

Description of phenomena vibration in hyperdeform polymers materials

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Abstract The issue of vibration damping occurs in many mechanical problems in the operation of various devices, in the automotive industry engineering, aerospace. In the case where damping by selection of the masses and dimensions is not possible due to various reasons or for other reasons it was abandoned, vibration dampers are used. Minimization of adverse impact of dynamic interaction effects is an important research and technical problem. Passive energy absorbers used today (complex of bumpers, passenger lifts buffers typically allows to the safe dissipation of energy within a certain range of loads. In the case of high-impact loading variability is desirable to use an adaptive energy absorption system capable of rapid change their dynamic characteristics. The main issue in the analysis of interactions impact of dynamic loads on objects is dispersion (dissipation) of kinetic energy during impact. In paper a description of model of internal damping was proposed with the proof the influence of component part of polynomial. For example elastomer material EPUNIT will be used to present prepare the buildings of model hyperdeform material. Was present conclusion of analyses systems hyperdeform composite materials.

Keywords Hyperdeform materials · Elastomers · Vibration · Internal damping

1 Introduction

The issue of vibration damping occurs in many mechanical problems in the operation of various devices in the automotive industry engineering, aerospace. In the case where

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damping by selection of the masses and dimensions is not possible due to various reasons or for other reasons it was abandoned, vibration dampers are used [1].

Minimization of adverse impact of dynamic interaction effects is an important research and technical problem. Passive energy absorbers used today (complex of bumpers, passenger lifts buffers typically allows to the safe dissipation of energy within a certain range of loads [2,3]. In the case of high-impact loading variability is desirable to use an adaptive energy absorption system capable of rapid change their dynamic characteristics [4]. The main issue in the analysis of interactions impact of dynamic loads on objects is dispersion (dissipation) of kinetic energy during impact [5].

The energy dissipation is the irreversible process of transforming structured forms macroscopic movement of energy distributed randomly in a number of degrees of freedom, usually in the thermal energy of the movement of microparticles (increasing the relative amount of thermal energy of the system and increases its entropy) [6]. Dissipative processes occur in systems in which the interaction between mating components, or within the structure of the material occur as a result of friction, viscous characteristics of the material, among others. following: changes in process temperature, deformation speed.

2 The model of internal damping in hyperdeforms materials

The features of elastomers materials were wildly examined in the activities [7–10], in this among other things segment polyurethane EPUNIT. These are a modern constructional material with a high useful features. There are wildly used in industry because of their wear resistant, especially for those parts using in conditions of mineral processing.

An interest in this materials is a result of capability of creating both chemical and physical structures. Using substrates of different chemical structure or variable molar ratio of the same substrates gives various polymers with different features (chemical and material structure) that can be used for specific purpose [11]. Experimental investigations of EPUNIT material were conducted in connection with their possible use in motor vehicle and aircraft industry.

The physics–chemical and strength features of segment polyurethane (calculate according with [10]) put in Table 1.

A polynomial model reduced of the sixth order was used for describing the elastic features. In the model of polynomial was used invariant form function of energy of figural deformation W written by the Eq. (1):

$$W = \sum_{i=1}^6 C_{i0}(I_1 - 3)^i + \sum_{k=1}^6 \frac{1}{D_k} (J^{el} - 1)^2 \quad (1)$$

where W is figural deformation energy, \bar{I}_1 is first invariant strain tensor Cauchy's–Green's, \bar{I}_2 is second invariant strain tensor Cuachy's–Green's, C_i is material constants, $C_{00} = 0$ is material constant, μ_0 is the initial transverse modulus of elasticity initial ratio, in which a first element of this formula describing a figural deformation—first invariant of deviator part of deformation is (2):

$$\bar{I}_1 = \bar{\lambda}_1^2 + \bar{\lambda}_2^2 + \bar{\lambda}_3^2 \quad (2)$$

Second module of dependence (3) it describes the volumetric deformations—third invariant of state of deformation (being with measure of change of volume) the figure has:

$$J^{el} = \lambda_1 \lambda_2 \lambda_3. \quad (3)$$

Dissipation function define as (4):

$$H = \sum_{i=1}^n C_i \cdot (\bar{I}_1 - 3) \quad (4)$$

Was accepted main direction and introduced in figure with strength of suppression (5) to characterize vibration about one degree discretion (5):

$$F_t = \sum_{i=1}^n c_i \cdot \dot{\lambda}_i^i \quad (5)$$

where $\dot{\lambda}_i^i$ is the speed of deformation, c_i is the dumping coefficients.

