Influence of Composite Neoprene upon the Energy Internal Dissipation in case of Harmonic Process

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Abstract: This paper presents the approach performed on viscoelastic systems with such geometrical configuration determining the behaviour as composite neoprene, tested under dynamic regime in two distinct cases, as follows:

- system having kinematical excitation and constant amplitude and
- system having dynamic excitation under inertial regime for the perturbing force generation.

Basing on both the dynamic response analysis and the dissipated energy inside the viscous element and assembly, it results in evaluation of the mechanical work in two different ways as a function of the exciting system parameters as well as the viscous force parameter.
This paper shows the different performance ways of the dissipated mechanical work depending on both the kinematical parameter changing (pulsation, amplitude) and the viscous damping factor.

Keywords: composite neoprene element, viscoelastic system, damping systems

1. INTRODUCTION

The structure of composite element is given by combination of unitary elements Hooke-Kelvin and Hooke-hysteretic, so that globally, the natural scale element could be modelled as Voigt-Kelvin or hysteretic element. For the damping systems in neoprene elements the elastical and dissipation behaviour both at compression or shearing under steady dynamic regime is followed. The energy internal dissipation capacity can be evaluated under steady harmonic dynamic regime at kinematical excitation of the form $x = A_0 \sin \omega t$ as well as at dynamic excitation of the form $F = F_0 \sin \omega t$ or $F = m_0 r \omega^2 \sin \omega t$, where F_0 is the constant amplitude of the dynamic force F and $m_0 r$ is the inertia unbalanced static moment and ω is the dynamic force pulsation.

The particularity of the viscoelastic systems basing on neoprene is that they are characterized by the internal loss angle or the hysteretic damping coefficient $\delta = \dfrac{c\omega}{k}$, where c represents the viscous damping factor and k – the rigidity factor and $h = c\omega$ represents the hysteretic damping factor.

2. KINEMATICAL EXCITATION OF THE COMPOSITE NEOPRENE ELEMENT

Evaluation of the internal dissipated energy for a viscoelastic element having neoprene single layer or more layers (sandwich) basis on Voigt-Kelvin model, mass less with the parameters c, k, kinematical excitation $x = A_0 \sin \omega t$ (see figure 1.a), equivalent to the hysteretic model k, h (figure. 1.b).

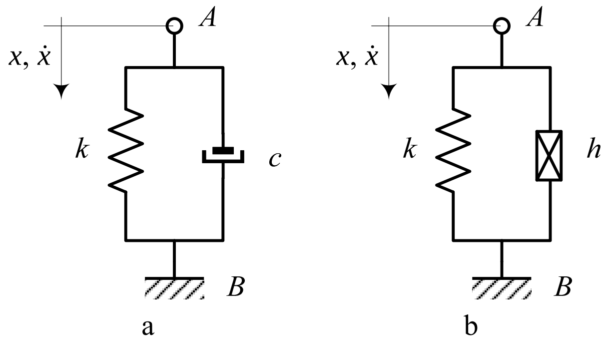

Figure 1.

In this case, the unbalanced force inside the material, in the action direction is expressed as:

$$H(t) = F_{el}(t) + F_v(t)$$

or

$$H(t) = kA_0 \sin \omega t + cA_0 \omega \cos \omega t \qquad (1)$$

where

$$F_{el}(t) = kA_0 \sin \omega t \;;\; F_v(t) = cA_0 \omega \cos \omega t$$

The internal force work H (t) is given by relation:

$$L = \int_0^T H(t) dx = \int_0^T H(t) \dot{x} dt \qquad (2)$$

where replacing (1) in (2) and solving the integrals it results in:

$$L = W_d = \pi c \omega A_0^2 = \pi h A_0^2$$

or

$$L = W_d = \pi \delta k A_0^2 \qquad (3)$$

with W_d - the internal dissipated energy.

For the systems in neoprene kinematically excited we find the dissipated energy depends on both the damping element characteristics - k, δ and the kinematical excitation system characteristics ω, A_0. In this case, the dissipation capacity for the neoprene element represents a system characteristic and not a material characteristic.

