EXPERIMENTAL INVESTIGATION OF THE DYNAMIC PROPERTIES OF MATERIALS BY THE METHOD OF A UNLOADING TRANSVERSE IMPACT

MECHANICS

1965

SovietRxiv

Fig. 1

Figure 1: Fig. 1

Abstract

Full Text

UDC 539.4:678

MECHANICS

K. A. KERIMOV

EXPERIMENTAL INVESTIGATION OF THE DYNAMIC PROPERTIES OF MATERIALS BY THE METHOD OF A UNLOADING TRANSVERSE IMPACT

(Presented by Academician A. Yu. Ishlinskii, February 16, 1965)

The theory of transverse impact under an elastic-plastic deformation law and its application to obtaining the dynamic tensile diagram in the case of impact loading were considered in work (1). However, there is little information in the literature on the study of the properties of materials under dynamic unloading.

In works (2, 3) a method was developed for determining the dynamic diagram $T(\varepsilon)$ of unloading of materials under an unloading transverse impact.

This method is based on approximation of the dependences between the deceleration velocity and the corresponding angle of bend of the thread, obtained from experiment.

In the present work experimental results are given for the study of the mechanical properties of rubber cord Sh-65 under dynamic unloading transverse impact, and the method proposed in (2) for constructing the dynamic diagram $T(\varepsilon)$ of unloading is also illustrated.

Fig. 1. Scheme of loading (a) and unloading (b) of the specimen

The tests were carried out on a pneumatic pile driver on a specimen of rubber cord Sh-65 of diameter 5 mm, length 4 m, with linear mass density 0.00209 $\text{kg} \cdot \text{sec}^2/\text{m}^2$, in the range of velocities $v_0 = 129.5$ m/sec and v_1 from 96.7 to 31.4 m/sec, i.e., with $v_0 - v_1$ varying from 32.8 to 98.1 m/sec. The arrangement of the experiment and the scheme of the experimental setup are analogous to those indicated in work (4). In the case of unloading along the axis of the pneumatic pile driver barrel, a special device is installed by means of which braking of the striker is carried out, and consequently a partial unloading of the specimen of

Fig. 2. Several frames of high-speed motion-picture photography

Figure 2: Fig. 2. Several frames of high-speed motion-picture photography

Fig. 3. Dependence $v(\gamma)$ for rubber Sh-65

Figure 3: Fig. 3. Dependence $v(\gamma)$ for rubber Sh-65

the material under investigation (the scheme of the device is given in Fig. 1). This device changes the velocity of the impacting body by the instantaneous attachment to the striker of an additional mass during the impact process.

Carrying out analogous experiments for various masses m_i under different discrete impacts at constant v_0, we obtain a series of successive unloading impacts corresponding to different points of the unloading diagram.

Implementation of impact loading in this manner caused great difficulties associated with the use of an additional mass. The latter is a steel cylinder. As the projectile (which in this case has a long nose part) passes through the cylinder, the specimen is loaded up to the moment of attachment; then a cylinder is placed on the projectile body, reducing the velocity of the striking body, which causes a certain unloading. To prevent destruction of the projectile as a result of the impact at the moment when the unloading mass is attached, cushioning lead gaskets are placed inside the cylinder. To improve the adhesion of the gaskets to the cylinder body, grooves are cut on the inner surface of the cylinder.

Fig. 2. Several frames of high-speed motion-picture photography

The process was recorded by means of SKS-1 high-speed motion-picture photography. As can be seen from the picture of the unloading impact obtained by high-speed filming (Fig. 2), the angle γ_1 is not established immediately. This is explained by the fact that the velocity of the striking body changes monotonically from v_0 to v_1. From the same picture it is evident that, after some time following the attachment of the mass m_i, the velocity v_1 and the angle γ_1 remain constant. The established values of the velocity v_1 and angle γ_1 during unloading were determined from the results of processing the high-speed film. The accuracy of determining $v_1(\gamma_1)$ was in this case not lower than ±5%.

