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POLYMERS FOAM STRUCTURE NUMERICAL IDENTIFICATION

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Abstract

Polymers found regard among engineers and researcher their special proprieties. Now, we find using the polymers at present in the most advanced technically the branches of industry. In construction of machines, more and more often are practical used hyperdeform materials. The group of construction materials, called hyperdeformable, includes among others: elastomers, plastics made based on rubber, thermoplastic structures, such as polycarbonate, gels and sols, composites and foams: open and closed pores.

Porous structures are produced on the basis of different materials, synthetic thermoplastic polymers and thermosetting. The problem of porous materials is taken in many research centres in the world. Porous materials (also called cellular plastics, foam plastics or foamed plastics) include gas phase dispersed in a solid phase of polymeric material. Properties of such systems depend on the properties of the polymer warp and cell structure comprising the gas phase.

Approach previously used to anticipate and interpret the behaviour of the hyperdeformable structures, using the theory of hyperelastic materials, does not resolve the issue because it only describes the elastic properties. The article presents an original methodology developed structural identification the viscoelastic properties of hyperdeformable materials, and in particular modern construction materials from the group of plastics and composites of elastomers, foams, etc.

Keywords: *elastomers, polymers foam, oscillation, very large reversible deformation*

1. Introduction

Constantly growing demand for plastics with sublimed properties of materials has opened up prospects for further development. The high utility temperatures, good sliding properties and friction, high mechanical, dielectric and chemical resistance make polymers are extremely attractive material used by the current constructors.

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The group of construction materials, called hyperdeformable, includes among others: elastomers, plastics made based on rubber, thermoplastic structures, such as polycarbonate, gels and sols, composites and foams: open and closed pores. Porous structures are produced on the basis of different materials, synthetic thermoplastic polymers and thermosetting [1, 2]. The performance of these materials depends on the type of polymer used, the degree of foaming and pore and structure size. The cellular structure in polymers can be produced continuously or periodically by means of solid, liquid or gaseous foaming agents.

Considering the nature of the polymer warp, the foam can be divided into thermoplastic and thermoset in some cases, thermoplastics foam process is conducted in parallel with cross-linking of the polymer warp. In terms of the cellular structure of the foamed plastic material is divided into closed-cell and open pores. The cell foams (pores) closed, usually spherical in shape, each of the cells is completely surrounded by a thin polymer membrane, while in the open pore foam, the individual cells are connected among themselves.

This paper presents a general problem of porous materials. Addresses issues of numerical analysis foams used in shell seats by Faurecia and an assessment of the impact of factors affecting the operation of this type of structures. Detailed results are given in [3].

2. Numerical foams analysis

Elastomers, polyurethane foams, elastics and various similar materials on very large reversible deformation, called hyper-elastic, are more and more often used in construction of machines. In paper, was presented built methodology of elasticity propriety materials with large deformation and a description of model of internal damping was proposed with the proof the influence of component part of polynomial: figure and volumetric. External factors were executed was having on elasticity propriety – the level of dumping.

Describing the elastic feature can be used well elaborate and describe theories [5-7] where the most important are multinomial models and their specific cases: models of Money, Rivin, Yeoh and Ogden. The lack of description of viscoelastic feature could be seen as an obstacle – for instance energy dissipation, vibration damping in machines made of this type of materials.

Ogden's model is used to describe the viscoelastic materials, such as gums, polymers, soft tissues. It was proposed by Ray W. Ogden in 1972 [4]. The model assumes that the behaviour of the material during deformation can be described as a function of the density of shear and on the basis of the derived relationships between stresses and deformations.

Ogden's model is considered the best model for the analysis of major deformation, even up to 700%. With good approximative usually no need to employ a higher order than the development of n = 2 or n = 3. Ogden's model used in the most popular form of strain tensor eigenvalues. The model takes into account the structure of a large compressibility of the material. The best results are obtained for the isotropic material in which the deformation does not depend on the speed. Model [5, 6] in the form (1) can be widely used. Assuming the total value λ_i factors, such as 2, 4, 6, we obtain a polynomial model. In the event of any value, we obtain nonlinear model from the first word, in which there are exponential nonlinearity.