Figure 2 illustrates the curve family for the dissipated energy $W_d(A_0, \delta)$ as a function of the current variable A_0 and the discrete variable δ. Also, the discrete variation of k and the continuous variation of A_0 conduct to the curve family $W_d(A_0, \delta)$ represented in Figure 3.

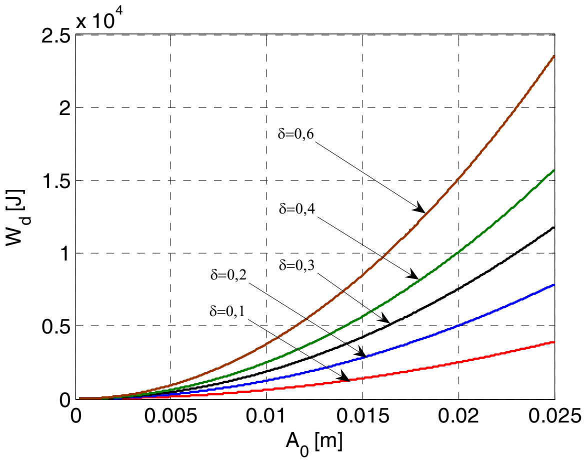

Figure 2

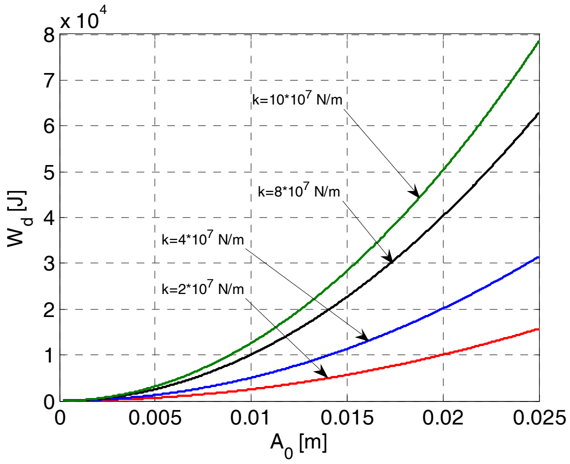

Figure 3

3. DYNAMICAL EXCITATION OF THE COMPOSITE NEOPRENE ELEMENT

3.1. Massless linear system

Figure 4 presents the dynamic model where the excitation force amplitude is constant, namely $F_0(t, \omega) = const$.

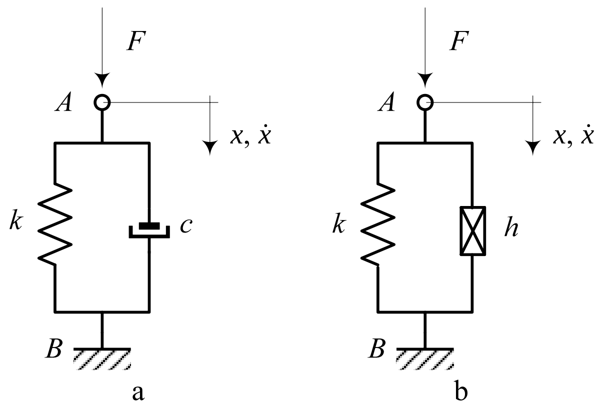

Figure 4

The linear viscoelastic force under steady regime is given by relation:

$$Q = kx + c\dot{x} = F'_0 \sin \omega t \qquad (4)$$

with the instantaneous displacement response under the form:

$$x = A \sin(\omega t - \varphi) \qquad (5)$$

$$\dot{x} = \omega A \cos(\omega t - \varphi) \qquad (6)$$

where A stands for the displacement amplitude given by:

$$A = \frac{F_0}{k} \frac{1}{\sqrt{1 + \delta^2}} \qquad (7)$$

φ - phase difference between force and displacement under the form:

$$tg\varphi = \frac{c\omega}{k} = \delta \qquad (8)$$

From relation (4) we have:

$$\sin\omega t = \frac{Q}{F_0}, \cos\omega t = \sqrt{1+\frac{Q^2}{F_0^2}} \qquad (9)$$

