IDENTIFICATION OF THE MICRO-HETEROGENEOUS MEDIUM MODEL PARAMETERS AND FUNCTIONS

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INTRODUCTION

This study focuses on the problem of the representation of a real material in the structural model of micro-heterogeneous medium. External conditions are considered when an element of body is deformed along a rectilinear trajectory with the constant state parameters. The internal constants, reflecting simultaneously the heterogeneities of the stress and strain tensors fields at the microscopic scale are determined on basic of the thermodynamic principles and of hypothesis that from all possible schemes of kinematic interaction between sub-elements the scheme with extreme discrepancy of macroscopic and microscopic measures corresponds to real interaction. The thermorheological features of the subelements are determined by proportional and isothermal tests of the thin-walled tubes strained by axial force and internal pressure.

1. LOCAL PHYSICAL EQUATIONS AND PRINCIPLES OF TRANSITION FROM MICROSTATE TO MACROSTATE

At the original time the studied macroscopic element is in a natural state then is subjected to mechanical and thermal action. It is assumed that during deformation the material behavior depends significantly on the velocity of loading and heating.

To describe the behavior of the micro-heterogeneous medium the macroscopically homogeneous volume element V_0 of the polycrystalline body bounded by the surface S_0 is considered to be composed of an infinite number of kinematically connected subelements with different thermorheological features. Subelement as the elementary structure identifies the set of all material particles in the interior domain V_0 that have the same irreversible strain tensors

$$\bar{p}_{ij} = \tilde{p}_{ij}, \qquad \bar{p}_{ij} = \left\langle \tilde{p}_{ij} \right\rangle_{\bar{V}}, \tag{1}$$

where $\bar{p}_{ij}$ implies average irreversible strain of the subelement with the volume $\bar{V}$.

The composition of material particles in the subelement remains invariable in all processes of the conglomerate strain. Particles of the same subelement may have different orientations and situations in the conglomerate space. Because the granules of the polycrystalline aggregate are nonuniformly deformed so that the mass and the volume of a single accepted subelement can be arbitrarily small. It is evident that proceeding from the selection of material particles in the accordance with the irreversible strain tensor other thermo-mechanical quantities change from a material particle to other one in the given subelement.

Despite the fact that subelements have only basic properties their set because of interactions between them possesses an extremely broad spectrum of features. Conglomerate characteristics are much more diverse than sum of the structural elements properties.

Within the limits of the examined model let us assume that all types of interactions between sub-elements in the conglomerate are formed only under the influence of average connections, i.e. material particles in the conglomerate do not deform independently, but only in a coordinated manner.

The phenomenon of the auto concordance of irreversible strain processes of subelements can be represented according to the concept of the average connections in the way of two equations [1, 4]:

– the yield condition for the subelement under the influence of structural modifications in conglomerate

$$\bar{e}_{ij} \frac{d\bar{p}_{ij}}{d\bar{\lambda}} = \tau(\psi, \gamma, \upsilon) + s + \bar{r}\cos\bar{\alpha}, \tag{2}$$

$$d\bar{\lambda} = \sqrt{d\bar{p}_{ij} d\bar{p}_{ij}}, \qquad \cos\bar{\alpha} = \frac{\bar{p}_{ij}}{\bar{p}} \frac{d\bar{p}_{ij}}{d\bar{\lambda}}; \tag{3}$$

– law about the overall orientation of irreversible yield processes for subelements

$$\frac{d\bar{p}_{ij}}{d\bar{p}} = \frac{dp_{ij}}{dp}, \tag{4}$$

$$d\bar{p} = d\sqrt{\bar{p}_{ij}\bar{p}_{ij}}, \qquad dp = d\sqrt{p_{ij} p_{ij}}, \tag{5}$$

where the functional τ represents scalar properties of subelements in the structurally stable state and can be identified with the initial yield point of subelement; $\overline{\alpha}$ is the angle between the tangent to the irreversible strain path and irreversible strain vector; and deviator of strain tensor is written as the sum of reversible $\overline{e}_{ij}$ and irreversible $\overline{p}_{ij}$ strains

$$\overline{\varepsilon}_{ij} = \overline{e}_{ij} + \overline{p}_{ij}\,; \tag{6}$$

As the state parameter identifying quantities $\overline{\tau}$ and $\overline{r}$ with certain subelement is chosen weight of irreversibly deformed subelements $\psi\ (0 \le \psi \le 1)$ that reflects the sequence of subelements transition from reversible to irreversible state under initial loading.

