

Modeling the deflection of a composite cantilever beam with varying reinforcement angle of unidirectional fabric

The paper presents a modeling of the stress-strain state of a composite cantilever beam taking into account the reinforcement angle.

Introduction.

In modern engineering, composite materials are gaining wider application due to their unique mechanical properties, such as high strength at low weight and resistance to corrosion. One of the pressing challenges is the study of the deflection of composite structures subjected to various types of loads. This article focuses on the modeling of the deflection of a cantilever beam made of composite material with unidirectional reinforcement. Special attention is given to the influence of the reinforcement angle on the structural behavior under load. The study of such parameters allows for the optimization of the design of composite elements, enhancing their performance and durability.

The modeling is carried out using numerical experiment methods, which make it possible to accurately predict the behavior of the beam at various reinforcement angles. The results of the study may be useful to designers and engineers working with composite materials in the aerospace, automotive, and construction industries.

The main part.

The object of the study is a cantilever beam 0.5 m long, 4.5 cm in diameter, with a wall thickness of 3.15 mm. The beam is formed by twenty-one layers of unidirectional fabric. The following options for the reinforcement angle are considered in the work. Fig. 1 shows a three-dimensional model of the beam under study.

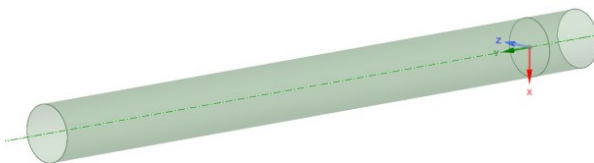


Fig. 1. 3D model of a beam

Twenty-one layers make up seven identical sets. In each set, the angle of the first and third layers changes, the angle of the second layer does not change and is 0° . The following combinations of angles are considered: $(0; 0; 0)$, $(+10; 0; -10)$, $(+20; 0; -20)$, $(30; 0; -30)$, $(45; 0; -45)$, $(90; 0; -90)$. In order to estimate the deflection from loading, loading with a concentrated force $F = 500$ N, torque $M = 100$ N m and complex loading with a concentrated force $F = 500$ N and torque $M = 100$ N m were considered separately. The loading scheme is shown in Fig. 2.

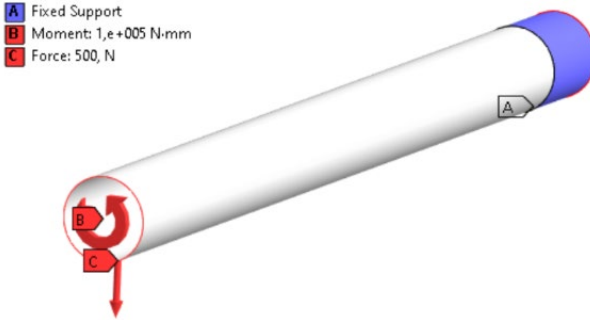


Fig. 2. Loading diagram

To simulate the loads of a composite beam, a mesh model was constructed (Fig. 3), the cell edge length is 3 mm, the mesh type is structured.

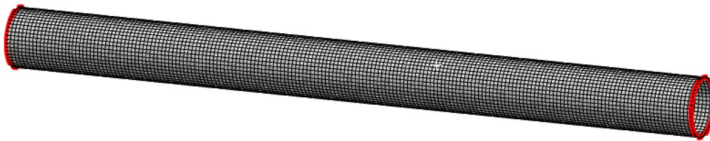


Fig. 3. Grid model of a beam

Fig. 4 shows visualizations of the distribution field of total deformations under loading with a concentrated force $F=500\text{N}$.

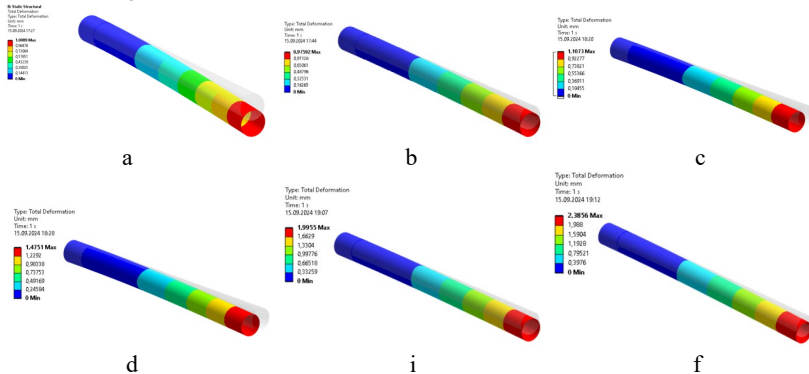


Fig. 4. Visualization of the distribution field of total deformations under loading with a concentrated force $F=500\text{N}$:
 a - combination of reinforcement angles $(0;0;0)$, b - combination of reinforcement angles $(+10;0;-10)$, c - combination of reinforcement angles $(+20;0;-20)$, d - combination of reinforcement angles $(30;0;-30)$, i - combination of reinforcement angles $(45;0;-45)$, f - combination of reinforcement angles $(90;0;-90)$

