VIBRATION CREEP OF POLYURETHANE IN A LIQUID MEDIUM MIXED WORKLOAD

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Abstract

The elastomers characterize by their limit deformation instead of their limit strength. The reason for this is their viscoelastic behavior and the strong influence of the liquid medium, variable loading, temperature, etc. on the deformation.

Key words and phrases: creep; elastomer; liquid media; static loading; cyclic loading

1 Introduction

The present paper is devoted to an investigation of the mechanical behavior and in particular its manifestation through the deformation of some elastomers in liquid industrial environments, under both static and cyclic loading. This motivate us to use some effective calculation, and thus to try to predict the behavior of the above mentioned materials.

2 State of the problem

In previous investigations based on short-term creep experiments (see e.g., [1, 9]) the resulting functions of the reduction and relaxation spectra (see e.g., [2, 3]) under unsteady vibration-concentration conditions of creep, and by replacing the real time with conditional one along with the integral transformations

$$\begin{aligned} t' &= \int_0^t a_{vc}\Big[\dot{\sigma}_\alpha(z), \overline{C}_m(z)\Big]dz, \\ s' &= \int_0^s a_{vc}\Big[\dot{\sigma}_\alpha(z), \overline{C}_m(z)\Big]dz, \end{aligned} \tag{1}$$

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we obtain a physical relation of the linear hereditary theory (see e.g., [5]), that is,

$$\varepsilon(t) = \frac{1}{E}\left[\sigma(t) + \int_0^t K(t^{'} - s^{'})\sigma(s^{'})ds^{'}\right] \tag{2}$$

(see e.g., [6, 8]). Here K is the kernel, a_{vc} - function of multiple vibration-concentration time reduction, $s^{'}$ - conditional time preceding the moment $t^{'}$, $t^{'}$ - conditional time , $\overline{C}_m$ and $\dot{\sigma}_\alpha \equiv \dfrac{d\sigma_\alpha}{dz}$ are functions depending on the time, and not depending on the space (see e.g., [4, 7]).

In the present work the law of creep, followed by the ratios (1), (2) is verified under various conditions as concentration and stress, comparing the theoretical curves with experimental values obtained to the deformation.

3 Vibration creep of dry and sorbed liquid medium elastomer

Suppose the following conditions hold:

1) Static stress and zero concentration. In this case there exist the relations

$$(a) \qquad \sigma_{11_0} = 5[\text{MPa}]; \quad \dot{\sigma}_{11\alpha} = 0; \quad C_{m1} = 0; \quad 0 \le t \le 48[\text{h}]$$

$$\varepsilon_{11}(t) = a_{1111}\sigma_{11_0} + \sigma_{11_0}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{t}{\tau_{0i}}\right)\right]. \tag{3}$$

Here a_{1111} is instant pliancy, b_{1111} - steady pliancy, $\dot{\sigma}_{11\alpha}$ - cyclic stress, $\sigma_{11\alpha}$ - static stress, τ_{0i} - discrete spectrum of relaxation times.

2) Constant concentration and static stress.

$$(a+b) \qquad \sigma_{11_0} = 5[\text{MPa}]; \quad \dot{\sigma}_{11\alpha} = 0; \quad C_{m3} = 0.71; \quad 0 \le t \le 48[\text{h}]$$

$$\varepsilon_{11}(t) = a_{1111}\sigma_{11_0} + b_{1111}\sigma_{11_0}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{a_c t}{\tau_{0i}}\right)\right]. \tag{4}$$

3) Cyclic stress and zero concentration.

$$(b) \qquad \sigma_{11_0} = 5[\text{MPa}]; \quad \dot{\sigma}_{11\alpha} = 28.08; \quad C_{m1} = 0; \quad 0 \le t \le 48[\text{h}];$$

$$\varepsilon_{11}(t) = a_{1111}\sigma_{11} + b_{1111}\sigma_{11}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{a_v t}{\tau_{0i}}\right)\right]. \tag{5}$$

4) Static and cyclic stress accompanied by constant concentration.

$$(a+b+c) \qquad \sigma_{11_0} = 5MPa; \quad \dot{\sigma}_{11\alpha} = 28.08; \quad C_{m3} = 0.71; \quad 0 \le t \le 48[\text{h}];$$

$$\varepsilon_{11}(t) = a_{1111}\sigma_{11} + b_{1111}\sigma_{11}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{a_v a_c t}{\tau_{0i}}\right)\right]. \tag{6}$$

Remark. Notations (a), (a+b), (b), (a+b+c), respectively, stand for that the reader must compare them on Fig. 1

On Fig. 1 by a solid line are shown the theoretical curves according to (3),(4),(5),(6) for conditions 1-4, and with dots are given the experimental results under the same conditions.

