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Energy Source Influence on Some Information Features of a Fluid Flow[1]

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Abstract: *The paper investigates some information features of a fluid flow. Theoretical analysis shows the efficient stabilization is to be achieved in means of the duct pressure stabilizer.*

Keywords: *pressure stabilization, frequency characteristics.*

1. Introduction

As already known, fluidics is solving the problems, concerning the acceptance, processing and transfer of technology information with the help of the interaction of microjet flows. Information carriers in fluid informative system are the different types of flows (laminar, turbulent, stationary, non-stationary).

This information carrier can be specified by concordant informative features. The following features could be used as informative in fluid systems: the amplitude, the frequency, the phase difference and the wavelength for periodic systems; threshold values of the pressure for discrete processes; changes in the properties of the fluid (density, viscosity, compressibility, electroconductivity, magnetoconductivity).

An informative feature – energy-source interaction exists, which causes referent changes in the informative features due to changes of source parameters. The source inputs of some more quantities of heat and air are followed by changes in the features density and compressibility, which on the other hand lead to a change in the feature "wavelength".

The informative features are influenced sometimes by effects, indirectly connected with the energy source, such as noise effects or external disturbances.

The basic element in every hydraulic system is the pressure source, its characteristics affecting the main system.

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The energy source is generally completed by a pump and an overflow valve, functioning as a pressure regulator. The pump flow-rate is irregular, so the pressure pulses at an amplitude, varying up to 20% of the midvalue. This induces vibrations and generates noise.

There are cases, however, when the user at the output is changing at high frequency. Such types of flow-rate are executed in jet discrete systems, in systems with changeable flow (wave hydraulics), etc.

The larger part of resonance oscillation processes can be contributed to high frequency pressure operating, followed by increasing of its amplitude, i.e. it results in change of the informative features “amplitude and phase difference”.

Often one and the same source feeds several lines and in one of them periodic high frequency may be created. These oscillations influence the rest part of the duct.

It is obvious that the problems, connected with the high frequency stabilization of the energy source may be of great interest for a particular system type.

In order to diminish the noise, to flatten the pressure oscillations, pressure regulators and pneumohydraulic accumulators are utilized. The problem is to investigate their capabilities in high frequency work ranges so that the pressure informative features “amplitude and phase difference” are stabilized.

Equation (1) proves the one-stage pressure regulator, having a transfer function $KW(s)$ and frequency characteristics $A(w)$ and $\varphi(w)$:

$$KW(s) = \frac{\Delta Q(s)}{\Delta P(s)} = \frac{T_2 s^2 + T_1 s + 1}{a_2 s^2 + a_1 s + 1}; \tag{1}$$

$$A(\omega) = \sqrt{\frac{\alpha_8\omega^8 + \alpha_6\omega^6 + \alpha_4\omega^4 + \alpha_2\omega^2 + \alpha_0}{\beta_8\omega^8 + \beta_6\omega^6 + \beta_4\omega^4 + \beta_2\omega^2 + \beta_0}}; \tag{2}$$

$$\varphi(\omega) = -\operatorname{arctg}\frac{\xi_1\,\omega}{\xi_4\omega^4 + \xi_2\omega^2 + \xi_0}, \tag{3}$$

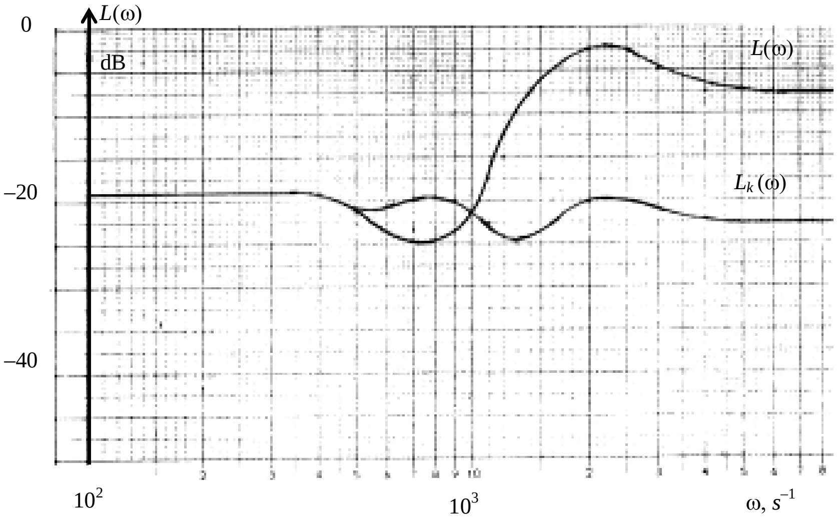

Fig.1. Logarithm amplitude-frequency characteristics:
$L(\omega)$ – with relief valve;
$L_k(\omega)$ – correction with oscillating and differentiating elements

where T_1, T_2, a_1, a_2 are time constants; α_i, β_i, ξ_i are the coefficients, characterizing the constructive and hydro-dynamic system objects and therefore having a logarithm amplitude-frequency characteristics $L(\omega)$ can not be pressure stabilizer at high frequencies. This is seen in Fig. 1, where $L(\omega)$ is shown. A correction of the logarithm amplitude-frequency characteristics is obviously necessary.

