It can be seen that the results of estimating strength by the two criteria mentioned give very different results. It appears that the deformation criterion gives correct results, although this conclusion needs experimental verification. Calculations were carried out by both momentless theory and consideration of the instantaneous nature of the stressed state by a combined algorithm. No effect of instantaneous state on strength of thin plates was detected.

In this work, based on numerical methods for calculating very large deformations of axisymmetric shells made of rubberlike and elastoplastic materials, it has been shown that instantaneous stresses occurring in thin plates with pulsed loading have a weak effect on the final stress–strain state of the shells obtained. Instantaneous stresses also have little effect on the failure of thin shells occurring with large deformations at a distance from the rim.

LITERATURE CITED

SUPPORTING CAPACITY AND OPTIMUM DESIGN OF MULTILAYER CONICAL SHELLS AND CIRCULAR PLATES

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1. We consider an axisymmetric problem of critical analysis for circular conical shells freely supported along the contour. Concentrated force P was applied at the apex of the shell and transmitted through a rigid pad of small diameter (Fig. 1) whose size excluded local failure as a result of puncturing or crumpling. The shell has a constant thickness h everywhere, and it is of multilayer structure. The number of layers may be arbitrary, their thickness is prescribed as \( h_\psi_1 \) (i = 1, 2, ... , n), and \( \sum_{i=1}^{n} \psi_i = 1 \). The layer material is ideally tough and ductile with a yield point \( \sigma_i \) in tension, and \( \mu_1 \sigma_i \) in compression. Some of the layers may play the role of a low-strength filler.

It is assumed that shear failure of the shell [1] is possible over a certain surface \( j \) separating the shell into two parts, i.e., inner part containing \( j \) layers (\( n \geq j \)) and outer part which consists of the rest of \( n - j \) layers. With the aim of realizing a shear type of failure it is necessary that tangential stresses in the \( j \)-th surface or in the layer adjacent to it reach the shear yield point \( \tau_j \).
We introduce the following symbols: $R$ is the radius of the circular supported contour; $\rho R$ is the radius of the rigid pad; $f$ is the rise; $\gamma = fR^{-1}$ is the slope; $\varepsilon = hR^{-1}$ is the relative thickness. Considering the axial symmetry of the problem and by analogy with [1], we take a meridional-annular type of failure for the shell (Fig. 1a) with a central disk of radius $R\xi$ ($\rho \leq \xi \leq 1$).

Using the equilibrium condition in the form of a principle for possible displacements, it is necessary to provide equilibrium of the sum of virtual work for the outer and inner forces. Shown in Fig. 1b is a diametral section of a spatial curve for virtual deflections corresponding to the type of failure assumed. With a single depression of the central disk the angle of mutual rotation of meridional and central disks is

$$\varphi = \left( R(1 - \xi) \right)^{-1}. \quad (1)$$

We first consider the outer part of the shell consisting of $J$ layers. In a circular flow line there is a linear bending moment $m_{o1}$ whose value is determined in accordance with the method in [2] and it depends essentially on the value of displacement $c$ [3] of the neutral surface of a relatively central surface in the outer part of the shell. In turn, displacement $c$ is connected with the value of tangential forces operating on the shear surface and, therefore, it depends on the size of the central disk in the failure scheme and also on the number of shear surfaces $J$.

Work of moments $m_{o1}$ in possible displacements equals

$$D_{a1} = 2\pi m_{o1}\xi (1 - \xi)^{-1} \quad (2)$$

and it is proportional to the square of the shell thickness.

We introduce the notation

$$m_{o1} = m_{o1}h^{-2} = m_{o1}e^{-2}R^{-2}.$$

Then from (2) we obtain

$$D_{a1} = 2\pi R^2 A_i; \quad A_i = m_{o1} e\xi (1 - \xi)^{-1}. \quad (3)$$

Moving on to calculation of the work for internal forces in meridional flow lines, it is noted that its value is proportional to the area $\Omega$ of the curve for concentrated plastic deformation:

$$D_{m1} = \Omega \sum_{i=1}^{J} \sigma_i \psi_i. \quad (4)$$

Overall area is connected with area $\omega$ (Fig. 1) included between the central surface of the upper part of the conical shell, the plane of the axis of rotation for rigid disks, and ordinates along the section of flow lines. Since the plane of the axis of rotation is located below the central surface by the amount of displacement $c$ from the central line, we obtain

$$\omega = \frac{1}{2} fR (1 - \xi)^3 - Rc (1 - \xi). \quad (5)$$

or, taking account of the notations adopted,