and developing relation (5) it results in:

$$x = A\sin\omega t\cos\varphi \qquad (10)$$

where introducing (9) we have:

$$x = A\frac{Q}{F_0}\cos\varphi - A\sin\varphi\sqrt{1-\frac{Q_2}{F_0^2}} \qquad (11)$$

resulting in the ellipse equation, in the rectangular axis system Q-x, representing the hysteretic loop, having the form:

$$\left(\frac{Q}{F_0}\right)^2 + \left(\frac{x}{A}\right)^2 - 2\frac{Q}{F_0}\frac{x}{A}\cos\varphi = \sin^2\varphi \qquad (12)$$

The graph $Q = Q(x)$ can be provided by the following function:

$$Q(x) = F_0\left[X\cos\varphi \pm \sin\varphi\sqrt{1-X^2}\right] \qquad (13)$$

where:

$$X = \frac{x}{A};\ \sin\varphi = \frac{\delta}{\sqrt{1+\delta^2}};\ \cos\varphi = \frac{1}{\sqrt{1+\delta^2}}$$

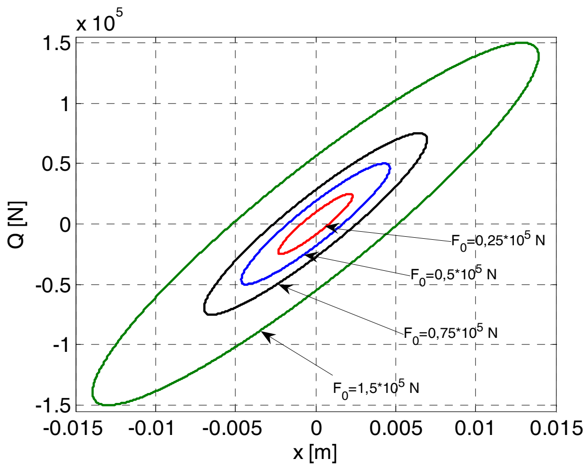

Figure 5

For the discrete variation of A_0 and continuous variation of x, we have the hysteretic loop family $Q = Q(x, F_0)$ represented in figure 5.

The dissipated energy W_d is under the form:

$$W_d = \pi\delta k A^2$$

or

$$W_d = \frac{\pi F_0^2}{k}\frac{\delta}{1+\delta^2} \qquad (14)$$

Figure 6 and figure 7 illustrate the curve families $A(\delta, F_0)$ and $W_d(\delta, F_0)$ respective:

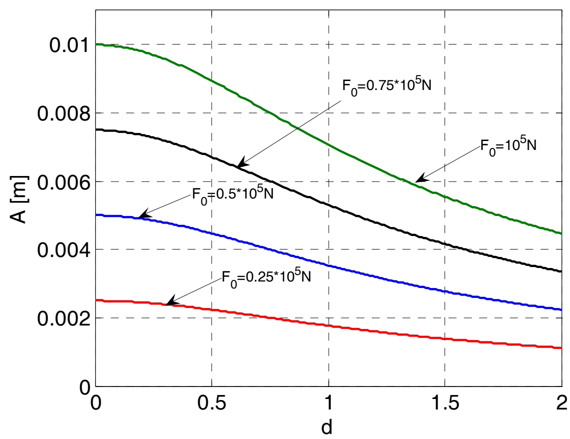

Figure 6

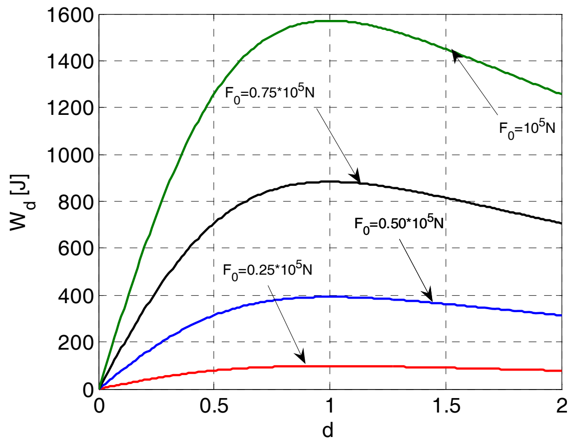

Figure 7

3.2. Linear viscoelastic system with mass

The dynamic model for the viscoelastic system having the parameters m, k, c and for the equivalent hysteretic system with the parameters m, $h = c\omega$, $\delta = \frac{h}{k}$ is represented in figure 8.