The interaction between two subelements is realized by means of the interactions between material particles which are appertained to the different subelements. This fact is reflected by replacement of the local state parameters in physical equation for subelement on the average values of the whole set:

$$\gamma = \frac{1}{\psi_\lambda}\int_0^1 \dot{\overline{\lambda}}(\psi')d\psi', \qquad \upsilon = \frac{1}{\psi_\upsilon}\int_0^1 \overline{\upsilon}(\psi')d\psi', \tag{7}$$

$$\dot{s} = \frac{1}{\psi_s}\int_0^1 \dot{\overline{s}}(\psi')d\psi', \qquad 0 \le \psi_\lambda, \psi_\upsilon, \psi_s \le 1, \tag{8}$$

where γ is the average velocity of irreversible deformation in a subset of subelements being under the loading above the elastic limit; υ describes inelastic volume variation; ψ is the distinctive parameter of subelement which during the initial loading coincides with the weight of irreversibly deformed subelements when this subelement exceeded the elastic limit; ψ_λ, ψ_υ, ψ_s – summary weights of subelements for which the corresponding parameters $\dot{\overline{\lambda}}$, $\overline{\upsilon}$, $\dot{\overline{s}}$ are nonzero.

Evolutional equation of the state parameter $\overline{s}$ characterizing the isotropic hardening owing to the modification of structure in the irreversible processes, is accepted as

$$\dot{\overline{s}} = \begin{cases} a\sqrt{\dot{\overline{p}}_{ij}\dot{\overline{p}}_{ij}}, & \overline{s} < \overline{x}(\gamma,\upsilon), \\ \dot{\overline{x}}, & \overline{s} = \overline{x}(\gamma,\upsilon). \end{cases} \tag{9}$$

At the beginning of the irreversible deformation $\overline{s}\big|_{t=0} = s_0$, where s_0 depends on the type of the heat treating of the material. If at the start of the process of the irreversible deformation the material is in the structurally stable state, then $s_0 = 0$.

The relation between the kinematic hardening $\overline{r}$ and the state parameters is expressed as follows

$$\overline{r} = \begin{cases} a_0\overline{p}, & a_0\overline{p} < \overline{x}_0(\gamma,\upsilon), \\ \overline{x}_0(\gamma,\upsilon), & a_0\overline{p} = \overline{x}_0(\gamma,\upsilon), \end{cases} \tag{10}$$

$$\overline{r} = \sqrt{\overline{r}_{ij}\overline{r}_{ij}}\,, \qquad \overline{r}_{ij} = \overline{r}\,\frac{\overline{p}_{ij}}{\overline{p}}\,. \tag{11}$$

In monotonous processes throughout the subset of irreversibly deformed subelements an active process of loading occurs, that corresponds to the monotony of the evolution of weight of irreversibly deformed subelements in this process. This means that towards ψ only one separation boundary forms between reversibly $\psi' < \psi \le 1$ and irreversibly $0 \le \psi \le \psi'$ deformed subelements. Since the variations $d\overline{p}$ in all subelements have one and the same sign, the law of the admissible trajectories (4) can be written as

$$\frac{d\overline{p}}{d\overline{\lambda}} = \frac{dp}{d\lambda}\,, \qquad \frac{d\overline{p}_{ij}}{d\overline{\lambda}} = \frac{dp_{ij}}{d\lambda}\,, \tag{12}$$

from where

$$\cos\overline{\alpha} = \frac{\overline{p}_{ij}}{\overline{p}}\frac{d\overline{p}_{ij}}{d\overline{\lambda}} = \frac{d\overline{p}}{d\overline{\lambda}} = \frac{dp}{d\lambda} = \frac{p_{ij}}{p}\frac{dp_{ij}}{d\lambda} = \cos\alpha\,, \tag{13}$$

$$d\lambda = \int_0^{\psi'} d\overline{\lambda}\,d\psi\,, \qquad d\overline{p}\big|_{\psi>\psi'} = 0\,, \qquad \gamma = \frac{\dot{\lambda}}{\psi'}\,. \tag{14}$$