The viscosity properties—the damping level dependent of many parameters: the composition of, structure, of building and composition segments, additions modificatory, the technology of production. The quantitative estimate could be execute only by use the results of experimental investigations. Arrangement was has given an examination described with Eq. (6):

$$P(t) = m \cdot \ddot{x} + \sum_{i=1}^n c_i \cdot \dot{\lambda}_i^i + \sum_{i=1}^n k_i \cdot \lambda_i^i \quad (6)$$

where m is mass of element, k is elastic modulus.

A coefficients k_i was accepted with results of investigations [10, 11]. The different possibilities of selection damping coefficients c_i were considered. According with theory of hyperdeform materials the largest n value was accepted $n = 6$. The results of executed tests and numerical calculation proved that the only odd components of explication had meaning the calculations one—accepted so the reduction, the components about numbers in modules of equation took into account $i = 1, 3, 5$. It the hysteresis loops in aim of comparison were executed: experimentally and used numerical calculation, by loading and unloading with slowly growing strength and dynamic in arrangement serf harmonic load. It was any tests variants considered: the samples materials differing with arrangement: the proportion of soft and straight piece, with regard on propriety of material—in different temperatures.

Table 1 Properties of segment polyurethane EPUNIT

Probe	S/G (mol/mol)	ρ (g/cm ³)	ΔV (cm ³)	H (°ShA)	η (%)		
Physics–chemical properties							
1.25/P (Epunit 3)	0.25	1.2275	0.0075	55	42		
1.5/P (Epunit 2)	0.5	1.2361	0.0093	62	41.5		
1.75/P (Epunit 1)	0.75	1.24264	0.0114	69	37		
Probe	σ_{100} (MPa)	σ_{300} (MPa)	R_m (MPa)	ϵ_{rt} (%)	ϵ_r (%)	E (MPa)	R_{rd} (kN/m)
Strength properties							
1.25/P (Epunit 3)	1.6	2.9	38.6	3.9	820	3.5	50.1
1.5/P (Epunit 2)	2.4	6.1	39.0	4.7	628	4.5	50
1.75/P (Epunit 1)	3.3	6.8	41.8	6.0	675	7.7	66.0