Fig. 3. Dependence $v(\gamma)$ for rubber Sh-65

In this case, for $m_0 = 138$ g, the values $m_1, m_2, \dots, m_i$ were varied (from 30 to 460 g). The experimental points obtained as a result of processing the photographs are well approximated by a function of the form:

$$v_1 = \frac{19.21\gamma_1^3 - 44.89\gamma_1^2 + 31.6\gamma_1 + 33.75}{1.57 - \gamma_1}. \tag{1}$$

Figure 4

Figure 4: Figure 4

The curves $v_1(\gamma_1)$ and $v_0 - v_1 = f(\gamma_0 - \gamma_1)$ are shown in Fig. 3. In this case the maximum error does not exceed 5%.

It should be noted that, in order to obtain a satisfactory approximation formula, an additional condition is introduced, consisting in the fact that, for the point corresponding to the end of loading and the beginning of unloading, $T_1 = T_0$ and $\varepsilon_1 = \varepsilon_0$. The value of the derivative $dv_1/d\gamma_1$ calculated for the indicated point is included in the system of equations, from whose solution formula (1) is obtained. Differentiating it, we obtain:

$$\frac{dv_1}{d\gamma_1} = \frac{57.63\gamma_1^2 - 89.78\gamma_1 + 31.6 + v_1}{1.57 - \gamma_1}. \tag{2}$$

As a result of processing the experimental data, the curves $v_1 = v_1(\gamma_1)$ and $v_0 - v_1 = f(\gamma_0 - \gamma_1)$ were obtained (Fig. 3).

The calculation formulas for constructing the dynamic unloading diagram, according to (2), have the form:

Fig. 4. Dependence $T(\varepsilon)$ for rubber Sh-65. A—dynamic curves, B—static curves

$$T_1 = \rho_0 \frac{(v_0 - v_1)^2 \cos^2 \gamma_0}{(1 + \varepsilon_1) \sin^2(\gamma_0 - \gamma_1)},$$

$$\varepsilon_1 = (1 + \varepsilon_0) e^{\Phi} - 1, \tag{3}$$

where*

$$\Phi = -\int_{\gamma_1}^{\gamma_0} \left[\frac{\omega}{2} \pm \sqrt{\left(\frac{\omega}{2}\right)^2 - \mu} \right] d\gamma_1,$$

$$\frac{\omega}{2} = \operatorname{ctg}(\gamma_0 - \gamma_1) - \frac{v'(\gamma_1)}{v_0 - v_1},$$

$$\mu = \left(\frac{\omega}{2}\right)^2 \left(\frac{\cos\gamma_1 - \cos\gamma_0}{\cos\gamma_0}\right)^2.$$

These formulas were obtained under the assumption that the change in deformation in the case of unloading is accompanied by weak discontinuities. The processing formulas obtained for a strong discontinuity (3) are not suitable in the present case, since in processing the experimental results a peculiarity appears that is expressed in the imaginary character of the root.

Calculation by formulas (3), taking into account the experimental curves $v_0 - v_1 = f(\gamma_0 - \gamma_1)$ and $v_1(\gamma_1)$, makes it possible to construct a complete diagram (Fig. 4). In Fig. 4 the loading curve $T(\varepsilon)$ is also shown.

Analysis of the curves shows that under dynamic loading there is an inflection. In the case of unloading, the curve has no inflection.

In Fig. 4 static diagrams are also presented for the same rubber ($d = 5$ mm). Analysis shows that in shape these diagrams are similar to one another; under loading, the dynamic curves lie higher than the static ones. The ratio of stresses at equal deformations varies within the range 1.5-2. The dynamic unloading curves lie below the static ones in the regions of zero tensions. The residual deformation in this case is approximately equal to 0.15, whereas under static unloading it is 0.05.

Institute of Mathematics and Mechanics
Academy of Sciences of the Azerbaijan SSR

Received
16 II 1965

CITED LITERATURE

1. Kh. A. Rakhmatulin, *Strength under impulsive and short-term loads*, Moscow, 1961.

2. K. A. Kerimov, *Izv. AN AzerbSSR*, Ser. Phys.-Math. and Tech. Sciences, No. 3 (1961).

3. K. A. Kerimov, *Dokl. AN AzerbSSR*, 18 (1962).

4. K. A. Kerimov, *Dokl. AN AzerbSSR*, 19, No. 4 (1963).

[*] A minus sign is taken before the root, since in this case the formulas give a real result for the deformation.

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.