On the basis of the stresses and strains fluctuations principle, formulated by V.Marina [2], of the first law of thermodynamics and of the law of the elastic volume variation in [3-5] was obtained the general scheme of the kinematic interaction between subelements:

$$\Delta\overline{t}_{ij} = -B\Delta\overline{d}_{ij} + \alpha\sqrt{\frac{B(B+K)}{3}\Delta\overline{d}_{nm}\Delta\overline{d}_{nm}}\;\delta_{ij}\,, \tag{15}$$

$$\alpha = \begin{cases} 1, & dac\breve{a}\ \ \overline{d}_{nm}\overline{d}_{nm} > d_{pq}d_{pq} \\ -1, & dac\breve{a}\ \ \overline{d}_{nm}\overline{d}_{nm} \le d_{pq}d_{pq} \end{cases},$$

where K volume compressibility modulus; internal parameter B reflects the fact that the processes of loading and deformation of subelements in the conglomerate occur both heterogeneously.

In consequence of the decomposition of stresses and strains fluctuations into the deviators and the spherical tensors

$$\Delta\overline{t}_{ij} = \Delta\overline{\sigma}_{ij} + \Delta\overline{\sigma}_0\delta_{ij}\,, \qquad \Delta\overline{d}_{ij} = \Delta\overline{\varepsilon}_{ij} + \Delta\overline{\varepsilon}_0\delta_{ij}\,. \tag{16}$$

were obtained two groups of equations

$$\Delta\bar{\sigma}_{ij} = -B\Delta\bar{\varepsilon}_{ij}\,, \tag{17}$$

$$\Delta\bar{\sigma}_0 = \alpha\sqrt{\frac{BK}{3}\Delta\bar{\varepsilon}_{nm}\Delta\bar{\varepsilon}_{nm}}\,, \tag{18}$$

$$\alpha = \begin{cases} 1, & dacă \quad \bar{\varepsilon}_{nm}\bar{\varepsilon}_{nm} > \varepsilon_{pq}\varepsilon_{pq} \\ -1, & dacă \quad \bar{\varepsilon}_{nm}\bar{\varepsilon}_{nm} \le \varepsilon_{pq}\varepsilon_{pq} \end{cases}.$$

The elastic properties of subelementelor and of the body element are assumed identical

$$\bar{e}_{ij} = \frac{\bar{\sigma}_{ij}}{2G}\,, \qquad e_{ij} = \frac{\sigma_{ij}}{2G}\,. \tag{19}$$

The equations of fluctuations of reversible and irreversible deformations are determined taken into consideration (6) and (19) in (17):

$$\bar{e}_{ij} - e_{ij} = m\left(p_{ij} - \bar{p}_{ij}\right), \quad m = \frac{B}{B + 2G}\,. \tag{20}$$

Unknown internal parameter m is determined on the basis of the principle of the measures discrepancy, formulated by V.Marina [2-3]: in all real interactions in conglomerate the discrepancy between the macroscopic measure and the suitable microscopic analogue reaches extreme values

$$\left\langle \bar{\sigma}_{ij}\bar{\varepsilon}_{ij}\right\rangle - \left\langle \bar{\sigma}_{ij}\right\rangle\left\langle \bar{\varepsilon}_{ij}\right\rangle = Extr\,. \tag{21}$$

From extremum of the discrepancy Δ [4,6] we obtained that parameter of the kinematic scheme m depends on the linear hardening coefficient a_0:

$$m = -a_0 + \sqrt{a_0 + a_0^{\;2}}\,. \tag{22}$$

Interdependence between the internal parameters B and m we find from the relation (20):

$$B = 2G\frac{m}{1 - m}\,. \tag{23}$$

2. IDENTIFICATION OF UNKNOWN PARAMETERS AND FUNCTIONS OF THE STRUCTURAL MODEL

The problem of the representation of a real material in the model will be solved if we will fix experiences from which rheological functions of subelements $\tau = \tau(\psi, \gamma, \upsilon)$ and unknown parameters a, a_0, m, B will be unequivocally identified.

To determine the functions $\tau = \tau(\psi, \gamma, \upsilon)$, reflecting thermoviscoplastic properties of the subelements, we will examine the deformation of the body element along a rectilinear trajectory.

