THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2010

THE UNDISSOLVED AIR INFLUENCES ON DYNAMIC BEHAVIOR OF HYDRAULIC DRIVING SYSTEMS

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ABSTRACT

This paper is a part of a group of papers which deal with the changes due to the oil - air mixture into the hydraulic actuating systems. The undissolved air into the hydraulic agent of technological equipment actuating system generates the negative effects on system behavior. The negative effects are produced by the cavitations phenomenon emergence, by the intense acoustical phenomenon due to the dynamic characteristics modification of the driving system (natural pulsation, damping factor, external exciting factors, period and frequency of pressure dynamic oscillation, etc). In this paper the authors propose expressions for practical computations of dynamic parameters as a function of rigidity characteristics changing for hydraulic agent contaminated with undissolved air, and of qualitative and quantitative influences analysis of undissolved air percentage from the total hydraulic agent into the system. The study becomes a strong argument for avoiding the dynamic phenomenon due to the air absorption in hydraulic systems. It is very useful for researchers and designing engineers on hydraulic actuated technological equipment domain.

KEYWORDS: hydraulic agent, acoustics, driving system

1. INTRODUCTION

The air into the hydraulic driving system generates the negative effects which consist of cavitations emergence, but also of elastic characteristics modification of hydraulic agent. The elastic characteristic changes lead into the driving system to an increase of hydraulic mixture (oil-air) compressibility. Hereby, the results a modification of hydraulic capacity of the hydraulic agent. The global effect of these modifications consist of dynamic characteristics, changing the actuating system, and, also, on aggravation or even loss of system stability.

The equation which describes the pressure variation into the actuating system due to the abrupt increasing of active moment at the rotative motor shaft, or, of active force at the linear motor stem, is [1], [4]:

$$\ddot{p} + 2\xi.\omega.\dot{p} + \omega^2 p = P \; ; \qquad (1)$$

where p is the instantaneous pressure into the system for increase of the moment M_E; ξ is the damping factor; ω is the natural pulsation of the system, and P represents the external exciting factor for the system, with dependences in resistances and reactions characteristics of the working area (forces or moments).

The elasticity modulus changing of hydraulic agent with respect in undissolved air percentage volume into the fixture [1], [4], [5], can be dignified with the expression:

$$E = \frac{E_o}{1 + \frac{V_a}{V_t} \cdot \frac{E_o}{p_{\max}}} \; ; \qquad (2)$$

where E_o is the elasticity modulus at 15 ^{0}C temperature; V_t is the total volume (air + liquid); V is the undissolved air volume; p_{max} is the instantaneous maximum pressure value for the evaluation.

The practical manner for dynamic characteristics influences due to the variation of dynamic charges on the system, regarding the pressure variation, is presented in figure 1, made for a rotative or linear motor, with the following characteristics:

$$\omega = 4{,}17 s^{-1} ; \xi = 0{,}0398$$
$$P = 185{,}565.10^6 N / m^2 s^2 .$$

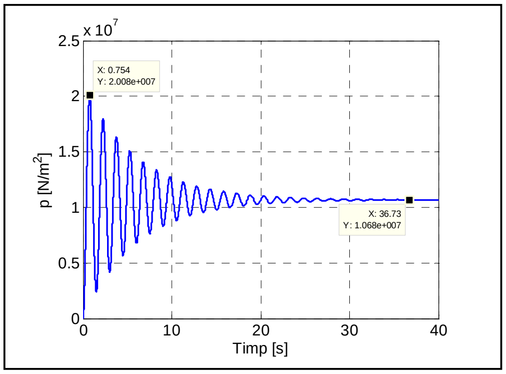


Fig.1. The pressure variation into the actuating system

2. THE DYNAMIC CHARACTERISTICS AS A FUNCTION OF UNDISSOLVED AIR VOLUME AND SYSTEM CHARGING

Let's consider $\upsilon -$ as undissolved air percentage into the fixture total volume, and λ the specific rigidity of the hydraulic agent [1]. Then the expression (2) becomes:

$$E = E_o \frac{1}{1+\lambda.\upsilon}; \qquad (3)$$

The equation (3) is the variation law of the elasticity modulus of hydraulic agent with respect to both the undissolved air percentage υ, and to parameter λ, which characterize the system charging.

The expression

$$1+\lambda.\upsilon = \psi \qquad (4)$$

represents the **changing factor of the elasticity modulus** for the hydraulic agent [1].

The expressions for dynamic parameters which characterize the actuating system are:

- The hydraulic capacity of the system:

$$\frac{C_h}{C_{ho}} = \psi; \qquad (5)$$

- The natural pulsation of the system:

$$\left(\frac{\omega_o}{\omega}\right)^2 = \psi; \qquad (6)$$

- The pseudo-pulsation of pressure oscillations in the system:

$$\left(\frac{T}{T_o}\right)^2 = \psi; \qquad (7)$$

- The damping factor of pressure oscillations:

$$\left(\frac{\xi_o}{2\xi}\right)^2 \approx \psi; \qquad (8)$$

- The external exciting factor of the system:

$$\frac{P_o}{P} = \psi; \qquad (9)$$

In equations (5)...(9) the notations $(*)_o$ represent the value of the respective parameter for E_o nominal value.