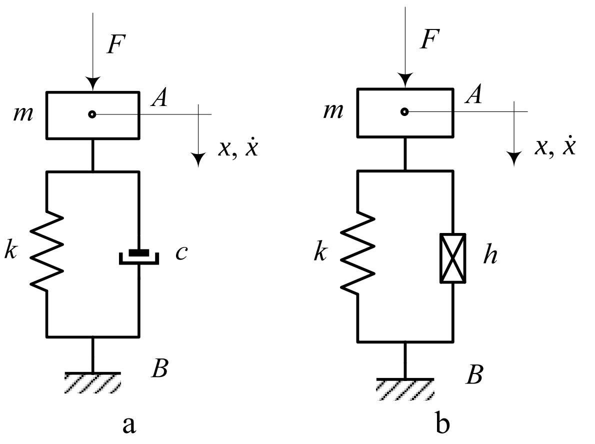

Figure 8

For the dynamic equilibrium, under steady regime with $\omega = const$, in case of the linear viscoelastic model we have the equation under the form:

$$m\ddot{x} + c\dot{x} + kx = F_0 \sin \omega t \tag{15}$$

and for the hysteretic model:

$$m\ddot{x} + \frac{h}{\omega}\dot{x} + kx = F_0 \sin \omega t \tag{16}$$

The dynamic response for the hysteretic model is:

$$x = A \sin(\omega t - \theta) \tag{17}$$

where

$$A = \frac{F_0}{k}\frac{1}{\sqrt{\left(1-\Omega^2\right)^2 + \delta^2}} \tag{18}$$

$$tg\theta = \frac{\delta}{1-\Omega^2}; \quad \Omega = \frac{\omega}{p}; \quad p^2 = \frac{k}{m} \tag{19}$$

The dissipated energy W_d is of the form:

$$W_d = \frac{\pi F_0^2}{k}\frac{\delta}{\left(1-\Omega^2\right)^2 + \delta^2} \tag{20}$$

The curve family $A(\omega,\delta)$ is represented in figure 9, and the curve family $W_d(\omega,\delta)$ in figure 10.

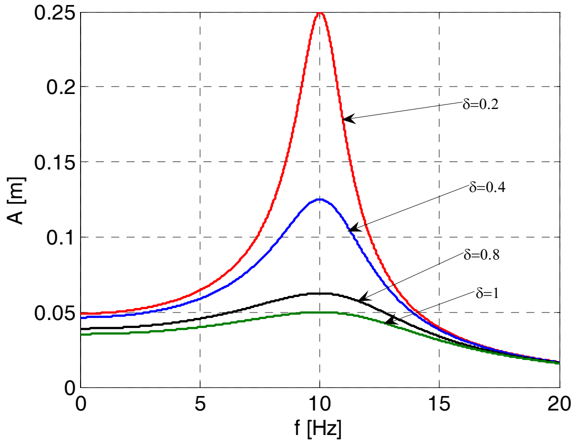

Figure 9

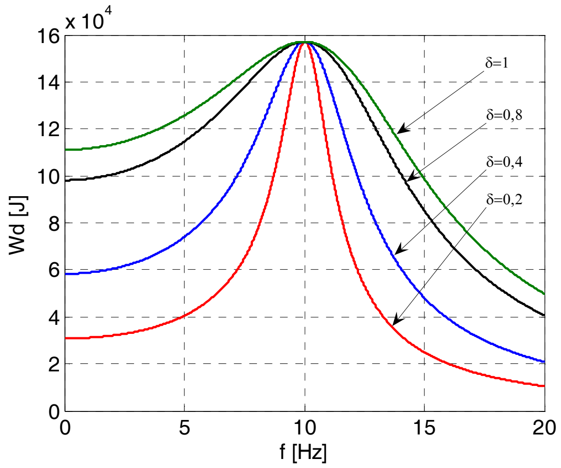

Figure 10

Figure 11 illustrates the curve family $A(\delta,\omega)$ and figure 12 the curve family $W_d(\delta,\omega)$.