2. The general characteristics correction method

The general characteristics correction method is applied, where the logarithm frequency characteristics of separate elements, chosen in a proper way to get the necessary characteristics are summed. Two new elements, one of them oscillating, the other one – differentiating, give the correction of $L(\omega)$ and deliver the wished characteristics of $L_k(\omega)$. The amplitude peaks are flattened following the same procedure – they are already 4 dB, starting from 20 dB (Fig. 1). Theoretically such correction can be implied by conjuction of two adjacent elements – an oscillating and differentiating one, following the pressure regulator.

The transfer function of the particular analysis [1] is

$$KW(s) = \frac{12.10^{-8}s^2 + 10^{-4}s + 1}{33.10^{-8}s^2 + 3.10^{-4}s + 1} \cdot \frac{a_2 s^2 + a_1 s + 1}{b_2 s^2 + b_1 s + 1} . \tag{4}$$

The necessary adjust nozzle expression is

$$KW(s) = \frac{a_2 s^2 + a_1 s + 1}{b_2 s^2 + b_1 s + 1} = \frac{25.10^{-8}s^2 + 5.10^{-4}s + 1}{10^{-6}s^2 + 10^{-3}s + 1} .$$

It is to be stated – such nozzle cannot be constructed. At first the oscillating element must be put into action and after that the second differentiating element and this is impossible in a technical aspect.

There exists another possibility for correction – to provide an integrating element $L_i(\omega)$ or an apperiodic element $L_a(\omega)$ which gives $L_k^A(\omega)$ and $L_k^I(\omega)$ (Fig.2).

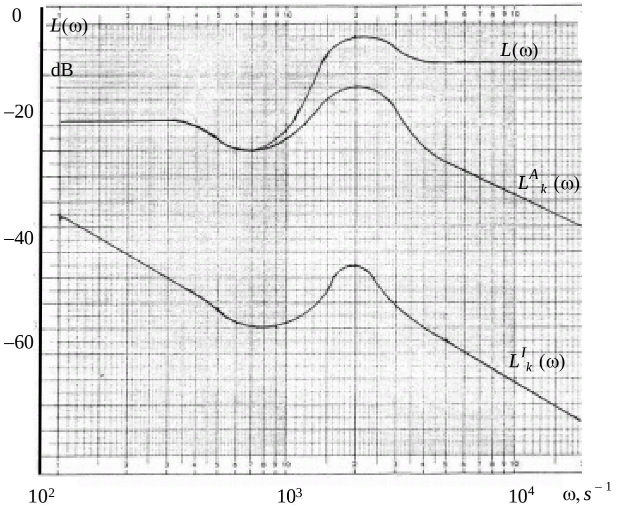

Fig.2. The Logarithm amplitude-frequency characteristics:
$L(\omega)$ – with relief valve;
$L^a_k(\omega)$ – correction with aperiodic element;
$L^I_k(\omega)$ – correction with integrating element

3. Pneumo-hydraulic accumulator and duct pressure stabilizer

The amplitude peaks are decreased in the course of such a correction. Excluding this, the technical realization of an integral or an aperiodic element is comparatively easy. Such an integrating element is the pneumo-hydraulic accumulator. At quick changes of load-unload cycles its heat exchange with the environment is near to the polytropic process The following expression [1] is easily determined.

$$Q_A = \frac{1}{n}\,\frac{V_A\,dp_1}{P_A\,dt} = K_A\frac{dp_1}{dt}\,, \tag{5}$$

where Q_A is the accumulator input and output flow rate; V_A , P_A are the gas volume and pressure in the accumulator; P_i is the pressure at the accumulator input.

The accumulator integrating character, according to this equation, is preserved only at tiny membrane displacement. The K_A value is changed extremely at great displacements. Both cases are possible: when the accumulator and regulator are in one and the same point or when they are apart one from another (Fig. 3).