Tensor properties of subelements in conglomerate under proportional loading are given, taking into account that the directris of the deviators reversible e_{ij}, $\bar{e}_{ij}$ and irreversible p_{ij}, $\bar{p}_{ij}$ strains coincide:

$$\frac{\bar{e}_{ij}}{\bar{e}} = \frac{e_{ij}}{e} = \frac{\bar{p}_{ij}}{\bar{p}} = \frac{p_{ij}}{p} = a_{ij}\,, \tag{24}$$

$$\bar{e} = \sqrt{\bar{e}_{ij}\bar{e}_{ij}}\,, \quad \bar{p} = \sqrt{\bar{p}_{ij}\bar{p}_{ij}}\,. \tag{25}$$

Local relation between reversible and irreversible strains (20) is represented in the form:

$$\bar{e} - e = m\left(p - \bar{p}\right). \tag{26}$$

In the monotonous process in the subelements set the two zones are formed with respect to ψ.

The irreversible deformation law in the first zone $\left(\psi \le \psi'\right)$ according to (2) is written as:

$$\bar{e} = \sqrt{\bar{e}_{ij}\bar{e}_{ij}} = \tau\left(\psi, \gamma, \upsilon\right) + s + \bar{r}\,, \tag{27}$$

where

$$\cos\alpha = \frac{p_{ij}}{p}\frac{dp_{ij}}{d\lambda} = 1\,, \qquad s = ap\,, \qquad \bar{r} = a_0\bar{p}\,. \tag{28}$$

For the group of subelements, operating in the reversible domain ($\psi > \psi'$, $\bar{p} = 0$), and according to (26) elastic deformations of subelements are identical and coincide with the limit elastic strain in the boundary subelement $\psi = \psi'$:

$$\bar{e} = e + mp = \tau\left(\psi', \gamma, \upsilon\right) + s\,. \tag{29}$$

The function $\tau\left(\psi', \gamma, \upsilon\right)$, reflecting thermo-viscoplastic properties of the subelements, can be expressed in terms of macroscopic quantities:

$$\tau\left(\psi', \gamma, \upsilon\right) = e + \left(m - a\right)p\,. \tag{30}$$

Differentiating (26) and (27) at a constant values of the state parameters γ and υ we obtain that the velocity of irreversible deformation has the same value for the subset of all subelements $\psi \le \psi'$

$$\dot{\bar{p}} = \frac{\dot{e} + \left(m - a\right)\dot{p}}{a_0 + m}\,. \tag{31}$$

According to the average connections concept

$$\dot{p} = \int_0^1 \dot{\bar{p}}\,d\psi = \int_0^{\psi'} \dot{\bar{p}}\,d\psi + \int_{\psi'}^1 \dot{\bar{p}}\,d\psi = \int_0^{\psi'} \dot{\bar{p}}\,d\psi\,. \tag{32}$$

Thus the distinctive parameter of subelements ψ' can be represented by the following relation

$$\psi' = \frac{\dot{p}\left(a_0 + m\right)}{\dot{e} + \left(m - a\right)\dot{p}}\,. \tag{33}$$

Based on (30) and (33) we can determine the thermoviscoplastic properties of subelements at the known state parameters γ and υ.

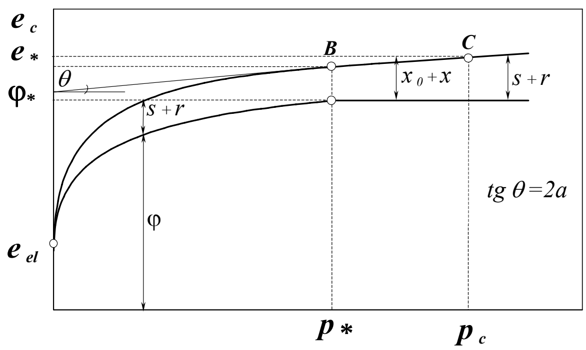

Figure 1. Diagram of the proportional loading of the thin-walled tubes by axial force and internal pressure at the constant temperature and the longitudinal strain velocity

