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QUALITATIVE ASSESSMENT OF DEFORMATION-PERFORMANCE PROPERTIES OF POLYMER TEXTILE MATERIALS

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A method of qualitative evaluation of deformation-performance properties of polymer textile materials based on the parameters of mathematical model of relaxation of these materials is described. The merit of this method is that for qualitative evaluation of deformation-performance properties of polymer textile materials expensive experiment is not required and it is enough to analyze the parameters of the mathematical model of the deformation or creep process.

The method of determination of deformation-performance properties of polymer textile materials, based on mathematical modeling, allows qualitative evaluation of their deformation-performance properties [1].

For evaluation of deformation-performance properties of polymer textile materials, we developed several criteria, which may be combined into a single integrated criterion in view of the fact that all deformation-performance parameters of the referred materials obey Cauchy probability law and include within it the evaluation of their quality [2].

For evaluation of deformation-performance properties of polymer textile materials, the following criteria are proposed for consideration [3]:

– criterion of intensity of deformation of the material in the performance process;
– criterion of degree of deformability of the material in the performance process;
– criterion of possibility of repeated deformation of the material in the performance process;
– time criterion of deformative action on the material in the performance process;
– criterion of resistance of the material to repeated deformation in the performance process.

It is proposed to make a quantitative evaluation of the parameters within the confines of these criteria of deformation-performance properties of polymer textile materials in dimensionless units, which may be presented as follows [4]:

1. *Criterion of intensity of deformation of the material in the performance process* [5].

Let us denote by

$$\beta_1 = b_{n\sigma} \quad (1)$$

the dimensionless variable characterizing the intensity of deformation of the material in the performance process, which is numerically equal to the intensity of the creep process that is responsible for deformation-performance and functional-consumer properties of the studied material. In this context, β_1 may acquire any nonnegative values ($\beta_1 \geq 0$). The lower the β_1 value, the faster the deformation of the material in the performance process and the faster does it correspond to its functional purpose.

2. *Criterion of degree of deformability of the material in the performance process* [6].

Let us denote by

$$\beta_2 = D_0 / (D_0 + D_\infty) \quad (2)$$

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the dimensionless variable characterizing the degree of deformability of the material in the performance process. In this case, β_2 acquires nonnegative values ($\beta_2 \geq 0$). The lower the β_2 value, the higher the degree of deformability of the material in the performance process and more does it correspond to its performance purpose. The higher the β_2 value, the less the possibility of deformation of the material and the less comfortable it is in the performance process.

3. *Criterion of possibility of repeated deformation of the material in the performance process* [7].

Let us denote by

$$\beta_3 = \sigma_0/\sigma_p \tag{3}$$

the dimensionless variable characterizing the capacity of the material to withstand repeated deformative action without appreciable impairment of the performance characteristic, where σ_b – breaking stress and σ_0 – a certain base value of the stress, for example, σ_0 = 1 MPa. Here, β_3 acquires positive values ($\beta_3 > 0$). The lower the β_3 value, the greater the possibility of withstanding repeated deformative action by the material.

4. *Time criterion of deformative action on the material in the performance process* [8].

Let us denote by

$$\beta_4 = \bar{\tau}_\sigma / t \tag{4}$$

the dimensionless variable characterizing the capacity of the material to retain the functional-consumer properties during deformation in the performance process, where t_1 – a certain value of the base time, for example, t_1 = 60 sec and $\bar{\tau}_\sigma$ – average deformation time that can be determined by the equation

$$\bar{\tau}_\sigma = \frac{\sigma_0}{\sigma_2 - \sigma_1} \int_{\sigma_1/\sigma_0}^{\sigma_2/\sigma_0} \tau_\sigma d\frac{\sigma}{\sigma_0}, \tag{5}$$

where σ_1 – the lowest and σ_2 – the highest value from the range of the studied stresses.

In this case, β_4 may acquire any nonnegative values ($\beta_4 \geq 0$). The lower the β_4 value, the faster the material undergoes deformation in the performance process, which ensures greater comfort.

5. *Criterion of resistance of the material to repeated deformation in/during the performance process* [9].