Model (1) gives good fit curves, if we are to ensure sufficient measurement data from different samples. The shear energy takes the form of (1):

$$W = \sum_{i=1}^{n} \frac{2\mu_1}{\alpha_1^2}\left(\lambda_1^{\alpha_i} + \lambda_2^{\alpha_1} + \lambda_3^{\alpha_1} - 3\right) - \sum_{i=1}^{n} \frac{1}{D_i}(J_{el-1})^{2i}, \quad (1)$$

where:

n – degree model,

μ_i, α_i – material constants,

$\lambda_1, \lambda_2, \lambda_3$ – strain tensor eigenvalues,

μ_0 – initial modulus of elasticity is defined as (2):

$$\mu_0 = \sum_{i=1}^{N} \mu_i. \quad (2)$$

Assuming the total value λ_i factors, such as 2, 4, 6, we obtain a polynomial model. In the event of any value, we obtain nonlinear model from the first word, in which there are exponential nonlinearity.

It was received; the considered material characterized by isotropic structure, deformation recorded (3):

$$\varepsilon_2 = -\nu\varepsilon_1 = -\nu(\lambda_1 - 1) = -\nu\lambda_1 + \nu,$$
$$\varepsilon_3 = -\nu\varepsilon_1 = -\nu(\lambda_1 - 1) = -\nu\lambda_1 + \nu, \quad (3)$$

the degree of the model n = 2 equation (1), after taking into account the incompressibility condition (4) and (5):

$$\lambda_1\lambda_2\lambda_3 = 1, \tag{4}$$

$$\lambda_2^2 = \frac{1}{\lambda_1}\lambda_3^2 = \frac{1}{\lambda_1}, \tag{5}$$

following equation describing the energy of amorphous deformation (6):

$$W = 2(\frac{\mu_1(2\lambda_1^{-\frac{\alpha_1}{2}}+\lambda_1^{\alpha_1}-3)}{\alpha_1^2} + \frac{\mu_2(+2\lambda_1^{-\frac{\alpha_2}{2}}+\lambda_1^{\alpha_2}-3)}{\alpha_2^2}. \tag{6}$$

After taking into account equality (7):

$$\sigma_1 = \frac{\partial W}{\partial \lambda_1} \tag{7}$$

and save the dimensionless variable λ_1 in the form of (8):

$$\lambda_1 = \frac{x_i+l_i}{l_i}, \tag{8}$$

obtained (9):

$$\sigma_1 = \frac{2((\frac{l+x}{l})^{-\frac{\alpha_1}{2}}((\frac{l+x}{l})^{\frac{3\alpha_1}{2}}-1)\alpha_2\mu_1+(\frac{l+x}{l})^{-\frac{\alpha_2}{2}}((\frac{l+x}{l})^{\frac{3\alpha_2}{2}}-1)\alpha_1\mu_2)}{(l+x)\alpha_1\alpha_2}. \tag{9}$$

To demonstrate the effect of deformation from the temperature dependence into account (10) defining the part of the volume of deformation in accordance with [8]:

$$\varepsilon_v = \varepsilon_S + \varepsilon_T, \tag{10}$$

where:
ε_S – elastic deformation,
ε_T – temperature-dependent deformation.

After taking into account: the determinant of the deformation gradient saved as (11):

$$J_{el} = \frac{J}{J^t}, \tag{11}$$

relative elongation ε_T, resulting from the free, thermal expansion of the material (12), equation (13):

$$\varepsilon_T = \alpha_T \Delta T_i, \tag{12}$$

$$\begin{gathered} \Delta T_1 = T_1 - T_0, \\ \Delta T_2 = T_2 - T_1, \\ \Delta T_3 = T_3 - T_2 \end{gathered} \tag{13}$$

and the adoption of the simplifications resulting from the thermal isotropy of the case, according to (14):

$$\begin{gathered} \alpha = \alpha_1 = \alpha_2 = \alpha_3, \\ \Delta T = \Delta T_1 = \Delta T_2 = \Delta T_3, \end{gathered} \tag{14}$$

obtained equation (15):

$$\sigma_1 = \frac{2\left(\left(\frac{l+x}{l}\right)^{-\frac{\alpha_1}{2}}\left(\left(\frac{l+x}{l}\right)^{\frac{3\alpha_1}{2}}-1\right)\alpha_2\mu_1+\left(\frac{l+x}{l}\right)^{-\frac{\alpha_2}{2}}\left(\left(\frac{l+x}{l}\right)^{\frac{3\alpha_2}{2}}-1\right)\alpha_1\mu_2\right)}{(l+x)\alpha_1\alpha_2} + \frac{12(l+x)^2\left(\frac{(l+x)^3}{3l^3\left(\left(1+\alpha(+T_1-T_0)\right)^3\right)}-1\right)}{3l^3D_1\left(\left(1+\alpha(+T_1-T_0)\right)^3\right)} +$$

$$+ 24(l + x)^2 \left(\frac{(l+x)^3}{3l^3\left(\left(1+\alpha(+T_1-T_0)\right)^3\right)} - 1 \right). \quad (15)$$