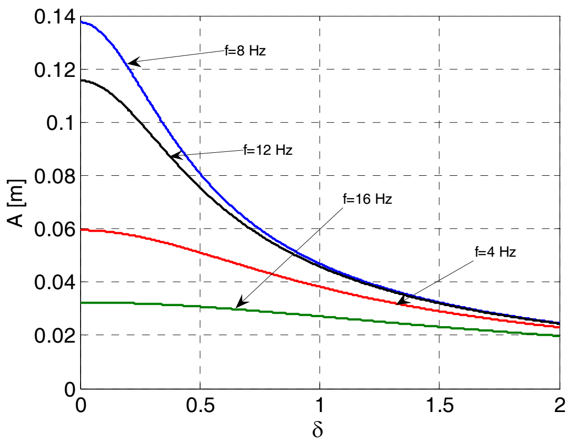

Figure 11

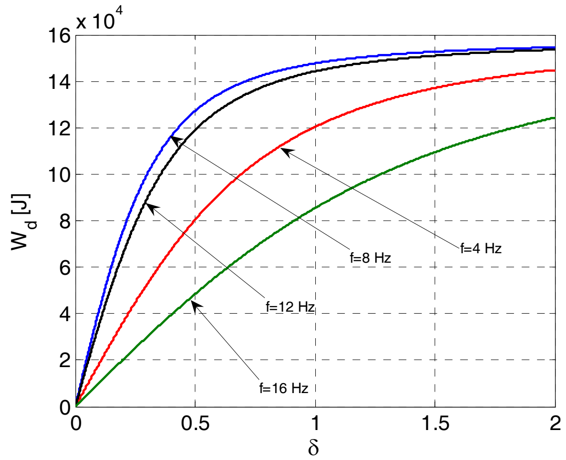

Figure 12

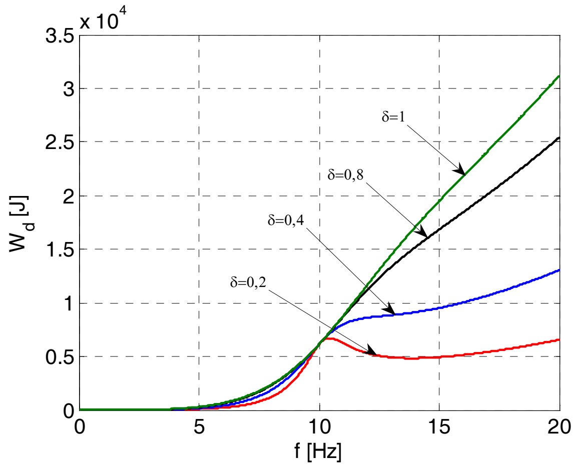

Figure 14

4. ENERGY DISSIPATED FOR HARMONIC DYNAMIC EXCITATION

The dynamic model presented in figure 8 has the excitation force $F = m_0 r \omega^2 \sin \omega t$ leading to the displacement amplitude and the dissipated energy expressed by the following relations:

$$A(\Omega,\delta) = \frac{m_0 r}{m} \frac{\Omega^2}{\sqrt{\left(1-\Omega^2\right)^2 + \delta^2}} \tag{21}$$

$$W_d(\Omega,\delta) = p^2 \pi \frac{(m_0 r)^2}{m} \frac{\Omega^4 \delta}{\left(1-\Omega^2\right)^2 + \delta^2} \tag{22}$$

The curve family $A(\Omega,\delta)$ is represented in figure 13 and the curve family $W_d(\Omega,\delta)$ in figure 14.