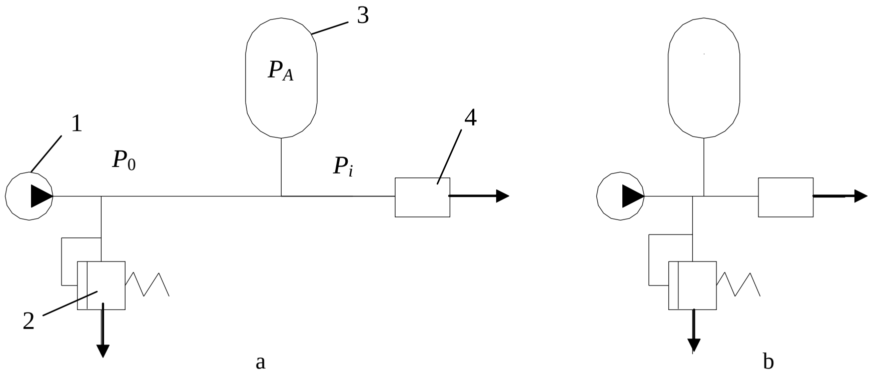

Fig.3. Schemes with long and short line:
1 – pump; 2 – releief valve; 3 – gas-loaded accumulator; 4 – high frequency oscillations generator; P_i – intput pressure; P_0 – output pressure; P_A – gas pressure.

In the case, shown in Fig. 3a, the transfer function and frequency characteristics are expressed by [1]:

$$KW(s) = \frac{\Delta P(s)}{\Delta Q(s)} = \frac{L_m s^2 + L_h s + L_c}{K_A L_m s^2 + (K_A L_h + T_2)s^2 + (T_1 + K_A L_c)s + 1}\,; \tag{6}$$

$$A(\omega) = \sqrt{\frac{a_4\omega^4 + a_2\omega^2 + a_0}{b_6\omega^6 + b_4\omega^6 + b_2\omega^2 + b_0}}\,; \tag{7}$$

$$\varphi(\omega) = -\operatorname{arctg}\frac{\alpha_5\omega^5 - \alpha_3\omega^3 - \alpha_1\omega}{-\alpha_4\omega^4 + \alpha_2\omega^2 - \alpha_0}\,. \tag{8}$$

The angular velocity ω and the operator S in the expressions above take into account the accumulator and the regulator constructive features, the regulator moving parts mass influence and its dampfer properties – the thermodynamic process character in the accumulator.

The amplitude-phase characteristics is shown in Fig. 4. It is depicted according to the expressions above given for a standard type of a regulator and an accumulator. It may be seen that the sharp amplitude diminishes at small frequency increase. As a result of all these considerations the standard pneumohydraulicaccumulator may give a very good stabilization. Unfortunately, the experiments do not confirm the analytic conclusions. In fact, at high frequencies (above 30 Hz), the pressure amplitude after the accumulator increases with the frequency growth, i.e. the stabilizing effect is missing. This mismatch between the analytic conclusions and the experiments may be interpreted with the help of the mutual perpendicular location between the pulse flow and the accumulator active chamber, and also with the significant fluid mass in it. This imposes the seek for new decisions. More efficient stabilization may be expected if the accumulating chamber – the pulse flow contact is planar instead of point, as the accumulator principle still keeps place, according to Fig. 4. Similar solution is shown in Fig. 5 [2]. The pulse flow duct is a spiral line – strip punched. The openings are small enough. The punched duct is enclosed in an elastic rubber tube. The chamber between this tube and the body is full of gas. The pulse flow-fluid chamber planar contact is fulfilled in that manner and the additional liquid volume, characteristic for the standard accumulator is missing. The disposed solution on the contrary to the standard pneumohydraulic accumulator can be labelled “duct pressure stabilizer”. The experimental results for this device are shown in Fig. 6.