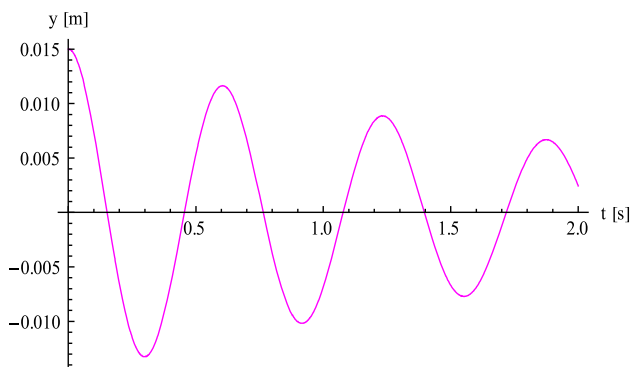


Fig. 1 Course of oscillation from linear damping

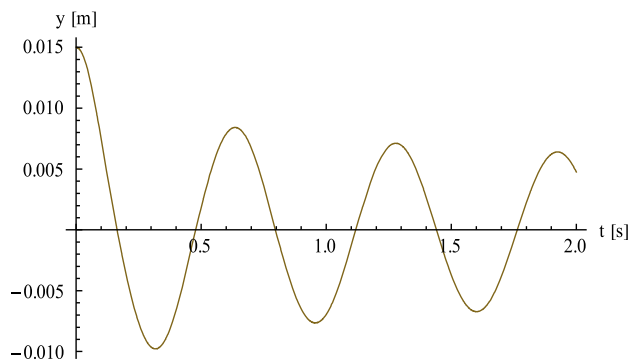


Fig. 2 Course of oscillation from non-linear damping

3 Internal damping in polymers elastomers materials

The simulations were executed the free numeric oscillation. Non-linear oscillation the occurrence in results was observed. Results are convergent with theoretical base with this field [1, 12, 13].

It the comparison of course of oscillation On Fig. 1 was introduced course of oscillation from linear damping and non-linear damping (on Fig. 2). We can see clear influence of non-linear on result of answer of arrangement.

It resonance curves on Fig. 3 were introduced was: (1) without damping, (2) with insignificant level suppression—was accepted $c_i = 0.002$. Visible it is that the typical sights of non-linear damping in system from hyperdeforms composite unit step out: the offset of resonance frequency in side of higher frequencies and the sudden reduction of amplitude after passage of resonance.

4 Evaluation of energy dissipation in systems with hyperdeformable polymres

The analysis with assumption of real hyperdeformable material properties into the equation requires differentiating feature for loading and unloading phases [14]. For analysis the equation system describing the vibrating elastic element made of an incompressible elastomer—according to the Eq. (7):

$$m \cdot \ddot{x}[t] + k \cdot (x[t] + l - l^3 \cdot (x[t] + l)^{-2}) = F[t] \quad (7)$$

It was also assumed that there is a viscous damping. Vibrations are described by the Eq. (8)

$$m \cdot \ddot{x}[t] + c \cdot \dot{x}[t] + k \cdot (x[t] + l - l^3 \cdot (x[t] + l)^{-2}) = F[t] \quad (8)$$

where b is damping factor.

Taken into account the extortion of the coverage elastomer systems work in the area of compressive loads (9):

$$F[t] = F \cdot \sin[\omega * t] - F \quad (9)$$

where ω is frequency of the exciting force, $F(t)$ is time variable forcing function.

Cellasto closed cell elastomer was taken to considerations. Material properties are defined using the results of experimental studies [14].

It was a clear effect of non-linearity, which is characterized in that the amplitude does not reach the infinitely large value for the finite frequency [1]. With an increase in the amplitude of the resonance zone moves in the direction of higher frequency. Figure 4 contains a non-linear dependence between the frequency of vibration amplitude of the curve in the form of skeletal structure obtained for the polyurethane foam Cellasto 550.

The effects of nonlinear damping pointing to the need for an individual description of the different stages, namely: loading and unloading. For this purpose, Eq. (7) was modified by introducing a record defining the various attenuation values for the individual phases of the element, in the form of (10):

$$m \cdot \ddot{x}[t] + c_1 \cdot \dot{x}[t] \cdot J[\dot{x}[t]] + c_2 \cdot \dot{x}[t] \cdot J[-\dot{x}[t]] + k \cdot (x[t] + l - l^3(x[t] + l)^{-2}) = F[t] \quad (10)$$

where $J = \begin{cases} 1 & \dot{x} > 0 \\ 0 & \dot{x} \leq 0 \end{cases}$ -ones zero function described with dependence, c_1, c_2 -damping coefficients, where $c_1 \ll c_2$.

Compared the responses obtained by numerical simulations for the elastomeric component. Results were obtained considering the description for the suppression of homogeneous deformation and is defined as an unbalanced individual for the individual stages ie. loading and unloading. It was found that The latter approach offers allows for to obtain closer to a real solution, comparable with experimental results.

