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Strength And Deformability Of Metal Glass-Plastic Shells Taking Into Account Shear Rigidity

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Abstract: The paper considers a two-layer combined shell made of composite layers differing in thickness and physical and mechanical properties, and also investigates the strength and deformability of metal-plastic shells, taking into account shear rigidity.

Keywords: two-layer combined cylinder shell, uniformly distributed load, system of differential equations, shell deformation, mid-surface displacement, shear function, shear stresses, deflection...

Introduction. One of the insufficiently studied areas of great practical importance is the study of the strength and deformability of shells made of composite and combined materials. Also, in many industries, cylindrical shells are often used [1,2,3].The development of the production of synthetic adhesives creates great prospects for the use of various types of glued structures in modern technology, including layered structures made on the basis of metal and fiberglass, various cylindrical fiberglass shells, winding, concrete slabs with external composite reinforcing layers, etc.

Such highly efficient combined structures with the use of plastics, which have such valuable properties as lightness, high transportability, chemical resistance, high strength, etc., are being increasingly used every year in shipbuilding, aircraft engineering, hydraulic engineering, chemical, industrial and urban construction and in a number of sectors of the national economy [4,5].

The modern level of designing these structures requires the creation of a fairly general calculation algorithm that allows one to explore a wide range of topical problems from a unified standpoint. Experimental and theoretical studies of the stress-strain state (SSS) and the stability of such structures are one of the important and complex sections of modern mechanics and are becoming increasingly important in practice [6,7,8].

Combined structures have various positive properties. The bearing layers of these structures are designed to absorb the main part of the current load. Reinforcing layers simultaneously increase the bearing capacity and service life of the structure, eliminating the need for additional protection against corrosion, chemical, thermal, radiation and other undesirable effects [9].Adhesive joints between layers serve to ensure the solidity of the structure and significantly affect the redistribution of forces between the bearing layers. When calculating the strength and stability of combined structures, taking into account the influence of the adhesive layer is especially necessary when the structure is subject to temperature effects or when there is a danger of loss of strength and stability of the adhesive and carrier layers from tangential loads [10,11,12].

Separate problems of the statics of two-layer plates and shells, which are based on the application of the Kirchhoff-Love hypotheses, are considered in the papers. In these papers, the stability and strength of two-layer shells under the action of internal pressure, as well as some problems of plate bending, are studied.

Research materials and methodology.

In the work of S.A. Ambartsumyan, two options for refining the theory of multilayer shells are proposed. The first option corresponds to the deflection according to the classical theory, and the second one represents the correction associated with taking into account the shifts in each layer. It is known that the accuracy of the constructed theories depends both on the geometric parameters of the structures under consideration and on other physical and mechanical characteristics of the layers [13, 14].

Thus, in the scientific literature devoted to the stress-strain state, strength, and stability of two-layer combined shells, a significant amount of research has been accumulated to determine the stress-strain state of individual types of shells: spherical, flat, conical, cylindrical, and others. Such structures include various tanks, aircraft and deep-sea vehicles, chemical industry devices, building structures, and many others [15].

In connection with the emergence of new structural composite materials, in recent years, two-layer shells have been widely used, which are characterized by a significant difference between the elastic constants of the materials of the layers. An actual problem is the calculation of structures taking into account various individual factors, such as taking into account the physical nonlinearity of the material, taking into account the transverse shear, the effect of the adhesive layer on the strength and stability of the shells. Neglect of these factors can lead to unacceptable errors.

The paper considers an axisymmetric problem of calculating a two-layer combined cylindrical one with coordinates made of composite layers that differ in thickness and physical and mechanical properties. The carrier layer is metal, and the second layer is composite (Fig. 1)

It is assumed that:

a) a uniformly distributed load acts on the shell, normal to the middle surface and smoothly changing along the generatrix;

b) the considered two-layer combined shell consists of a carrier (1), and a reinforcing and gluing layer (2), (see Fig. 1).Wherein:

c) the thickness of the bearing, reinforcing and gluing layers, constant;

d) the thickness of the carrier layer is much greater than that of the reinforcing one ($h>\delta 1$).

The calculation of the structure for strength and deformability, taking into account interlayer shifts of factors, will be carried out using a system of differential equations for the deformation of a cylindrical shell with respect to the unknowns U0, Φ1.2, τ1.2, W, υ0.