The function $\tau(\psi',\gamma,\upsilon)$ can be determined at $\gamma=const$, $\upsilon=const$ by means of the diagram of the proportional loading, represented in the figure 1:

$$e=\varphi(p,\gamma,\upsilon)+s+r\,, \tag{34}$$

During the scleronomous and isothermal loading we have $e,_p=\varphi,_p+a+a_0$, hence the relations (30) and (33) are obtained as follows

$$\tau(\psi',\gamma,\upsilon)=\varphi(p,\gamma,\upsilon)+(m+a_0)p\,, \tag{35}$$

$$\psi'=\frac{a_0+m}{\varphi,_p+m+a_0}\,. \tag{36}$$

Thus, the thermoviscoplastic properties of subelements at the known values of the parameters a_0 and m may be determined, based on diagrams of the proportional loading $e=e(p,\gamma,\upsilon)$ at the various constant value of the state parameters γ and υ.

The rheological effects of subelement due to inelastic volume variation are characterized by the parameter υ, representing the identical for all subelements ratio of the volume variation and its possible limit

$$\upsilon=\frac{1}{\varepsilon_{0k}}\int_0^1(\bar{\varepsilon}_0-\beta\bar{e}_0)d\psi\,. \tag{37}$$

or

$$\upsilon=\frac{\varepsilon_0-\beta e_0}{\varepsilon_{0k}}\,,\quad \varepsilon_0=\int_0^1\bar{\varepsilon}_0 d\psi\,,\quad e_0=\int_0^1\bar{e}_0 d\psi\,. \tag{38}$$

Differentiating (38) with respect to time we find the loading conditions at $\upsilon=const$:

$$\dot{\varepsilon}_0=\beta\dot{e}_0=\beta\frac{\dot{\sigma}_0}{K}\,. \tag{39}$$

Taking into account

$$\dot{\varepsilon}_0=\dot{e}_0+\dot{p}_0+\dot{\varepsilon}_T\,,\qquad \dot{\varepsilon}_T=\alpha_T\dot{T}\,, \tag{40}$$

and assuming, that at the low level of irreversible deformations the elastic volume variation considerably exceeds the irreversible, we obtain that the velocity of temperature's change is proportional to the velocity of average stress's change

$$\dot{T}=-\frac{1-\beta}{\alpha_T K}\dot{\sigma}_0\,. \tag{41}$$

The deformation at $\upsilon=const$ corresponds to isothermal loading, if $\beta=1$.

Let us specify the conditions of the experiment at the constant parameter γ. In the monotonous process of deformation along a rectilinear trajectory

$$\dot{\bar{\lambda}}=\frac{d}{dt}\sqrt{\bar{p}_{ij}\bar{p}_{ij}}=\dot{\bar{p}}\,, \tag{42}$$

$$\gamma=\frac{1}{\psi'}\int_0^{\psi'}\dot{\bar{p}}d\psi=\frac{\dot{p}}{\psi'}\,,\quad \dot{\bar{p}}\Big|_{\psi>\psi'}=0\,. \tag{43}$$

The state parameter γ can be expressed in terms of macroscopic quantities, taking into account the relation (33), obtained for the distinctive parameter of subelements ψ':

$$\gamma=\frac{\dot{e}+(m-a)\dot{p}}{a_0+m}\,, \tag{44}$$

Let's pass to the velocities of the modules of the stress and strains tensor deviators

$$\gamma=\frac{1-m+a}{a_0+m}\frac{\dot{\sigma}}{2G}+\frac{m-a}{a_0+m}\dot{\varepsilon}\,. \tag{45}$$

where

$$\dot{\varepsilon}=\dot{e}+\dot{p}\,,\qquad \dot{e}=\frac{\dot{\sigma}}{2G}\,, \tag{46}$$

$$\dot{\varepsilon}=\frac{d}{dt}\sqrt{\varepsilon_{ij}\varepsilon_{ij}}\,,\qquad \dot{\sigma}=\frac{d}{dt}\sqrt{\sigma_{ij}\sigma_{ij}}\,. \tag{47}$$

The relation structure (45) follows that within the limits of the investigated model the continuity condition of the material transition from reversible to irreversible state is satisfied automatically.

