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DYNAMIC MODEL FOR HYDRAULIC DISSIPATERS

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ABSTRACT

The paper deals with the problem of energy hydraulic dissipaters used as dissipative links for mechanical structures subjected to earthquakes, shocks and vibrations. The authors propose a mathematical model of a hydraulic link with energy dissipation, the device working reversibly to the alternative traction and compression movement. The dynamic behaviour of the energy hydraulic dissipater depends on the instantaneous frequency (speed) of the excitation generated by the earthquake, mechanical shock or vibration. The control of dissipaters is obtained by appealing at a system composed of devices for regulating pressure (energy regulators), located outside the dissipater.

KEYWORDS: Hydraulic dissipater, Mathematical model, Dynamic behavior, Dissipater's control

1. INTRODUCTION

In the case of the shock and vibration generating machinery and equipments, a part of the technological shock and vibration's energy is transmitted from the equipment to the environment generating unwanted effects on the environment. The same phenomenon occurs in the case of earthquakes.

There are technologies that use energy dissipaters, with flexure, used in the building's resistance structure, or in the foundation of technological equipments, that require the structure to be reinforced with dissipaters made of carbon fiber that absorbs the energy of the shock or vibration, in the area of the dissipater, by flexing the dissipater. There are complex structures that absorb the effects of earthquakes, shocks and vibrations, through viscous-elastic absorbers, made of rubber or composite materials, or complex systems that allow the positioning of buildings or foundations on viscous environments (clay, rubber plates, carbon fibers, etc) or even on water.

This article refers to the **complex dissipaters** made of hydrostatic equipments that are capable of destroying the energy of the earthquake, shock or vibration, for various frequencies, dissipaters that connect the material system object to the dynamic phenomenon with the bases. Thus, the higher the energy dissipated in the hydrostatic system is, the lower the energy of the earthquake, shock or vibration, transmitted to the building, or from the shock or vibration generating equipment to the environment is. [4], [5], [6].

2. THE HYDRAULIC DISSIPATER

The **hydraulic energy dissipater** is constructed as a cylinder (1) with two chambers separated by a piston (2), chambers filled with a viscous environment (synthetic oil, silicon oil, particles in suspension, liquid metals etc.). The piston is connected to a bar (3) and a compensation tube that crosses the two chambers on either side of the piston.

A third chamber (4) is situated inside the compensation tube and has the role of compensating the dilatation or the contraction of the viscous environment under thermal effect. The dissipater's bar is connected at the base of the construction (I) and the body at the foundation of the construction, (II) with plane or spatial joints (5). The device works reversibly to the alternative traction and compression movements and the dynamic behaviour depends on the instantaneous frequency (speed) of the excitation generated by the earthquake, mechanical shock or vibration. (fig. 1).

This action is generated by a system of pressure adjusting equipments (6), (7), (8) (energetic regulators) created for various dissipation areas, equipments placed outside the dissipater.

The opening of a regulator, or more regulators, or their closing depend on the commands given by an electronic monitoring system of the earthquake and technological shock or vibration, depending on their frequency and intensity, which leads to various stages of dissipation.

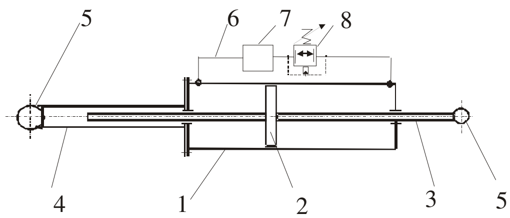

Fig. 1 Construction of the hydraulic energy dissipater

The symbols used for the dissipater scheme and necessary connections are presented in fig. 2.

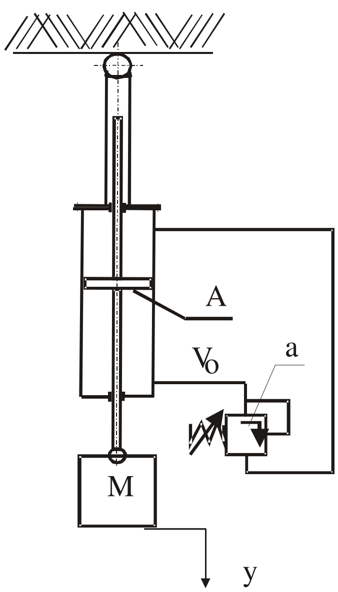

Fig. 2 Dissipater's calculation dimensions

3. DETERMINING THE DYNAMIC MODEL OF THE HYDRAULIC DISSIPATER

3.1. The equation of the circulated flows

If we consider the dissipater from fig. 1 and fig. 2 for which the momentous area of the regulator (8) is (a), and the frontal area of the piston 2 is (A), then based on the static equilibrium relation we can establish the characteristic of the pressure regulator:

$$p.a = k_r(x + \delta) \tag{1}$$

where: δ - the positive coverage of the regulator, x - the momentous movement of the regulator's chamber, k_r - regulator's elastic constant (rigidity), further, the resisting force of the dissipater is:

$$F_r = A.p\,; \tag{2}$$

Q – the hydraulic agent flow going through the dissipater's regulator according to the movement of the piston 2

$$Q = A.\dot{y} - \frac{V_0}{E}\frac{dp}{dt}\,; \tag{3}$$

where the first term represents the flow proportional to the speed inside the dissipater, and the second term is the corresponding flow taken by the elasticity of the hydraulic agent of volume V_0.