Where: (U0 and υ0) - displacement of the middle surface; Φ1,2-shear functions, τ1,2-tangential stresses, W-deflection (i=1,2)

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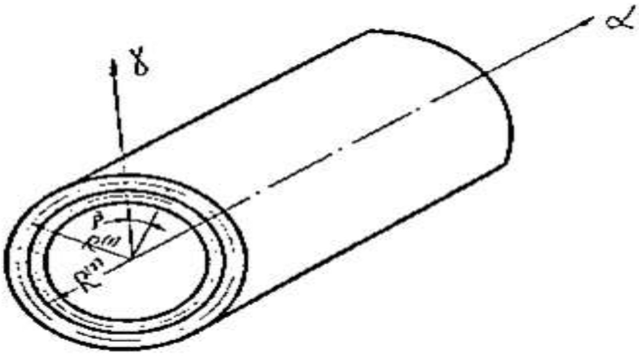

where are the stresses between the layers, G are the shear moduli of the layers.

Carrier layer shear deformations:

$$e_{\alpha\gamma}^{(1)} = 0.5\left(\frac{h^2}{4}-\gamma^2\right)\Phi_1(\alpha,\beta) + \left(0.5-\frac{\gamma}{h}\right)\frac{\tau_1(\alpha,\beta)}{G_{\alpha\gamma}^{(1)}}$$

$$e_{\beta\gamma}^{(1)} = 0.5\left(\frac{h^2}{4}-\gamma^2\right)\Phi_2(\alpha,\beta) + \left(0.5-\frac{\gamma}{h}\right)\frac{\tau_2(\alpha,\beta)}{G_{\beta\gamma}^{(1)}}$$

Shear deformations of reinforcing layers:

$$e_{\alpha\gamma}^{(2)} = \left(\frac{1}{2}+\frac{\gamma_1}{\delta_1}\right)\frac{1}{G_{\alpha\gamma}^{(2)}}\cdot\tau_1(\alpha,\beta)$$

$$e_{\beta\gamma}^{(2)} = \left(\frac{1}{2}+\frac{\gamma_1}{\delta_1}\right)\frac{1}{G_{\beta\gamma}^{(2)}}\cdot\tau_2(\alpha,\beta)$$

Here h, δ - thickness of the bearing and reinforcing layers;

$\Phi_i = \Phi_i(\alpha, \beta)$ – arbitrary desired shift functions;

$\tau_i = \tau_i(\alpha, \beta)$ are the desired shear stresses;

$G_{ik}^{(1)}$, $G_{ik}^{(2)}$ are shear moduli of the first and second layers

(i = 1, 2; k = 2) .

The expression for the total energy can be obtained on the basis of the Lagrange variational principle. According to this principle, the potential energy of an elastic system in the equilibrium position takes on a stationary value. It consists of the potential energy of elastic deformation of the layers, the adhesive line and the work of the external load. Taking into account the expression for the total energy, we obtain in the form of a double integral functional [16].

Tangential stresses $\tau_{\alpha\gamma}^{(i)}$, $\tau_{\beta\gamma}^{(i)}$, (i=1,2) – or deformations corresponding to them $e_{\alpha\gamma}^{(i)}$, $e_{\beta\gamma}^{(i)}$ change along the shell thickness according to the given law, the displacement normal to the middle surface of the shell does not depend on the coordinate γ; there is no pressure between the layers ($\sigma_\gamma=0$).It is also believed that between the two bearing and reinforcing layers there is a thin adhesive layer, which works only on shear in the vertical plane. The adhesive layer does not perceive any tensile or bending stresses. Shear stresses acting in this layer are transferred to the bearing and reinforcing layers. The law of distribution of these stresses in the layers can be taken as linear, so that the boundary conditions for shear stresses on the upper and lower surfaces are satisfied.

To obtain the basic equations for the deformation of a two-layer shell, taking into account the transverse shear and compliance of the adhesive joint, the variational Lagrange principle was used, which serves as the basis for various approximate methods, including the solution of combined orthotropic shells with interlayer shifts. When determining the stress-strain state of the shells, the shear moduli and the thickness of the gluing seam were varied, and the effect of changing the thicknesses of the bearing layers was studied [17].

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Numerical calculations have shown that the shear modulus and the thickness of the seam have a significant effect on the strength and deformability of the combined two-layer shells, if the shear modulus of the adhesive layer is significantly less than the shear modulus of the layers. If the first layer consists of a composite material, then the effect of transverse shear on the stress-strain state of the combined shells will be greater.

Research results.

The results of the calculation of a two-layer cylindrical shell with a fiberglass reinforcing layer are shown in the form of a graph, stress changes in the layers and the seam, as well as the shear and deflection functions. Figure 3 shows the change in physical and mechanical characteristics with a change in the shear modulus of the weld.

It can be seen from the dependences obtained that the smaller the shear modulus of the weld compared to the layer, the greater the effect of the weld compliance on the stress-strain state of three-layer shallow shells.

