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Non-Uniformly Scaled Buckling Modes of Reinforcing Elements in Fiber Reinforced Plastic

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Abstract—We consider a problem about non-uniformly scaled buckling modes of isolated fiber (without accounting of interaction with the surrounding epoxy) or bundle of fibers, which are structural elements of fiber reinforced plastics under the transverse tension (compression) and shear stresses in prebuckling state. Such initial state is formed in fibers and bundles of fibers at tension-compression tests of flat specimens from cross ply composites with unidirectional fibers. For problem statement we use equations recently constructed by reduction of consistent version of geometrically nonlinear equations of theory of elasticity to one dimensional equations of rectilinear beams. Equations are based on refined shear S. P. Timoshenko model with accounting of tension-compression stresses in transverse directions. We give theoretical explanation of developed phenomenon as reducing shear modulus of elasticity of fiber reinforced plastic during the increasing of shear strains. We show that under the loading process of specimens under review uninterruptedly structure reconstruction of composite trough implementation and uninterruptedly changing of internal buckling modes at changing wave parameter is feasible.

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For describing of the deformation process of fiber reinforced plastics, which is two-phase medium, the analytical model is extensively used in compliance with which fibrous composite is represented as multilayered structure with alternate stiff layers with thickness t and soft layers of epoxy with thickness h (Fig. 1). Under the tension with stress $\sigma_x = P$ of the specimen with cross-ply stacking sequence with angle $\pm 45^\circ$ to the tension direction (axis $\widetilde{x}$, Fig. 2), both in stiff and soft layer are formed shear $\sigma^0_{12} = P/2$ and normal $\sigma^0_{22} = P/2$ stresses, which compress composite's layers in transverse direction (Figs. 2, 3). If between fibers with average diameter of $d_f \sim 5 \div 10$ micrometers, which is part of bundle of fibers with average diameter $d_b \sim 0.1 \div 0.2$ mm, epoxy (adhesive layer) is absent, then formation in the bundle of fibers (i.e., in lamina of thickness t) stress σ^0_{12} may be due to dry frictional forces, which related with stress σ^0_{22} by Coulomb's law. With such formation mechanism of stress σ^0_{12} is quite clear the explanation of the process of reducing mean shear modulus G^+_{12} of the composite under the specimen's tension due to scheme shown on Fig. 2. The experiments show [1] that obtained curves $G^+_{12} = G^+_{12}(\gamma_{12})$ are rather nonlinear (Fig. 4).

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