At present, various types of composite materials which combine such valuable properties as high strength and low density are finding wide application. A large number of works have been devoted to a study of the strength of composites in extension. In the present work an attempt is made to obtain a theoretical basis for the character of failure and to determine the strength of laminar fiberglass-plastics in compression.

Numerous compression tests of carefully polished fiberglass-plastic specimens (10 × 10 × 40 mm in size and cut at angles of 0°, 45°, and 90° to the direction of the base) showed that almost all specimens fail as a result of shear through an area inclined at a certain angle \( \theta \) to the compression axis (Fig. 1). Fiberglass-plastic SVAM (1 : 1) is an exception. Specimens cut from this material at an angle of 0° (90°) to the direction of reinforcement do not give a chip angle - they delaminate. This will be discussed in more detail below. In all, about 40 specimens were tested. In Table 1 we give averaged data on chip angles and failure stresses for the tested materials. In Fig. 2 we show a failure scheme for laminar fiberglass-plastics in compression. Compression is carried out along the x axis. The \( \xi \) and \( \eta \) axes, which are located in the xz plane, have the directions of the base and the fill, respectively, or of the reinforcing glass fibers in the case of equal-strength fiberglass-plastics such as SVAM (1 : 1). Hereafter, we shall call the angle \( \varphi \) composed by the x and \( \xi \) axes the cutting angle.

We shall interpret the chip band as a slippage band in an ideal elastoplastic anisotropic body having a plasticity condition of the Mises type:

\[
F (\sigma_\xi - \sigma_\eta)^2 + G (\sigma_\eta - \sigma_z)^2 + H (\sigma_z - \sigma_\xi)^2 + 2L\tau_{\xi\eta}^2 + 2M\tau_{\xi z}^2 + 2N\tau_{\eta z}^2 = 1. \tag{1}
\]

Here the constants \( F, G, H, L, M, \) and \( N \) depend on the cutting angle. For a flat stressed state in the xy plane, Eq. (1) is rewritten in the form

\[
(G + H)\sigma_\xi^2 - 2H\sigma_\xi\sigma_\eta + (H + F)\sigma_\eta^2 + 2N\tau_{\xi\eta}^2 = 1. \tag{2}
\]

In this case the value of \( \theta \) which interests us is determined from the relationship [1]

\[
tg^2 \theta = \frac{H + G}{H}. \tag{3}
\]

The constants which enter into this are expressed on the basis of Eq. (1) via the yield points \( X, Y, \) and \( Z \) in compression along the \( x, y, \) and \( z \) axes:

\[
H + G = \frac{1}{X^2}; \quad 2H = \frac{1}{X^2} + \frac{1}{Y^2} - \frac{1}{Z^2}. \tag{4}
\]

The value of \( Y \) is given by

\[
Y = \sigma_{ms}. \tag{5}
\]

(\( \sigma_{ms} \) is the yield point of the matrix), and \( X \) and \( Z \) are connected by the relationship

\[
Z \left( \frac{\pi}{2} - \varphi \right) = X(\varphi). \tag{6}
\]

We determine \( X(\varphi) \) by using for the xz plane, instead of (1), a limiting condition which takes account of the structural peculiarities of composites. The principles of obtaining such conditions are outlined in [2].

We have the following: The matrix material follows the usual Mises plasticity condition, and the limiting surface for the reinforcement in \( \sigma_\xi, \sigma_\eta, \tau_{\xi\eta} \) space is a rectangle \( (\tau_{\xi\eta} = \tau) \):

\[
\tau = 0; \quad |\sigma_\xi| \leq \sigma_{\xi}; \quad |\sigma_\eta| \leq \sigma_\eta. \tag{7}
\]

Moreover, \( \sigma_\xi = S_\xi V_\xi + \sigma_{\xi M} \) and \( \sigma_\eta = S_\eta V_\eta + \sigma_{\eta M} \). Here \( \sigma_\xi \) and \( \sigma_\eta \) are actual stresses in the composite; \( S_\xi \) and \( S_\eta \) in the reinforcement; \( \sigma_{\xi M} \) and \( \sigma_{\eta M} \) in the matrix; \( \sigma_{\xi} \) is the limiting compressional stress in the glass fiber; \( V_\xi \) and \( V_\eta \) are the proportions of reinforcement in the \( \xi \) and \( \eta \) directions, respectively; \( u_\xi = 1 - V_\xi; \quad u_\eta = 1 - V_\eta \).
TABLE 1. Comparison of the Theoretical and Experimental Values of the Chip Angle $\theta$

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield point of matrix, $\sigma_{m} \cdot 10^{-7}$, Pa</th>
<th>Cutting angle, $\phi$, deg</th>
<th>Failure stress, $X \cdot 10^{-7}$, Pa</th>
<th>Chip angle, $\theta$, deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>SVAM (1:1)</td>
<td>3.0</td>
<td>45</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>PN-1</td>
<td>3.0</td>
<td>45</td>
<td>8.1</td>
<td>25</td>
</tr>
</tbody>
</table>

Fig. 1. Failure of specimens of PN-1 with cutting angles equal (from left to right) of 0°, 45°, and 90° in compression.

Fig. 2. Scheme of failure of laminar fiberglass-plastics in compression.

Fig. 3. Section of limiting surface by the plane $\tau = 0$.

According to the results of [2], the limiting surface which is of interest to us is the envelope of the family

$$
\frac{(\sigma_x - S_x V_x)^2}{u_x^2} + \frac{(\sigma_y - S_y V_y)^2}{u_y^2} + \frac{(\sigma_z - S_z V_z)}{u_z u_y} + 3\tau^2 = 3k^2 = \sigma_m^2
$$

on the condition that the vector $(S_x, S_y)$ traverses a rectangle (6). A section of this envelope by the plane $\tau = 0$ is shown in Fig. 3. It is bounded by the planes $\tau = \pm k$, four ellipsoids:

$$
\frac{(\sigma_1 \pm \sigma_0)^2}{u_1^2} + \frac{(\sigma_2 \pm \sigma_0)^2}{u_2^2} + \frac{(\sigma_3 \pm \sigma_0)}{u_3 u_2} + 3\tau^2 = 3k^2,
$$

which are located at the corners of rectangle (6), and also by two pairs of elliptical cylinders:

$$
\frac{(\sigma_1 \pm \sigma_0)^2}{4u_1^2} + \tau^2 = k^2;
$$

$$
\frac{(\sigma_2 \pm \sigma_0)^2}{4u_2^2} + \tau^2 = k^2,
$$

whose axes coincide with the sides of the rectangle (6).

Now the value of $X = X(\varphi)$ is defined as the value of the parameter $\sigma_X$ of the line

$$
\sigma_1 = \sigma_x \cos^2 \varphi; \quad \sigma_2 = \sigma_x \sin^2 \varphi; \quad \tau = \sigma_x \sin \varphi \cos \varphi
$$

at the point of its intersection with the limiting surface.