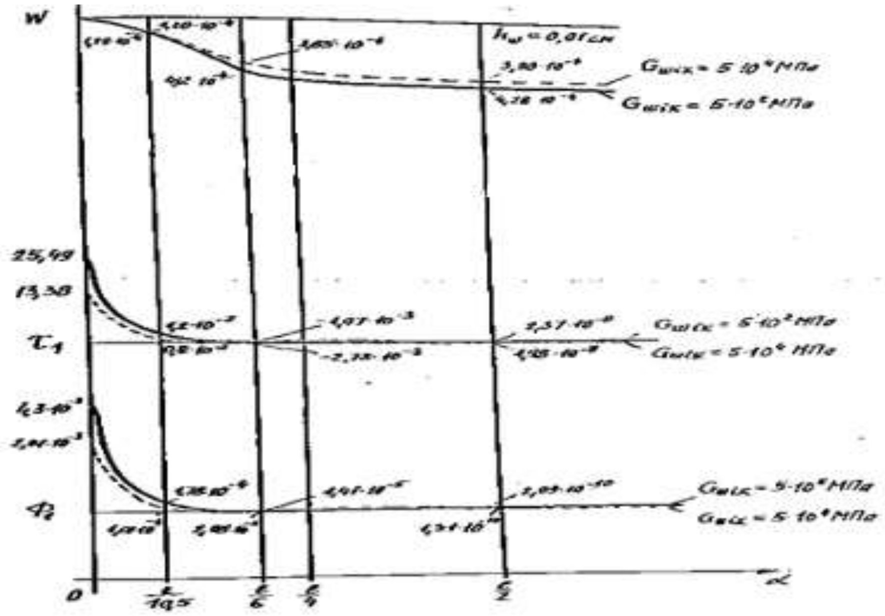

Fig. 2 change in the shear modulus of the joints

From the given examples (Fig. 2) it can be seen that the shear modulus (G_shik) and thickness (h_sh) have a great influence on the bearing capacity of the combined two-layer cylindrical shells, if the value of the shear modulus of the bonding layer is significantly less than the shear modulus of the layers.

To analyze the effect of transverse shear and compliance of the adhesive joint are considered. long two-layer axisymmetric cylindrical shells. The shells are rigidly clamped at the ends and loaded with an internal uniformly distributed pressure [18].

When determining the SSS of two-layer cylindrical shells, they varied. Shear moduli and adhesive layer thickness.

As an example, a two-layer shell with a fiberglass reinforcing layer was calculated with the following parameters:

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- fiberglass and metal shear modules G112=5.5*103MPa, G113=4.2*103MPa, G123=0.35*103MPa, G212=G213=G223=7.87*104MPa,
- elastic moduli of fiberglass and metal E11=1.7*104MPa, E12=5*103MPa
E21= E22=2.02*105 MPa
- internal pressure q=0.1 MPa;
-Poisson's ratios of metal and fiberglass
μ212= μ221=0.3 μ112= μ121=0.4
- shell length l=30 cm;
- radii of the fiberglass and metal layer Rp=10.5cm Rm=10.3cm
- metal thickness hm=2.5mm
- thickness of fiberglass layer δn=0.95MM

The shear modulus of the seam GSH13 and GSH23 varied from 1 to 5*105 MPa,

An increase in the shear modulus of the seam by 1 times (from 50 to 500 MPa) will change the stress in the metal by 5.1%, and in the reinforcing (fiberglass) layer by 9.1%. With a higher shear modulus of the seam (for example, GSik=5*102 MPa), increase the shear modulus of the seam by a factor of up to 5.103 MPa changes the stress δ2β by only 0.12% [19].

It can be seen from the dependences obtained that the lower the shear modulus of the weld compared to the layer (Gshik < Gi (1), Gshik < Gi (2)), the greater the effect of the weld compliance on the stress-strain state, the more two-layer shells. An increase in the shear modulus of the weld by 10 times (from 50 to 500 MPa) changes the stress in the metal by 5.2%, and in the reinforcing layer by 7.5%.

At a higher shear modulus of the weld (Gshik =5 102 MPa), an increase in the shear modulus of the weld by a factor of 10 from Gshik =5 102 MPa to 5 103 MPa changes the stress σβ by only 0.08%.

Conclusion

It can be seen from the dependences obtained that the lower the shear modulus of the weld compared to the layer (Gshik < Gi (1), Gshik < Gi (2)), the greater the effect of the weld compliance on the stress-strain state, the more two-layer shells. An increase in the shear modulus of the weld by 10 times (from 50 to 500 MPa) changes the stress in the metal by 5.4%, and in the reinforcing layer by 8.3%.

With a higher shear modulus of the weld, an increase in the shear modulus of the weld by a factor of 10 from Gshik =5·102 MPa to 5·103 MPa changes the stress σβ by only 0.08%.

Thus, it can be noted that the shear modulus of the weld has a much lesser effect on the SSS of two-layer combined shells with a reinforcing layer at values of the shear modulus of the weld and layers close in magnitude [20].

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