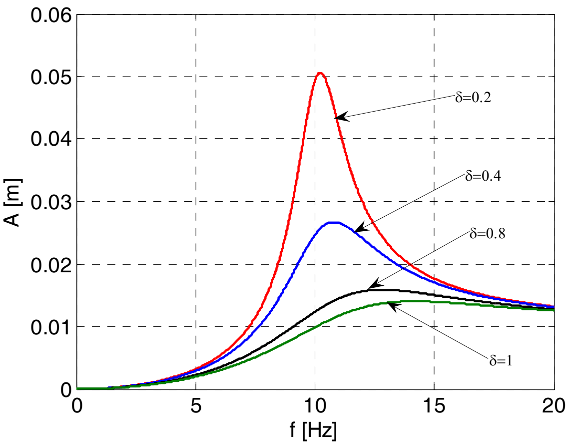

Figure 13

Figure 15 illustrates the curve family $A(\delta,\Omega)$ and figure 16 the curve family $W_d(\delta,\Omega)$.

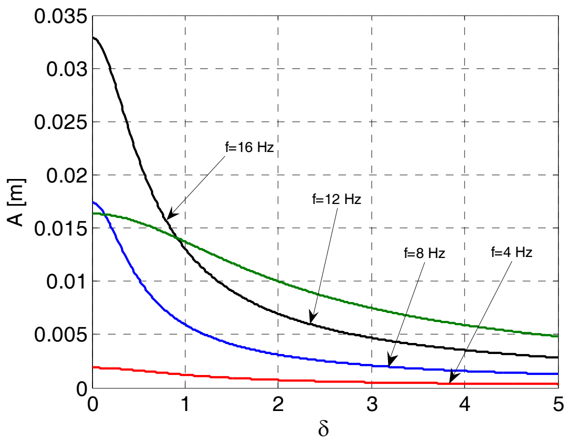

Figure 15

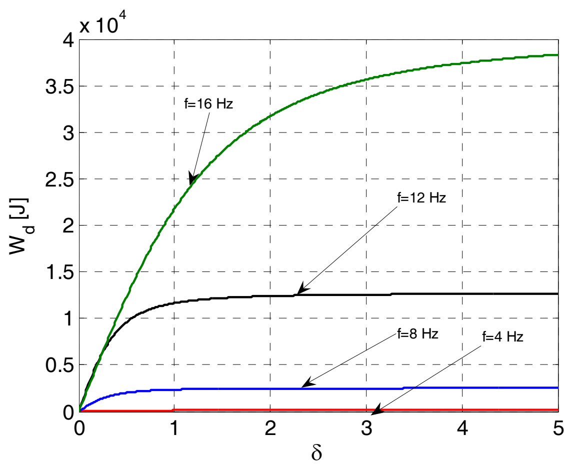

Figure 16

5. CONCLUSION

The dissipation capacity of the damping systems basing on composite neoprene elements is expressed by the internal dissipated energy W_d representing a system characteristic and not a material characteristic. This parameter is very important for the evaluation of the damping system capability. Thus, depending on the excitation, the dynamic response in displacement changes with the amplitude $A(\omega,\delta)$ having as result the dissipated energy dependence on the excitation parameters F_0, ω, under steady dynamic balanced regime.

Having in regard the above mentioned items, one can conclude the following:

a) in case of the kinematical excitation having odd harmonic displacement and the amplitude A = const, the dissipated energy is not a function of the pulsation ω and only depends on the parameter $h = \delta k = const$ and the amplitude A_0 that can be modified at interest discrete values;

b) in case of dynamic excitation with steady harmonic forces with constant amplitude $F_0 = const$ or inertial amplitude $F_0 = m_0 r \omega^2$, the dissipated energy is a function of the dynamic response amplitude in displacement $A(\omega,\delta)$ as a result of the dynamic equilibrium for the whole system;

c) the internal energy dissipation capacity for the damping elements in neoprene, in various constructions represents a system characteristic and not a material characteristic. As material, the elastomer is characterized by parametric values only stated on reduced scale samples and not for the whole damping element natural scaled.

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