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Comparison of creep in free polymer rod and creep in polymer layer of the layered composite

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Abstract

Deformation of the rigid polymers represents the sum of elastic and high elasticity deformations. In the article is compared the deformation of polymer layer of layered composite with rectangular section that is compared with a free prismatic polymer rod is made from the same material as the adhesive layer in composite, under tensile load. Interaction between polymer layers and layers of substratum in composite is accomplished by the contact layer in which it is mixed the substances of adhesive and the substratum. We will consider the contact layer as a transversal anisotropic medium with such parameters that it can be represented as a set of short elastic rods, not connected among them-selves. For simplicity, we assume that the rods are normally oriented to the contact surface.

The value of deformation of the polymer layer, for the same loading conditions should be different from similar strains in free prismatic polymer rod, which is in the uniaxial stress-strain state because triaxial stress-strain state in the composite is greatly inhomogeneous. This paper shows that the rigid connection of adhesive and sub-stratum complicates high elasticity deformations in polymer layer.

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Keywords: Strain; composite; layered composite; elasticity; adhesive; substratum; adhesive interaction; polymer rod; creep; contact layer.

Nomenclature

q	tensile force
l	size of cross-section

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μ_k	Poisson's ratio of layer k
E_k	Young's modulus of layer k
h_k	thickness of layer k
$\sigma_{x,k}$, $\sigma_{y,k}$	normal stresses in layer k
g_k^*	averaged shear modulus of contact layer k, $g_k^* = G_k^*/h_k^*$
G_k^*	shear modulus of contact layer k
h_k^*	thickness of contact layer k
$\varepsilon_{i,k}^{h.e.}$	high elasticity deformations of layer k in direction i
s	number of component of relaxation time spectrum
$E_{\infty,s,k}$	high elasticity deformations modulus
$\eta_{0,s,k}$	modulus of initial relaxation of viscosity
$m_{s,k}$	modulus of speed, reflecting the influence of strain speed on stress at a given fixed deformation

1.1. Statement of the problem

Resolving equations of the stress-strain state of a layered composite under a tensile force q, obtained in [1], are presented below.

$$\left.\begin{aligned}
&h_k\frac{\partial^2\sigma_{x,k}}{\partial x^2} = g_k^*\cdot\left(\frac{1}{E_k}\cdot\left[\sigma_{x,k}-\mu_k\cdot\left(q+\sigma_{y,k}\right)\right]+\varepsilon_{x,k}^{h.e.}\right)-g_k^*\cdot\left(\frac{1}{E_{k-1}}\cdot\left[\sigma_{x,k-1}-\mu_{k-1}\cdot\left(q+\sigma_{y,k-1}\right)\right]+\varepsilon_{x,k-1}^{h.e.}\right)-\\
&-g_{k+1}^*\cdot\left(\frac{1}{E_{k+1}}\cdot\left[\sigma_{x,k+1}-\mu_{k+1}\cdot\left(q+\sigma_{y,k+1}\right)\right]+\varepsilon_{x,k+1}^{h.e.}\right)+g_{k+1}^*\cdot\left(\frac{1}{E_k}\cdot\left[\sigma_{x,k}-\mu_k\cdot\left(q+\sigma_{y,k}\right)\right]+\varepsilon_{x,k}^{h.e.}\right);\\
&h_k\cdot\frac{\partial^2\sigma_{y,k}}{\partial y^2} = g_k^*\cdot\left(\frac{1}{E_k}\cdot\left[\sigma_{y,k}-\mu_k\cdot\left(q+\sigma_{x,k}\right)\right]+\varepsilon_{y,k}^{h.e.}\right)-g_k^*\cdot\left(\frac{1}{E_{k-1}}\cdot\left[\sigma_{y,k-1}-\mu_{k-1}\cdot\left(q+\sigma_{x,k-1}\right)\right]+\varepsilon_{y,k-1}^{h.e.}\right)-\\
&-g_{k+1}^*\cdot\left(\frac{1}{E_{k+1}}\cdot\left[\sigma_{y,k+1}-\mu_{k+1}\cdot\left(q+\sigma_{x,k+1}\right)\right]+\varepsilon_{y,k+1}^{h.e.}\right)+g_{k+1}^*\cdot\left(\frac{1}{E_k}\cdot\left[\sigma_{y,k}-\mu_k\cdot\left(q+\sigma_{x,k}\right)\right]+\varepsilon_{y,k}^{h.e.}\right),
\end{aligned}\right\} \quad (1)$$

in which

$$\varepsilon_{i,k}^{h.e.} = \sum_{s=1}^{2}\varepsilon_{s,i,k}^{h.e.}. \quad (2)$$

Two summand (s =1,2) in equation (2) correspond to two components of the relaxation time spectrum and are determined from solution of non-linear differential equation Maxwell-Gurevich [3]:

$$\left.\begin{aligned}
&\frac{\partial\varepsilon_{s,i,k}^{h.e.}}{\partial t} = \sum_{s=1}^{2}\frac{\sigma_{i,k}-E_{\infty,s,k}\varepsilon_{s,i,k}^{h.e.}}{\eta_{0,s,k}}\exp\left|\frac{\sigma_{i,k}-E_{\infty,s,k}\varepsilon_{s,i,k}^{h.e.}}{m_{s,k}}\right|,\ i=x,\ y;\\
&\frac{\partial\varepsilon_{s,z,k}^{h.e.}}{\partial t} = \sum_{s=1}^{2}\frac{q-E_{\infty,s,k}\varepsilon_{s,z,k}^{h.e.}}{\eta_{0,s,k}}\exp\left|\frac{q-E_{\infty,s,k}\varepsilon_{s,z,k}^{h.e.}}{m_{s,k}}\right|.
\end{aligned}\right\} \quad (3)$$

It is experimentally established [3, 4] that for highly elastic deformations with high precision, the next relationship is performed