Using expression (3), considering that the flow Q is the one going through the dissipater's regulator, we deduce:

$$Q = \pi d.x\sqrt{\frac{2}{\xi\rho}}\sqrt{p}\,; \tag{4}$$

Considering (1) and (3), we have:

$$A\frac{dy}{dt} - \frac{V_0}{E}\frac{dp}{dt} = = \frac{\pi^2 d^3}{4k_r}\sqrt{\frac{2}{\xi\rho}}\sqrt{p^3} - \pi d\delta\sqrt{\frac{2}{\xi\rho}}\sqrt{p} \tag{5}$$

and if we note:

$$D = \frac{\pi^2 d^3}{4.k_r}\sqrt{\frac{2}{\xi\rho}};\; H = \pi d\delta\sqrt{\frac{2}{\xi\rho}}\,; \tag{6}$$

and:

$$\frac{dy}{dt} = \frac{D}{A}\sqrt{p^3} - \frac{H}{A}\sqrt{p} + \frac{V_0}{AE}\frac{dp}{dt} \tag{7}$$

In relation (7), we did not take into consideration the flow losses through gaps, because the tightness of the piston does not allow for volume losses because they are self deforming on the cylinder's bore.

The flow losses on the regulator can be considered as neglectable because of the small dimensions of the regulator compared to the dissipater's cylinder. ($d/D_d \le 10/150 = 1/15$), where:

d - the diameter of the pressure regulator's chamber
D_d - the diameter of the dissipater's cylinder bore.

3.2. The movement equation

If we consider y - the momentary movement of the dissipater’s piston, to which we apply the force - $F_a(t)$, induced by the movement of the body of mass M, supported by the dissipation system, then applying the d’Alembert principle while neglecting the dry friction forces, we have:

$$M\frac{d^2y}{dt^2}+C\frac{dy}{dt}+Ky=F_a(t)-F_r \qquad (8)$$

where: M - the suspended mass, C - the viscous friction coefficient on the dissipation system, K - the elastic constant of the support system, $F_a(t)$, given by the weight of the suspended body or the inertia force induced in the connection, F_r - obtained from the relation (2). From equation (8), we have:

$$\frac{d^2y}{dt^2}+\frac{C}{M}\frac{dy}{dt}+\frac{K}{M}y=g-\frac{A}{M}p \qquad (9)$$

Equations (7) and (9) represent the mathematical model of a hydraulic connection with energy dissipation made on the *y* movement direction of the suspended structure. For three-dimensional movements we use three such systems that work on the three orthogonal directions involved in movement.

4. THE REAL EXTERNAL CHARACTERISTIC OF THE HYDRAULIC DISSIPATER

If we record the force variation on an energetic dissipater depending on its run, we obtain the characteristic from fig. 3, to where the speed of the piston is kept constant on all the length of movement cycle $\pm y$

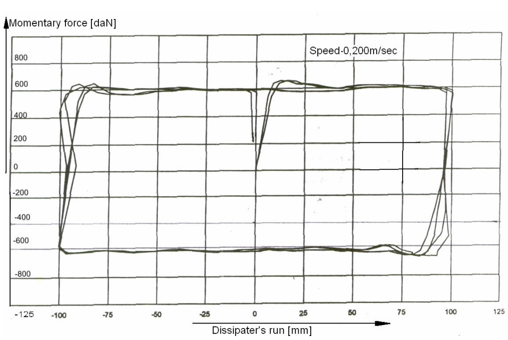

Fig. 3 Real characteristic F=F(y)

5. THE VARIABLE THEORETICAL CHARACTERISTIC OF THE HYDRAULIC DISSIPATER

The dissipater’s characteristic is the law of the variation of the resisting force depending on the dissipater’s bar run.

In fig. 4 we present the characteristic of a dissipater without adjusting the resisting force while fig. 5 presents the characteristic for a dissipater with the adjusting of the resisting force. We notice that this characteristic is actually the dissipated energy on a complete run of the dissipater, corresponding to the maximumal run of the piston. This energy is situated inside the parallelogram described by the force resisting to the bar.

