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TECHNICAL STRENGTH THEORY OF ELASTIC COMPOSITE LAMINATES

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ABSTRACT

The simple strength theory of CFRP type laminates is proposed, which make possibly can be found the strain-strength properties of lamina *in situ* and assessment the laminates strength using end formulas without lamina-by-lamina analysis.
The simplified failure criterion of a lamina according to the condition of matrix fracture is given. This fracture occurs when the criterion function reaches its greatest value on a certain plane. On this critical plane stress vector has the smallest value and according to the point of parametric conical limiting surface [1, 2]. The parameter is inclination angle of critical plane to fibres plane. The relations for determining the material constants of this criterion from standardized tests or also determining they're *in situ* from the tests of check piece laminates or the witness samples are found. The equation for finding the orientation of the critical plane in case 3D stress is obtained. For cases where there are no tangential stresses across or along the fibres, the fracture criterion is given in final form, only through the components of the stress tensor. Also, explicit the criterion is given for a plane stress state. The stress ranges corresponding to the critical plane orthogonal or inclined to the plane of the fibres are determined. It is shown that for the orthogonal orientation of the critical plane, the obtained fracture criterion is linear, for inclined it is quadratic. An experimental verification of this criterion and its comparison with known fracture criteria for volumetric, plane and one-dimensional loads has been carried out. Its best correspondence to experimental data is shown that for many more complex criteria.
The simplest failure criterion of a lamina according to the condition fibre fracture is given [2]. This fracture criterion does not allow the paradox of increasing strength in the region of transition from fibre fracture to matrix fracture. The relations for determining the material constants of this criterion from standardized tests or also determining they're *in situ* from the tests of check piece laminates and the witness samples are found.
The relations governing the change of the failure lamina mechanisms from the destruction of fibers to the destruction of the matrix, and vice versa, are obtained. It follows from that the range action of the fibers in lamina increases along with the resistance of the matrix to shear along the fibers. On the other hand, the longitudinal strength of the lamina should not be too great. An experimental verification of this criterion and of the change of the mechanisms of failure lamina its comparison with known fracture criteria for one-dimensional loads has been carried out. Its best correspondence to experimental data is shown that for same more complex criteria.
Laminates of the CFRP type are considered in which the elasticity modulus of lamina across the fiber and the shear modulus in the plane fibers are negligibly small as compared to the elasticity modulus along the fibers [3]. Due to this circumstance, the end formula for the relationship between the elastic modulus of the laminate in each direction and the longitudinal elastic moduli of the laminas was obtained. If there is no delamination, then defects arise in the plane of the fibers. Formulas for calculating the ultimate strengths of each lamina under a given load on the laminate with typical layers layup (0, ±45, 90) are obtained. They are different for matrix or fiber fracture conditions. It is remarkable that these formulas like classical criteria do not directly depend on the elastic properties of the material. Following [4] it is shown that the calculation of the laminate strength is reduced to the calculation according to these formulas without layer-by-layer analysis. A distinction is made between the so-called primary and secondary strengths of laminate. Primary strength is determined by the first fracture of the matrix in any lamina. Secondary strength of laminate is determined by the first fracture

of fibers in any lamina or by the fracture of the matrix in any two laminas. The curves of primary and secondary strengths are presented depending on the direction of tension-compression of the laminate. For each load direction, laminas are identified, the failure of which defines the primary and secondary strength of the laminate. The predicted values are compared to available experimental data.

The problem of founded the elastic and strength properties of laminas in situ in the current state of the laminated structure is formulated [5]. A method to assessment the properties of lamina *in situ* is proposed. It based on direct test data of check of piece laminates and the witness samples of laminated structures. Formulas for calculating the mechanical properties of laminas are given. Examples of implementing this method are given and analyzed. The significant differences between the lamina properties in angle-ply laminated composite and those of the separately polymerized unidirectional layer is detected. These differences may be aggravated during the service life of laminated under the influence of operational cyclic, periodic and impact loads and climatic factors.

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