During deformation along a rectilinear trajectory the directrixes of the stress and strain deviators velocities coincide:

$$\frac{\dot{\sigma}_{ij}}{\dot{\sigma}} = \frac{\dot{\varepsilon}_{ij}}{\dot{\varepsilon}} = a_{ij} . \qquad (48)$$

Considering that $a_{ij} = const$ we obtain

$$\dot{\sigma} = \frac{\dot{t}_{ij} - \dot{\sigma}_0 \delta_{ij}}{a_{ij}} , \qquad \dot{\varepsilon} = \frac{\dot{d}_{ij} - \dot{\varepsilon}_0 \delta_{ij}}{a_{ij}} , \qquad (49)$$

$$\langle i, j = 1,2,3 \rangle .$$

The indexes taken in the angle brackets talk about the fact that in the corresponding formulas the summation is not performed.

Substituting (49) and (39) into (45) we obtain the following expression for the state parameter γ

$$\gamma = \left[\frac{1 - m + a}{a_0 + m} \frac{\dot{t}_{ij} - \dot{\sigma}_0 \delta_{ij}}{2G} + \frac{m - a}{a_0 + m} \left(\dot{d}_{ij} - \beta \frac{\dot{\sigma}_0}{K} \delta_{ij} \right) \right] \frac{1}{a_{ij}} ,$$

$$\langle i, j = 1,2,3 \rangle . \qquad (50)$$

We will examine the loading of the thin-walled tubes with the tensile force F and the internal pressure P_i. The radial stress t_{rr}, being of the internal pressure order, can be neglected in comparison to the axial t_{zz} and circumferential $t_{\varphi\varphi}$ stress

$$t_{zz} = \frac{F}{2\pi R h} + \frac{P_i R}{2h} , \qquad t_{\varphi\varphi} = \frac{P_i R}{h} . \qquad (51)$$

The orientation of the loading trajectory in the space of axial t_{zz} and circumferential $t_{\varphi\varphi}$ stresses we will define by the parameter

$$\zeta = \frac{t_{\varphi\varphi}}{t_{zz}} , \qquad (52)$$

and will determine the ratio of tensile force and the internal pressure using parameter ζ

$$\frac{F}{P_i} = \frac{2 - \zeta}{\zeta} \pi R^2 . \qquad (53)$$

Let us transform equation (50) considering (52)

$$\gamma = \left[\frac{(1 - m + a)(2 - \zeta)}{6G(a_0 + m)} - \frac{\beta(m - a)(1 + \zeta)}{3K(a_0 + m)} \right] \frac{\dot{t}_{zz}}{a_{zz}} + \frac{m - a}{a_0 + m} \frac{\dot{d}_{zz}}{a_{zz}} . (54)$$

In laboratory conditions, the simplest is experiment at a constant velocity of movement of the grip, in this case $\dot{d}_{zz} = const$. To achieve this condition we establish the rectilinear trajectory orientation of the loading in the stress space t_{zz} and $t_{\varphi\varphi}$, equaling to zero the expression in square brackets

$$\zeta = \frac{2 - \eta}{1 + \eta} , \qquad \eta = \beta \frac{2G}{K} \frac{m - a}{1 - m + a} . \qquad (55)$$

According to (48)

$$a_{zz} = \frac{\sigma_{zz}}{\sigma} = \frac{2 - \zeta}{\sqrt{6\left(1 - \zeta + \zeta^2\right)}} , \qquad (56)$$

or if $\dot{d}_{zz} = const$

$$a_{zz} = \frac{\eta}{\sqrt{2\left(1 - \eta + \eta^2\right)}} . \qquad (57)$$

If the condition (55) is satisfied then deformation at a constant velocity $\dot{d}_{zz} = const$ is the outward sign of loading with the constant parameter γ, which is given by the expression

$$\gamma = \frac{m - a}{a_0 + m} \frac{\sqrt{6\left(1 - \zeta + \zeta^2\right)}}{2 - \zeta} \dot{d}_{zz} , \qquad (58)$$

or

$$\gamma = \frac{m - a}{a_0 + m} \frac{\sqrt{2\left(1 - \eta + \eta^2\right)}}{\eta} \dot{d}_{zz} . \qquad (59)$$