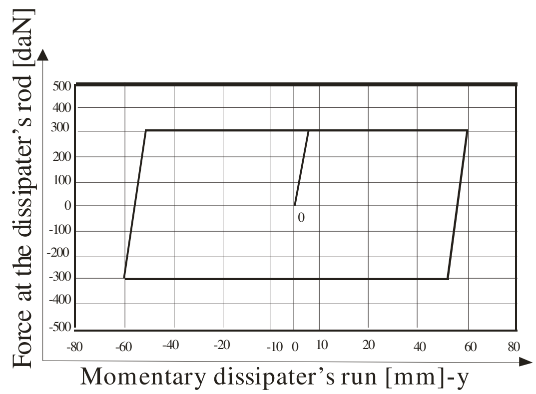

Fig.4. The characteristic of the energetic dissipater

In the case of dissipaters with the adjustment of the dissipation force, we may notice that the dissipated energy along the movement cycle varies according to the external commands given by a monitoring system for the dynamic phenomenon.

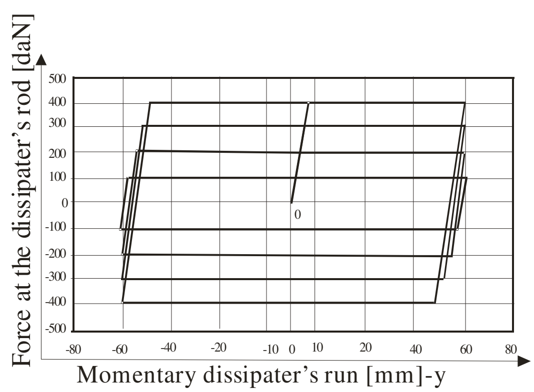

Fig. 5 The theoretical characteristic of the adjustable force dissipater

The adjustment of the dissipation force of the system is obtained by adjusting, with special pressure adjustors, the pressure from the dissipater's chambers along the two movement directions of the piston (stretching and compression).

If the energetic dissipation characteristic of the dissipater is as presented in fig. 4, with those notations, we can define it analytically, thusly:

$$F_{rez} = \begin{cases} \dfrac{2F_0}{\delta} \cdot y \leftarrow y \in (0, \delta/2] \\ F_0 \leftarrow y \in (\delta/2, y_0] \end{cases} \tag{10}$$

$$F_{rez} = \begin{cases} F_0 + \dfrac{2F_0}{\delta}(y - y_0) \leftarrow y \in (y_0, y_0 - \delta] \\ -F_0 \leftarrow y \in (y_0 - \delta, -y_0] \\ -F_0 + \dfrac{2F_0}{\delta}(y + y_0) \leftarrow y \in (-y_0, -y_0 + \delta] \\ F_0 \leftarrow y \in (-y_0 + \delta; y_0] \end{cases} \tag{11}$$

where:

$F_0 = A \cdot p_0$, is the adjusted dissipation force of the energy dissipation system's regulator,

y_0, is the maximum run of the dissipater's piston and δ, the maximum run of the pressure regulator.

6. THE NUMERICAL MODELING OF A HYDROSTATIC DISSIPATER

For the numeric case represented by the following values:

A=115,4 cm^2,
V_0=3460 cm^3,
K_r=104 daN/cm,
d=0,45 cm,
p_{max}=700 bar,
ξ=1,8,
δ=0,9 cm,
ρ=0,9 kg/cm^3,
E=16900 daN/cm^2,
M=60000 kg,
g=9,81 m/s^2,
$p \in [0, p_{max}]$,
C=0,07…1,5 daNs/cm,
K=7…20 daN/cm,
$y \in [0, y_0]$, y in [cm]

and through numerical integration, we obtain diagrams as those in fig. 6.

The characteristic in fig. 6 results by numerically integrating the mathematical model given by (7) and (9) in a variable independent of time and then we represent the force as a function of the momentary run.

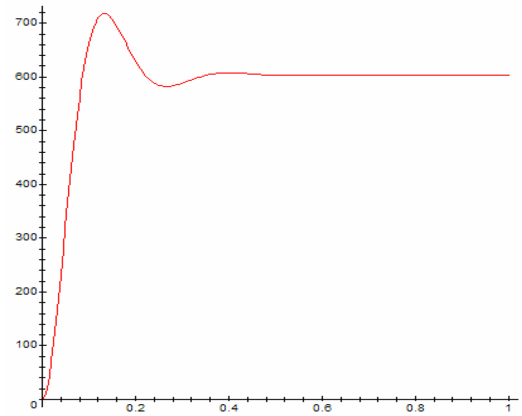

Fig. 6 Theoretical characteristic F=F(y)

7. CONCLUSIONS

By comparing the diagram in fig. 6, obtained from the theoretical model, with the one in fig. 3, the real one obtained experimentally, we have the main following conclusions:

1. The theoretical model of the dissipater is precise enough in order to underline the equipment's transitorial behaviour phenomenon;
2. The model allows the extension of the study to the case of the rigid with dissipative connections;
3. We recommend the linearization of the mathematic model and the comparative study on the linear model.

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