From the equations (5)...(9), taking into account the expression (3), results:

$$\left(\frac{\omega_o}{\omega}\right)^2 = \left(\frac{T}{T_o}\right)^2 = \left(\frac{\xi_o}{2\xi}\right)^2 = \frac{P_o}{P} = \frac{C_h}{C_{ho}} = \frac{E_o}{E} = 1+\lambda.\upsilon = \psi; \qquad (10)$$

3. DATA ANALYSIS

For analysis of dynamic parameters variation it was depicted the diagram of ψ parameter changing, as a function of undissolved air percentage, supposed with 0,1-3% variation from the total volume of the hydraulic agent contained into the actuating system (see figure 2).

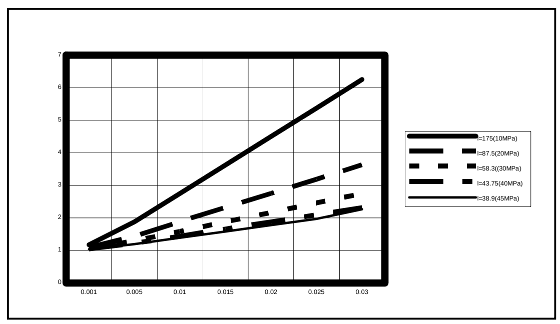


Fig.2. The variation of factor ψ, with respect to υ, and the parameter λ

4. CONCLUSIONS

The results of this study lead to the conclusion that the dynamic parameters of a hydraulic driving system have been influenced by the undissolved air into the fixture. Hereby:

1. The dynamic parameters of the actuating system are very much influenced at low pressure values, that means working state without charging of the fixture, when the system lost the stability and the capacity of good working;
2. The elasticity modulus of the hydraulic agent, with 3% air content, decreases from the nominal value E_o=17,5.10^8 N/m^2 for 6.25 times, with values increasing to 2.25 times, one time with pressure increasing for the

working domain of 0-10 MPa towards 30-45 MPa;

3. The hydraulic capacity of the system, with 3% air content, increases for 6.25 times, with decreasing tendency of values to 2.25 times, the one time with pressure increasing for working domain of 0-10 MPa towards 30-45 MPa;
4. The natural frequency of the system, with 3% air content, decrease for 2.5 times from the nominal value, the increasing tendency of 1.5 times, one time with pressure increasing for working domain of 0-10 MPa towards 30-45 MPa;
5. The damping factor of the system, with 3% air content, decreases for 5 times from the nominal value, with increasing tendency to 3 times, one time with pressure increasing for the working domain of 0-10 MPa towards 30-45 MPa;
6. The external exciting factor of the system, with 3% air content, decreases for 6.25 times from the nominal value, with increasing tendency, one time with pressure increasing for the working domain of 0-10 MPa towards 30-45 MPa;

The nominal values E_o, C_{ho}, ω_o, ξ_o, P_o, refer to the values obtained for 15^o C temperature and 0,1 Mpa pressure.

The dynamic parameters changes have the direct effect of wrong working state of the hydraulic actuating system. This fact results from the diagram in figure 3.

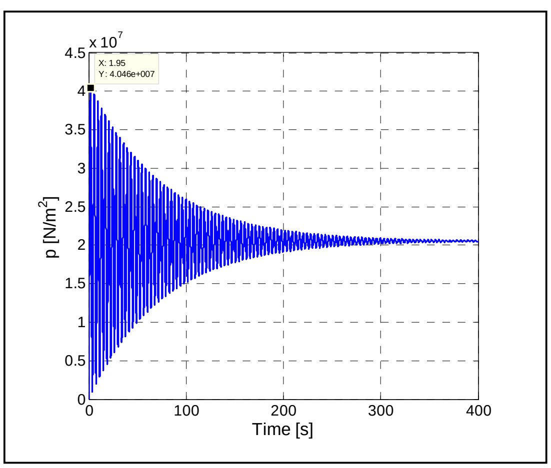
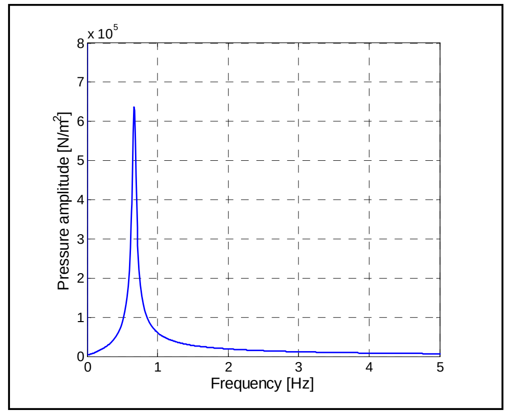
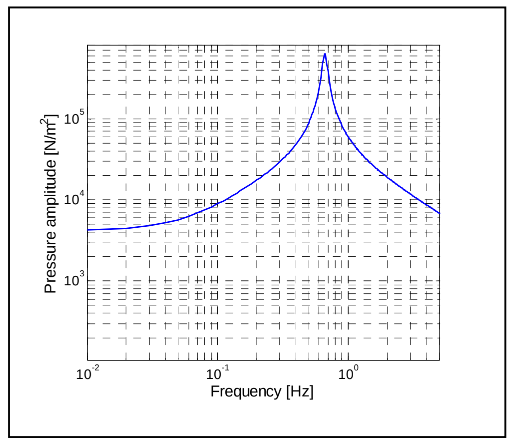