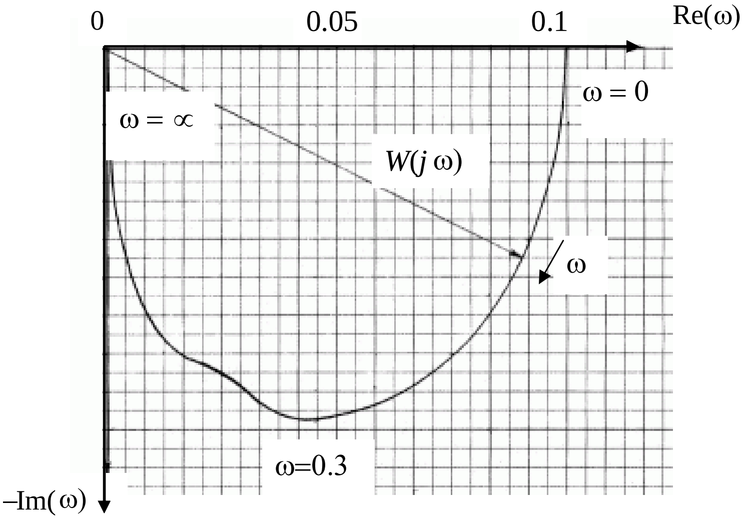

Fig.4. The amplitude – phase characteristics with gas – loaded accumulator

The Euler equation, the continuity equation and the pressure gas equation (in the chamber) are used for designation of the duct stabilizer theoretical model. The friction is approximately indicated as for a stationary process. The flow-rate at punched openings V_C is determined from the Darcy equation and a consequent correction coefficient for a non-stationary process:

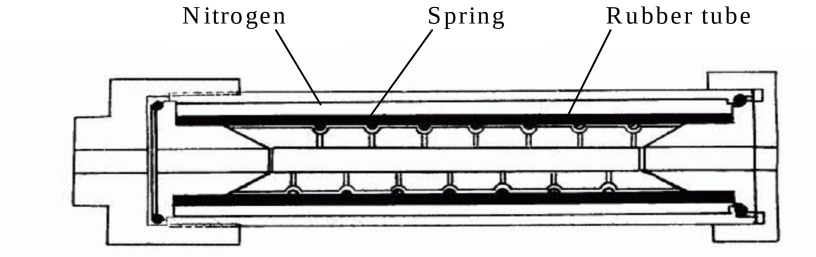

Fig.5. The duct pressure stabilizer

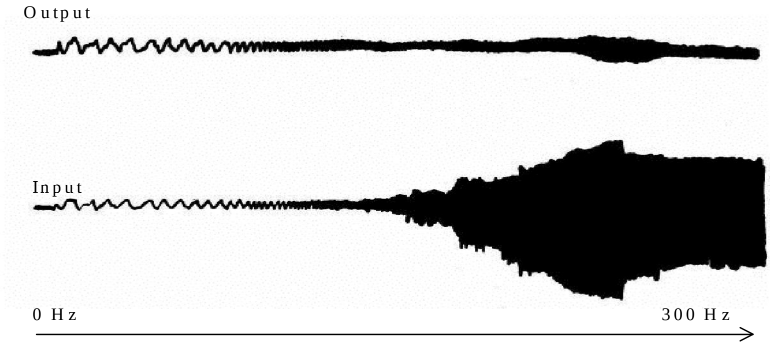

Fig.6. Experimental results with the duct pressure stabilizer

$$V_c = \alpha K_D \frac{\partial p}{\partial n}, \tag{9}$$

where K_D is Darcy coefficient.

The change of the gas condition in the chamber is presumed as adiabatic $P_c W^x_c = p_{co} W^x_{co}$, where P_c and W_{co} are the initial pressure and volume values.

The equations are expressed as follows [3]:

$$\frac{1}{g}\frac{\partial p}{\partial t} + \frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + \frac{\lambda}{2D} V|V| = 0, \tag{10}$$

$$\frac{\partial p}{\partial t} + V\frac{\partial p}{\partial x} + ga^2\frac{\partial V}{\partial x} + z_p\frac{\partial p}{\partial n} = 0, \tag{11}$$

$$\frac{\partial p_c}{\partial t} - z_w p_c^{(\wp+1)/\wp}\frac{\partial \bar{p}}{\partial t} = 0, \tag{12}$$

where λ is a linear resistance coefficient; a – elastic oscillations distribution velocity,

$$z_p = ga^2\alpha K_n S_c/A,\ A = \pi D^2/4;$$

$$z_w = \wp\alpha K_n SL/(p_{co}^{1/\wp}\omega_{co}).$$

The characteristics method in an uniform diagonal-rectangular network is operating the numeric solution of the equations system at determined initial and boundary conditions [3].

4. Conclusions

The investigation results show that the implementation of the standard pneumo hydraulic accumulators do not provide the needed high frequency pressure stabilization - the main informative feature in information transfer along a fluid line. Theoretical analysis shows that the efficient stabilization is to be achieved in means of the duct pressure stabilizer.

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Влияние на енергийния източник върху някои информативни признаци на флуидно течение

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(Резюме)

В статията се разглежда флуидно течение като информационен носител – амплитудата и фазовата разлика на налягането при периодични трептения са информативен признак.

Установява се, че източникът на течението като енергиен източник влияе, особено при по-високи температури, на амплитудата и фазовата разлика на предаваното налягане.

Разглежда се метод за намаляване на това влияние чрез въвеждане на корегиращи звена и се предлага конкретно устройство за целта.