Let us denote by

$$\beta_5 = D_0 / (D_\infty - D_0) \tag{6}$$

the dimensionless variable characterizing the resistance of the material to repeated deformation in the performance process. Here, β_5 may acquire any nonnegative values ($\beta_5 \geq 0$). The less the β_5 value, the more the resistance of the material to repeated deformation in/during the performance process. The value $\beta_5 = 0$ corresponds to the condition of full resistance of the material to repeated deformation in the performance process.

Since the key deformation characteristics D_0, D_∞, $b_{n\sigma}$, and τ_σ were obtained by mathematical modeling of deformation-performance properties based on Cauchy probability distribution, the integral distribution function of which is NAL function, all β_1–β_5 variables, as noted earlier, also obey the Cauchy probability distribution [10].

Cauchy probability distribution is quite close to normal distribution, differing in certain properties, for example, by a slower convergence of integral function to its asymptotic values. This property of Cauchy distribution makes it possible to process with greater reliability the statistical samples that are significantly scattered, which indeed characterizes the aggregate of deformation-performance properties of polymer textile materials.

In view of the aforesaid, the probabilistic deformation characteristic σ_p may also be considered as Cauchy law abiding.

6. Integrated *criterion of deformation-performance properties.*

Since all the introduced probability characteristics β_1–β_5 are distributed in accordance with the Cauchy law, it is expedient to consider a new deformation-performance parameter:

$$B_d = \beta_1 + \beta_2 + \beta_3 + \beta_4 + \beta_5, \quad (7)$$

is also distributed in accordance with the Cauchy law.

Based on the properties of the summands β_1, β_2, β_3, β_4, β_5 the variable B_d acquires nonnegative values ($B_d > 0$), in which case deformation-performance properties will be better if the deformation-performance parameter B_d is lower.

Thus, the criterion of improvement of the quality of deformation-performance properties of polymer textile materials, which are responsible for their functional-consumer deformation-performance properties can be formulated as follows:

$$\frac{\sum_{k=1}^{N} B_{dk}}{N} = \frac{\sum_{k=1}^{N} (B_{1k} + B_{2k} + B_{3k} + B_{4k} + B_{5k})}{N} = \overline{B}_d \to \min \quad (8)$$

where N number of studied samples of the materials (volume of sampling); $\overline{B}_d$ – average value of deformation-performance parameter.

Consequently, the developed criteria of optimization of deformation-performance properties of polymer textile materials bear an integrated nature and includes optimization based on the five discussed partial criteria of deformation-performance properties of the referred materials [11].

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REFERENCES

1. A.G. Makarov and A.V. Demidov, *Dizain. Materialy. Tekhnologiya*, No. 1 (65), 130-135 (2022).
2. A.V. Demidov and A.G. Makarov, *Dizain. Materialy. Tekhnologiya*, No. 4 (68), 125-132 (2022).
3. A.G. Makarov and S.V. Kiselev, *Vestn. SPGUTD*, Ser. 4, *Prom. Tekhnol.*, No. 1, 76-84 (2022).
4. M.A. Egorova and I.M. Egorov, *Khim. Volokna*, No. 3, 34-37 (2022).
5. S.V. Kiselev, A.A. Kozlov, and I.M. Egorov, *Izv. Vuzov. Tekhnol. Tekst. Prom.*, No. 3, 214-220 (2022).
6. S.V. Kiselev, *Izv. Vuzov. Tekhnol. Leg. Prom.*, No. 3, 46-50 (2022).
7. V.I. Wagner, S.V. Kiselev, and A.A. Kozlov, *Ibid.*, 56-62.
8. A.A. Kozlov, *Dizain. Materialy. Tekhnologiya*, No. 1, 88-96 (2022).
9. M.A. Egorova and I.M. Egorov, *Ibid.*, 136-143.
10. S.V. Kiselev, *Ibid.*, 144-153.
11. A.A. Kozlov, *Vestn. SPGUTD*, Ser. 4, *Prom. Tekhnol.*, No. 1, 129-137 (2022).