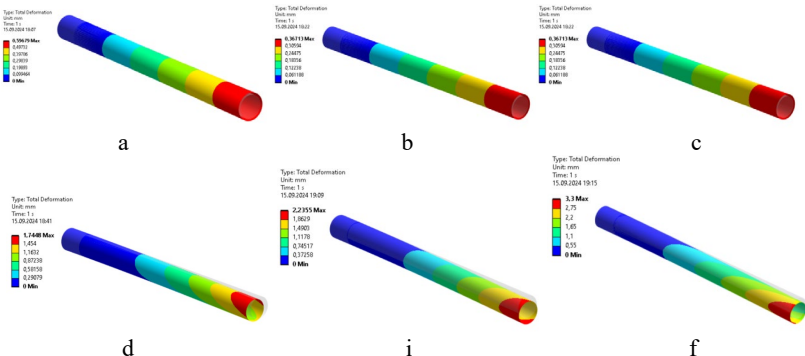


Fig. 5. Visualization of the distribution field of total deformations under loading with a torque of $M = 100 \text{ N}\cdot\text{m}$:

- a - combination of reinforcement angles $(0;0;0)$, b - combination of reinforcement angles $(+10;0;-10)$, c - combination of reinforcement angles $(+20;0;-20)$, d - combination of reinforcement angles $(30;0;-30)$, i - combination of reinforcement angles $(45;0;-45)$, f - combination of reinforcement angles $(90;0;-90)$

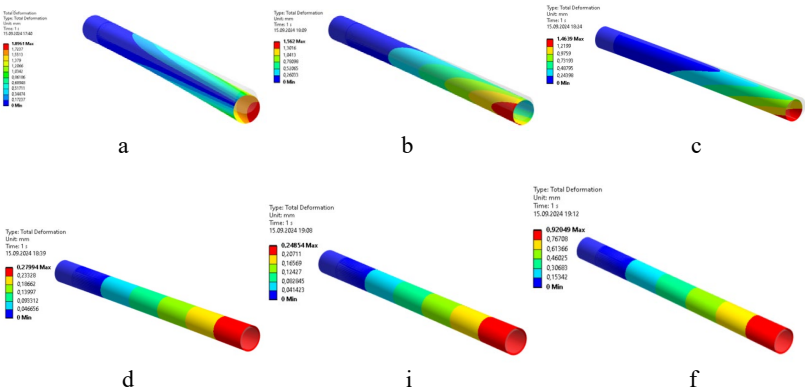


Fig. 6. Visualization of the distribution field of total deformations under complex loading:

- a - combination of reinforcement angles $(0;0;0)$, b - combination of reinforcement angles $(+10;0;-10)$, c - combination of reinforcement angles $(+20;0;-20)$, d - combination of reinforcement angles $(30;0;-30)$, i - combination of reinforcement angles $(45;0;-45)$, f - combination of reinforcement angles $(90;0;-90)$

The results of modeling the stress-strain state showed that the reinforcement angle of the composite beam affects the deflection value. To estimate the reinforcement angle, the dependence of the deflection value on the reinforcement angle of the first layer of unidirectional fabric of the sample was constructed (Fig.

7).

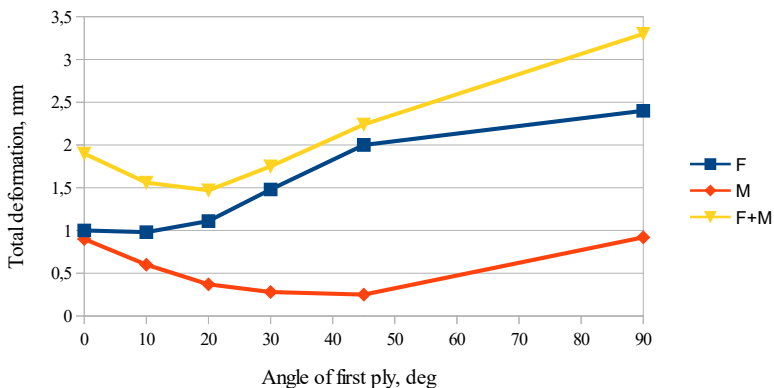


Fig. 5. Dependence of the deflection value on the reinforcement angle of the first layer of unidirectional fabric

When loaded with a concentrated force $F=500\text{N}$, the smallest value of the deflection is shown by the sample with a combination of reinforcement angles $(0;0;0)$ and $(+10;0;-10)$, with an increase in the angle, the total deformation also increases. When loaded with a torque of $M=100\text{Nm}$, the smallest value of the deflection is shown by the sample with a combination of reinforcement angles $(45;0;-45)$. With complex loading, the most optimal reinforcement angle is $(+20;0;-20)$.

Conclusion

The results of stress-strain modeling showed that the reinforcement angle of the composite beam affects the deflection value. In the future, it is planned to study the optimization of the shape of a composite beam of variable cross-section with an optimal reinforcement angle of unidirectional and bidirectional fabric.