solution for the dynamic response of pressure valve as a confirmed at least as qualitative solution, by the author, and of other researchers in the field.

KEYWORDS: hydraulic components, pressure valve, analytical solution, valves

1. INTRODUCTION

This paper aims at highlighting the pulsating character of the operating pressure and the valve is part of a cycle of works that highlight this reaction to most of the active components of hydrostatic system (hydraulic units, valves, regulators, etc.). [2]. To emphasize better these functional behaviours in dynamic behaviour, it will study several methods so as to clearly show the multitude of impact parameters and especially the impact process of constructive parameters of hydraulic and operating environment.

Listed in each category are:

- Structural features of impact of the rated device: gap-diameters, areas, diameters, gaps, flowing sections, volumes, masses, rigidities, range limits, speed limit forces, etc;
- Characteristics of hydraulic environment of the rated system: density, viscosity, kinematic viscosity and elasticity, dynamic viscosity, etc.
- Operating features: the temperature regime, the degree of filtering, hydraulic controls, gears, levels, time, and levels of adjustment of the impact parameters.
- Inter-correlation characteristics of the evaluated system are called: pre-loaded limits, elastic forces, range limits, etc.

2. NUMERICAL MODEL OF NON-LINEAR VALVE

We consider the pressure limiting valve with direct command, the model of which is described by the differential equation, reproduced below [1], [3].

$$\begin{cases} Q_E = Q_I - K_S x\sqrt{p} - \beta_S \dfrac{dp}{dt} \\ m_r \dfrac{d^2x}{dt^2} + K_f \dfrac{dx}{dt} + Kx = A_n p + K_D xp - F_0 \end{cases} ; \quad (1)$$

The first equation is the equation of the liquid flow through the valve and the second equation of motion of the valve body (sealing organ ensemble, arc, and liquid column). The system (1): non-linear mathematical model of pressure limitation valve with direct command. Using numerical integration methods, model (1) turns into an analytical system that allows for the use of numerical integration methods [1], [5].
The system becomes after specific numerical modelling substitutions:

$$\begin{cases} \frac{dp}{dt} = \dot{p} = u \\ \frac{dx}{dt} = \dot{x} = v \\ K_S.x.\sqrt{p} + \beta_S.u = \Delta Q \\ m_r.\dot{u} + K_f v + K.x = A_n.p + K_D.x.p - F_0 \end{cases} \quad ;(2)$$

In the system (2), the sizes involved are: u-speed variation of the pressure valve, pressure-assisted; v-velocity of motion of the pilot valve; $\Delta Q -$ agent flow hydraulic pressure valve ejected through the opening (parametric); F_0- the force of the initial pre-loaded valve spring, (initial setting). (Parametric controls). The constants of the differential equations are determined as numeric values according to [1]. For a pressure control valve, DN 6, adjusted directly to 325 bars, the chart of the resulting pressure variation through computational model (2) is presented in fig.1.

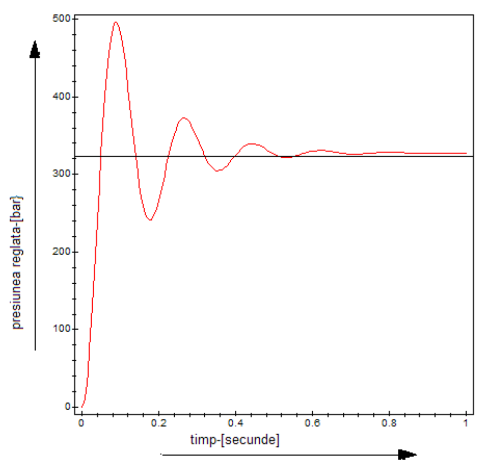
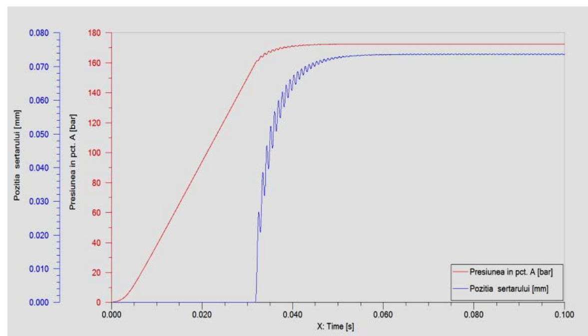


Fig.1. The variation of the pressure on the valve adjusted pressure

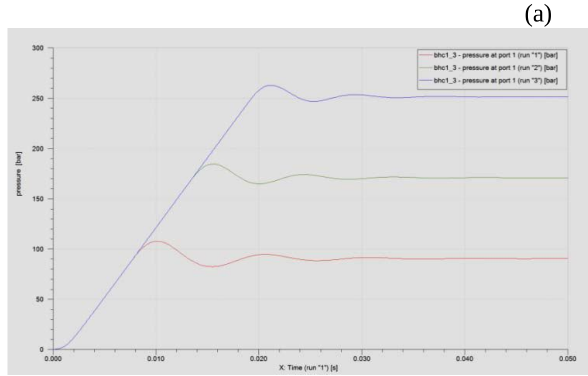
Analyzing the graph of the variation in pressure in Figure 1, it appears that although the model is non-linear (2), the behaviour of the valve is specific in terms of the variance of the parameter set (pressure) as any pulsating component. This leads to the idea that the makers have a non-negligible the influence and as a result they can be either neglected or linearized around some specific values (stabilized demeanour or permanent), actually known and applied in this case.

3. NUMERICAL SIMULATION MODELS

An example meaningful in terms of the behaviour of dynamic pressure valve with direct command and piloted is retrieved from the research conducted in the laboratories of the Polytechnic University of Bucharest [3] using a simulation program: AMESIM. The model considers the dynamic forces of flow of the liquid in the appliance. Figures obtained for the direct control and valve departs are shown in Fig. 2.



