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Constitutive equations for dissipative materials operationg under finite deformations

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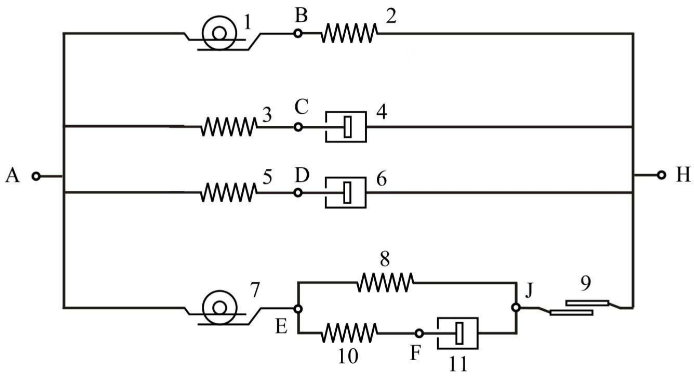
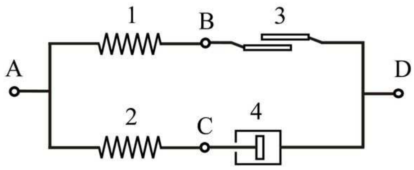
ABSTRACT

A method of constructing the system of constitutive equations for incompressible nonlinear dissipative materials capable of working under finite deformations was developed. To construct the constitutive equations, a phenomenological scheme for the mechanical behaviour of the material was used, as shown in Fig. 1. The points on this scheme are connected by elastic, viscous, plastic and transmission elements. The material properties of each of the scheme elements are described by the known equations of the nonlinear elasticity theory, the theory of nonlinear viscous fluids and the theory of plastic flow under finite deformations. To complete the system of constitutive equations it is suggested to use a proportional relation between the strain rate tensor of the material and the strain rate tensors of plastic elements.

In the model we do not use the concept of deformation gradients for internal points in the scheme for the mechanical behaviour of the material. Therefore it is impossible to use multiplicative decomposition of the deformation gradient of the material into the product of deformation gradients of scheme elements. Instead, for creation of the mathematical model the hypothesis about additive decomposition of the rate of deformation tensor of the medium into the rate of deformation tensors of the elements is used.





a b

Fig. 1. Models of rubber compound (a) and polyethylene (b)

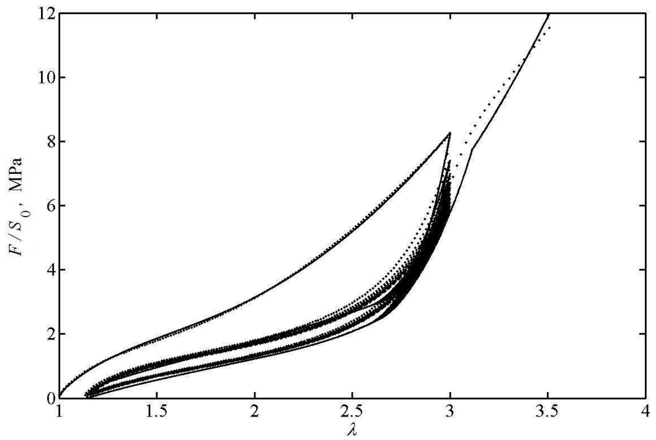


Fig. 2. Comparison of theoretical (solid line) and experimental data (dashed line) for rubber compound under cyclic deformation

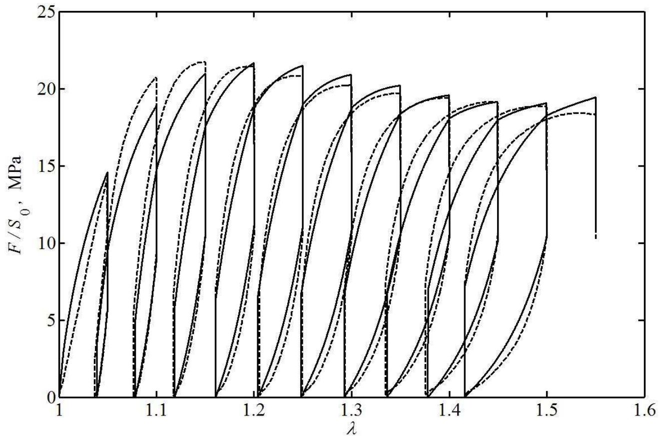


Fig. 3. Comparison of theoretical (solid line) and experimental data (dashed line) for polyethylene under cyclic deformation with 10 minutes of stress relaxation at maximum and minimum values of material stretches on each cycle

A distinguishing feature of the model is the application of transmission elements. Those elements are used for taking into account the difference between the macroscopic deformations of the material and the deformation of elements on the structural level. Transmission elements increase the rate of deformation tenors and decrease the Cauchy stress tensors in elastic elements without changing the energy balance.

The method of constructing the system of constitutive equations was applied to develop models describing the behaviour of rubber compounds and polyethylene (Fig.1). Suggested models simulated with a good accuracy the effect of softening of the material after the first stretching (Mullin effect) and viscoelastic properties at cyclic deformation under large amplitudes of rubber compounds (Fig.2) and viscoplastic properties of polyethylene under cyclic deformation with time interval of stress relaxation (Fig.3).

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