5 Conclusions

In study was introduced the method of identification of propriety of viscoelastic hyperdeform materials. Affirm,

Fig. 3 Resonance curves for system of forced vibrations

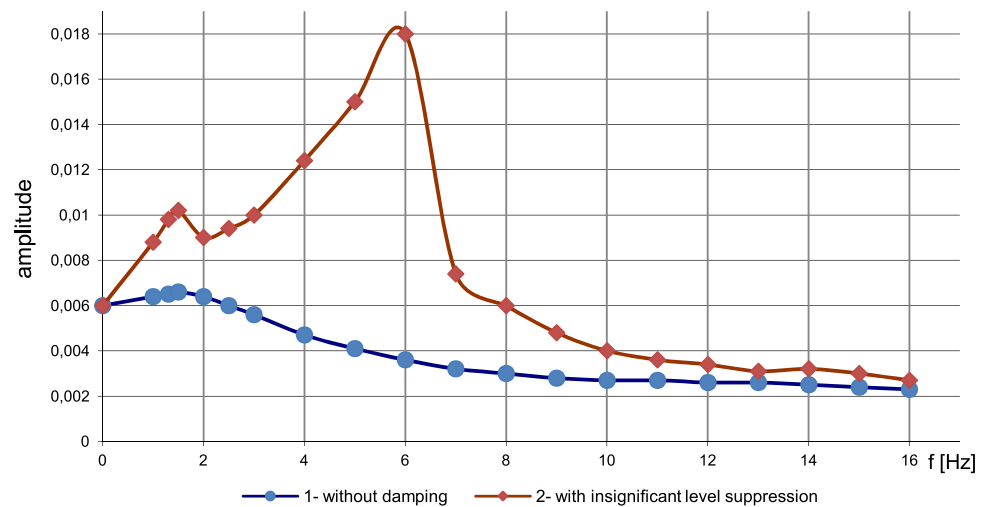
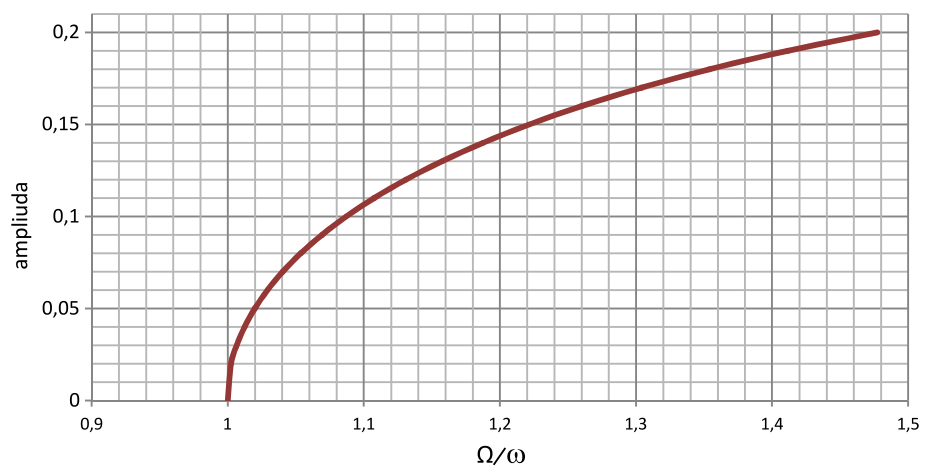


Fig. 4 Nonlinear frequency dependence of the amplitude of vibration and vibration sample chart



that to description of materials about small compressibility (practically incompressible) are better the multinomial model. To model in case of large compressibility larger exactitude guarantee the Ogden model (different lines).

Experimental tests permitted on ascertainment that stresses with growth of content, was also observed increase in value Young module, durability on bumping and tearing apart, plastic deformation, hardness, and waste abrasive thickness grows larger also, to break decrescent deformation and buffering.

It has been shown that the behavior of the system constructed on the basis of a polymeric component, in particular a hyper deformable material eg. polyurethane elastomer, to a large extent depend on the temperature of the system, as well as the deformation speed.

The description of behaviour the arrangement from hyperdeform composite element should to take into account requires differentiating feature for loading and unloading phases.

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