(a)



(b)

Fig.2.Dynamic response of pressure valve, model AMESIM [3]
a) Direct operated valve; b) departs valve

4. SYNTHESIS OF DYNAMIC PROCESSES

If the analogue and numerical modelling shows that a hydrostatic component has damped oscillatory behaviour, then it follows that dynamic process can be linear so as to achieve a linear model that can achieve a broad analysis of the dynamic behaviour without having to customize the model with coefficients specific to a particular building. For the previous example, it follows that in order to achieve linear mathematical model, it is necessary to linearize differential equations around the State quantities which make the value of movement and pressure:

$$K_S x\sqrt{p} = \frac{K_S}{\sqrt{p_{0R}}}x + \frac{1}{2}K_S x_0 \frac{1}{\sqrt{p_{0R}}} p$$

Similarly in the second equation of the model it results:

$$F_D = K_D xp = \frac{\partial F_D}{\partial x}\bigg|_{p=p_{0R}} dx + \frac{\partial F_D}{\partial p}\bigg|_{x=x_0} dp$$

Substituting this into the final relation, it follows the linear numerical model of valve:

$$Q_E = Q_I - K_S\sqrt{p_{0R}}\,x - \frac{1}{2}K_S x_0 \frac{1}{\sqrt{p_{0R}}} p - \beta_S \frac{dp}{dt}$$

$$m_r \frac{d^2x}{dt^2} + K_f \frac{dx}{dt} + (K - K_D p_{0R})x = \\ = (A_n + K_D x_0)p - Kx_0 \qquad (3)$$

If the first relation (3) is carried out:

$$Q_I - Q_E = \Delta Q; \quad K_S\sqrt{p_{0R}} = K_1;$$

$$\frac{1}{2}K_S x_0 \frac{1}{\sqrt{p_{0R}}} = K_2; \quad Kx_0 = F_0$$

It yields:

$$x = \frac{\Delta Q}{K_1} - \frac{K_2}{K_1}p - \frac{\beta_S}{K_1}\dot{p}; \qquad (4)$$

Substituting (4) in a second relation (3) and making notations:

$$a = \frac{m_r\beta_S}{K_1}; \; b = \frac{m_r K_2 + K_f\beta_S}{K_1};$$

$$c = \frac{K_f K_2 + (K - K_D p_{0R})\beta_S}{K_1};$$

$$d = \frac{(K - K_D p_{0R})K_2 + K_1(A_N + K_D x_0)}{K_1};$$

$$f = \frac{(K - K_D p_{0R})\Delta Q + K_1 F_0}{K_1}$$

the differential equation becomes:

$$a.\dddot{p} + b.\ddot{p} + c.\dot{p} + d.p = f; \qquad (5)$$

It is noted that equation (5) is a non-linear and differential equation of third order that has solutions of the form:

$$p = \frac{f}{d} + e^{-r_1 t}(p_1 \cos r_2 t + p_2 \sin r_3 t); \; (6)$$

$$p = \frac{f}{d} + e^{-r_1 t}(p_1.e^{r_2 t} + p_2.e^{-r_3 t}); \; (7)$$

the solution (6) is for real solution r1 and complex solutions of the equation characteristic, r2 and r3, and (7) for all real roots.

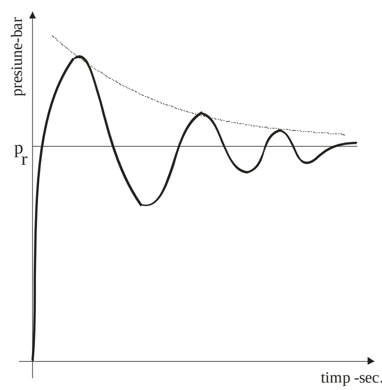
P1 and p2 are constants determined from the initial conditions of dynamic process of valve. In the case of the solution (6) because the complex roots of r2 and r3 are complexly conjugated, separating the real and complex and realizing the appropriate calculations, the solution can be put into final form:

$$p = p_r + e^{-nt}(p_1 \cos\omega_1.t + p_2 \sin\omega_1 t); \; (8)$$

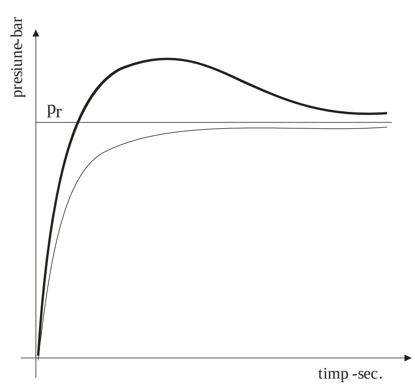
Similarly you can proceed with the solution (7) where analytical solution results in:

$$p = p_r + e^{-nt}(p_1 e^{\omega_1 t} + p_2 e^{-\omega_1 t}); \quad (9)$$

The solutions (8) and (9) are one of the types of charts fig. 3 a, b.



(a)



(b)

Fig.3. The change in pressure valve (analytical solution)
a) complex roots of the characteristic equation;
b) the real roots of the characteristic equation

The characteristics of p_r, n, ω_1 have the meaning described in [2] and determine the identification of coefficients a, b, c, d, f of equation (5) with the coefficients of the equation developed roots by r1, r2 and r3.

4. CONCLUSIONS

The analysis conducted in this paper is part of a series of papers outlining the pulsating character of pressure transient of hydrostatic equipment, analytical solutions for highlighting this functional parameter. This approach allows realizing direct links between structural and functional sizes of the instrument under consideration and its dynamic behaviour.

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