Fig.3. The pressure variation into the system after the air absorption

From the diagram it results that the stabilization time of the pressure oscillations growing up to 10 times compared to the normal fixture state without air inside and also growing up the stabilization pressure value for 2 times, both for the same loads induced by the technological equipment. These modifications can be explained through dynamic effects produced into the system, which induce effects also on the system energeticall state which means losses increasing.

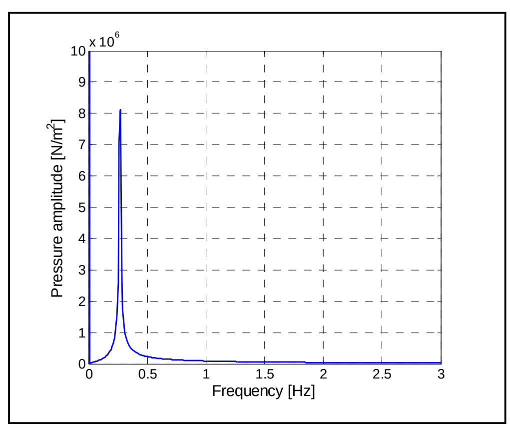


a)



b)

Fig. 4. Spectral composition for the diagram in fig. 1



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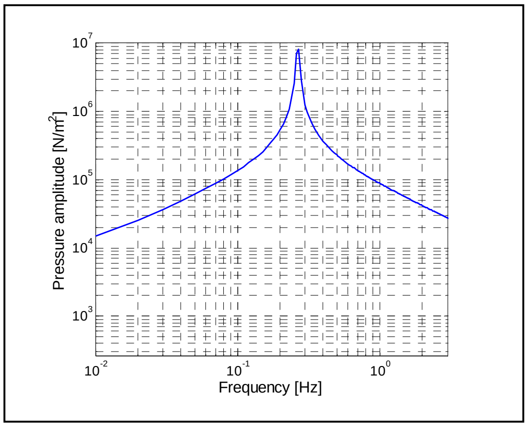

b)

Fig.5. Spectral composition for the diagram in fig.3

If we computer a spectral analysis of the two cases previously presented it results that for the equation (1) with the specific coefficients from fig.1, it is obtained the datum depicted in fig.5.a - with respect to linear coordinates, and in fig.5.b - to logarithmic coordinates.

In fig.6 it is presented the same kind of analysis, of with respect to frequency, for the datum depicted in fig.4. Hereby it is observed that modification due to the undissolved air leads to great disturbances of system dynamics, even the air percentage is only 3%.

REFERENCES

[1] **Axinti G**; **Axinti A.S**. - *Influenţa aerului nedizolvat în agentul hidraulic, asupra factorilor dinamici ai sistemului hidraulic cu motor rotativ*-în buletinul Jurnalului Român de Acustică şi Vibraţii, nr. 9- 2010.

[2] **Axinti G**; **Axinti A.S**. - *Analiza dinamica a sistemelor de actionare hidrostatica, in analogie cu sistemul mecanic oscilant, cu legaturi vascoelastice*- in Buletinul celei de-a XXVII-a conferinte Nationale de Mecanica Solidelor—Pitesti 23-24 mai 2003-Vol I-seria Mecanica Aplicata-ISSN-1582-9561;

[3] **Axinti,G.; Dumitrache,P.** - *On the undulatory processes in the hydrostatic sytems with a rotary hydraulic engine*-, in Buletinul "proceedings of the VIII-th Symposium-Acustica si vibratiile structurilor mecanice- Editura Politehnica –Timisoara- mai 2005-ISBN- 973-625-238-8, pg. 239-246;

[4] **Axinti G**; **Axinti A.S**. - *Acţionări hidraulice şi pneumatice-Dinamica echipamentelor şi sistemelor*-Editura Tehnica Info-Chişinău 2008.

[5] **Vasiliu, N; Catana I.** - *Transmisii hidraulice si Electrohidraulice-Masini hidraulice volumice*- Editura Tehnica, Bucuresti,1988.