The analyses of foams used in automotive seats, e.g. in the company-manufactured model is used Faurecja "Hyperfoam" foams with very high compressibility, which uses part of the exponential describing the volumetric strain described relationship (16):

$$W = \sum_{i=1}^{n} \frac{2\mu_i}{\alpha_i^2} (\lambda_1^{\alpha_i} + \lambda_2^{\alpha_i} + \lambda_3^{\alpha_i} - 3) + (\sum_{i=1}^{n} \frac{1}{\beta_i} (J)^{-\alpha_i\beta_i} - 1). \quad (16)$$

For the case n = 2, and after substituting equation (4), (5) the equation (16) in the form (17):

$$W = 2[\frac{\mu_1}{\alpha_1^2}\left(2\lambda_1^{-\frac{\alpha_1}{2}} + \lambda_1^{\alpha_1} - 3\right) + \frac{\mu_2}{\alpha_2^2}\left(2\lambda_1^{-\frac{\alpha_2}{2}} + \lambda_1^{\alpha_2} - 3\right)] + \beta_1{}^{-1} + \beta_2{}^{-1} - 1. \quad (17)$$

After the derivative with respect to λ_i obtained (18):

$$\frac{\partial W}{\partial \lambda_1} = \frac{2}{\lambda_1}\left(\frac{\mu_1\lambda_1^{-\frac{\alpha_1}{2}}(\lambda_1^{\frac{3\alpha_1}{2}} - 1)}{\alpha_1} + \frac{\mu_2\lambda_1^{-\frac{\alpha_2}{2}}(\lambda_1^{\frac{3\alpha_2}{2}} - 1)}{\alpha_2}\right). \quad (18)$$

After taking into account (8) and conversion of the obtained equation defining the behaviour of the polymeric foam structure (19):

$$\sigma_1 = \frac{2\left(\left(\frac{l+x}{l}\right)^{-\frac{\alpha_1}{2}}\left(\left(\frac{l+x}{l}\right)^{\frac{3\alpha_1}{2}} - 1\right)\alpha_2\mu_1 + \left(\frac{l+x}{l}\right)^{-\frac{\alpha_2}{2}}\left(\left(\frac{l+x}{l}\right)^{\frac{3\alpha_2}{2}} - 1\right)\alpha_1\mu_2\right)}{(l+x)\alpha_1\alpha_2}. \quad (19)$$

In order to establish the effect of temperature on the nature of the deformation of the structure of foamed PUR, assumptions (12÷14). Consequently, the obtained relationship (20):

$$\sigma_1 = \frac{2\left(\left(\frac{l+x}{l}\right)^{-\frac{\alpha_1}{2}}\left(\left(\frac{l+x}{l}\right)^{\frac{3\alpha_1}{2}} - 1\right)\alpha_2\mu_1 + \left(\frac{l+x}{l}\right)^{-\frac{\alpha_2}{2}}\left(\left(\frac{l+x}{l}\right)^{\frac{3\alpha_2}{2}} - 1\right)\alpha_1\mu_2\right)}{(l + x)\alpha_1\alpha_2}$$

$$- \frac{3\alpha}{l + x}\left(3^{\alpha\beta_1}\left(\frac{(l + x)^3}{l^3(1 - \alpha T_0 + \alpha T_1)^3}\right)^{-\alpha\beta_1} +\right.$$

$$\left. 3^{\alpha\beta_2}\left(\frac{(l+x)^3}{l^3(1-\alpha T_0+\alpha T_1)^3}\right)^{-\alpha\beta_2}\right). \quad (20)$$

3. Conclusion

Teams of machines performing special tasks, such as: energy dissipation, such as safety buffers lifts (elevators); reduce or eliminate the impact of unwanted vibrations, such as the automobile suspension shock absorber assemblies; integrated energy and sound barriers used in road, parts of car seats and trolleys for persons with reduced traffic, require the use of special polymer materials. It is appropriate to learning, examination and conducting numerical interpretation of the above-mentioned phenomena. structures aim to design and proper selection of materials for specific applications.

In study was introduced the method of identification of propriety of viscoelastic hyper-elastic materials. Affirm that to description of materials about large compressibility larger exactitude guarantee the Ogden model (different lines). The conclusions these are essential with regard on planned practical use of materials in craft damper.

The structural description of the analysed material model was built on the assumption of non-linear behaviour of the polymers. It has been found that it is appropriate to consider all the factors conditioning the work material such as temperature. It has been found that the properties of polymer materials hyper deformable vibration affect the occurrence of a strongly non-linear, which is consistent with experimental results [9].

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