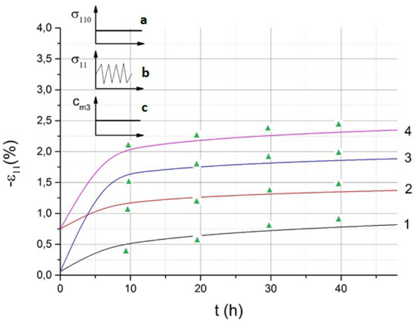

Fig.1. Experimental results from 1-4 control experiments

Creep by a mixed mode of loading.

Conditions of conducting the experiment:

5) Static stress accompanied by certain concentration for a time period of 12 [h].

$$\sigma_{11_0} = 5[\text{MPa}]; \quad \dot{\sigma}_{11\alpha} = 0; \quad C_{m1} = 0.71; \quad 0 \ \leq \ t \ \leq \ 12$$

$$\varepsilon_{11}(t) = a_{1111}\sigma_{11_0} + b_{1111}\sigma_{11_0}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{a_c t}{\tau_{0i}}\right)\right] \tag{7}$$

6) Static and cyclic loading with a concentration for a period of time of 24 [h].

$$\sigma_{11_0} = 5[\text{MPa}]; \quad \dot{\sigma}_{11\alpha} = 28.08; \quad C_{m3} = 0.71; \quad 12 \ \leq \ t \ \leq \ 24$$

$$\begin{aligned}\varepsilon_{11}(t) = a_{1111}\sigma_{11_0} + b_{1111}\sigma_{11_0}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{a_c t}{\tau_{0i}}\right)\right] + \\ + b_{1111}\sigma_{11\alpha}\frac{1}{N}\sum_{i=1}^{N}\left[1 - \exp\left(-\frac{a_c a_v t - t_1}{\tau_{0i}}\right)\right].\end{aligned} \tag{8}$$

7) Static and cyclic stress along by a concentration for a time of 36 [h].

$$\sigma_{11_0}=5[\mathrm{MPa}];\quad \dot{\sigma}_{11\alpha}=28.08;\quad C_{m1}=0.71;\quad 24\ \leq\ t\leq\ 36$$

$$\begin{aligned}
&\varepsilon_{11}(t)=a_{1111}\sigma_{11_0}+b_{1111}\sigma_{11_0}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_c t}{\tau_{0i}}\right)\right]+\\
&+b_{1111}\sigma_{11\alpha}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_c t-t_2}{\tau_{0i}}\right)\right]+\\
&+b_{1111}\sigma_{11\alpha}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_v a_c t-t_1}{\tau_{0i}}\right)\right].
\end{aligned}\tag{9}$$

where, a_c-function of concentration-time reduction, a_v-function of vibration-time reduction

8) Constant and cyclic stress accompanied by a constant concentration for a period of 48 [h].

$$\sigma_{11_0}=5[\mathrm{MPa}];\quad \dot{\sigma}_{11\alpha}=28.08;\quad C_{m3}=0.71;\quad 36\ \leq\ t\ \leq 48$$

$$\begin{aligned}
&\varepsilon_{11}(t)=a_{1111}\sigma_{11_0}+b_{1111}\sigma_{11_0}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_c t}{\tau_{0i}}\right)\right]+\\
&+b_{1111}\sigma_{11\alpha}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_v a_c t-t_3}{\tau_{0i}}\right)\right]+\\
&+b_{1111}\sigma_{11\alpha}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_c t-t_2}{\tau_{0i}}\right)\right]+\\
&+b_{1111}\sigma_{11\alpha}\frac{1}{N}\sum_{i=1}^{N}\left[1-\exp\left(-\frac{a_v a_c t-t_1}{\tau_{0i}}\right)\right].
\end{aligned}\tag{10}$$

On Fig. 2 with a continuous line are shown the theoretical curves for conditions 5-8 and with dots the experimental results under the relevant conditions.

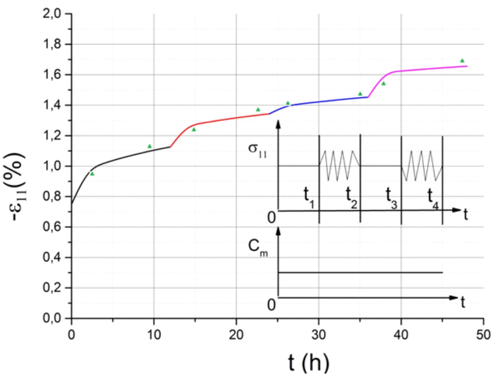

Fig.2. Experimental results from attempts 5-8, accompanied by the specified conditions.

4 Conclusion

The conducted experiments confirm the possibility to describe the viscoelastic behavior based on the short-term creep experiments with elastomers under conditions of liquid medium and mixed loading. This approach reduces much the time of prediction, and by reason of the relaxation spectrum it allows sufficiently precise description of the viscoelastic behavior. The graphs on Fig. 1 and Fig. 2 show that the deviation does not exceed 15 [%] .

The described computational procedures are implemented by the software system Mathcad Prime 3.0.

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