Let us determine the ratio of the tensile force and the internal pressure, that must be observed during the experiment at the constant state parameter γ

$$\frac{F}{P_i} = \frac{3\eta}{2 - \eta} \pi R^2 . \qquad (60)$$

In the case of axial tension $\zeta = 0$ and, according to (55), to make the experiment at the constant state parameter γ we must satisfy the following condition

$$\frac{m - a}{1 - m + a} = \frac{1}{\beta} \frac{2(1 + \nu)}{1 - 2\nu} . \qquad (61)$$

Taking into account the limits of variation of the parameters $0 \le a < \infty$ and $0 \le m \le 0{,}5$, the left side of the relationship ranges from -1 to 0. The right side relationship with regard to the possible theoretical limits of the Poisson's $0 \le \nu < 0{,}5$ ranges from 2 to ∞. Thus, in the case of the axial tension is impossible to carry out experiment at a constant state parameter γ. Therefore, the solution of the problem of the representation of the real material in the structural model on the basis of experiments conducted by stretching can be achieved only in an approximate way.

In order to execute the tensile tests at a constant velocity of movement of the gripping device $\dot{d}_{zz} = const$ we must know the rectilinear trajectory orientation ζ, expressed in the parameters of a and m, which are still unknown.

A number of authors [7] found that in the strain diagram $e \sim \varepsilon$ is observed a linear hardening sector, the slope of which does not depend on the temperature and rate of loading.

Within the linear hardening sector of the diagram $t_{zz} \sim d_{zz}$, according to (54), the axial tension at a constant velocity of the grip movement approaches the test at a constant parameter γ. Let us rebuild the diagram $t_{zz} \sim d_{zz}$ in the space of modules of strain deviators $e \sim \varepsilon$

$$\sigma = \sqrt{\frac{2}{3}} t_{zz}, \quad e = \sqrt{\frac{2}{3}} \frac{t_{zz}}{2G}, \quad \varepsilon = \sqrt{\frac{3}{2}} (d_{zz} - \varepsilon_0). \quad (62)$$

Assuming that the volume varies elastically, we find

$$\varepsilon = \sqrt{\frac{3}{2}} \left(d_{zz} - \frac{t_{zz}}{3K} \right). \quad (63)$$

Linear hardening coefficient æ according to the diagram $e \sim \varepsilon$

$$æ = \frac{\Delta e}{\Delta \varepsilon} = \frac{\Delta \sigma}{2G\Delta \varepsilon}, \quad (64)$$

or taking into account the relations (62) and (63)

$$æ = \frac{2(1+\nu)æ_{zz}}{3-(1-2\nu)æ_{zz}}, \quad æ_{zz} = \frac{\Delta t_{zz}}{E\Delta d_{zz}}. \quad (65)$$

Knowing the hardening coefficient æ on the diagram $e \sim \varepsilon$, we determine the hardening coefficient on the diagram $e \sim p$ in the figure 1 within sector $p_* \le p \le p_c$ (where p_* corresponds to the time when all the subelements exceeded the elastic limit $\psi' = 1$, p_c is a measure, starting from which the linear isotropic hardening is broken)

$$a + a_0 = \frac{\Delta e}{\Delta p} = \frac{\Delta e / \Delta \varepsilon}{1 - \Delta e / \Delta \varepsilon} = \frac{æ}{1 - æ}, \quad (66)$$

$$a = \frac{æ}{(1-æ)(1+\chi)}, \quad a_0 = \frac{\chi æ}{(1-æ)(1+\chi)}. \quad (67)$$

Next, using the formula (22), we define the parameter m, then on the basis of expression (55) find the orientation of the rectilinear trajectory of loading ζ.

To the obtained value of the ratio ζ are performed experiments under various constant velocity of movement of the gripping device and temperature levels.

CONCLUSIONS

It is considered solution of the problem of the representation of a real material in the structural model of micro-heterogeneous medium that satisfies the uniqueness condition.

Local yield laws simultaneously consider kinematic and isotropic hardening of subelements. Using the laws of thermodynamics, the phenomenon of the auto concordance of irreversible processes of local deformation and the hypothesis that from all possible schemes of kinematic interaction between subelements the scheme with extreme discrepancy of macroscopic and micro-scopic measures corresponds to real interaction, the parameters of the equation of the interconnection between subelements have been identified.

To determine the thermorheological properties of subelements have been studied the external conditions when an element of body is deformed along a rectilinear trajectory at the constant state parameters.

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