A NOVEL APPROACH FOR ANALYSING FLEXURE TESTS OF MULTIDIRECTIONAL LAMINATES

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Summary. This work deals with a new approach for determining displacement and stress fields of multidirectional laminates in three-point bending. The approach is based on Engesser’s theorems, taking into account hygrothermal effects.

Three-point bending of off-axis unidirectional laminates has been analysed by the author of this work [1,2]. As a result, a new method for determining in-plane shear properties has been proposed [3]. Nevertheless, the analysis based on energy theorems has not been extended to the case of multidirectional laminates.

Usually, mechanical testing in composite specimens is based on laminate configurations that prevent different types of coupling effects. In general terms, symmetric and balanced configurations are adopted for mechanical testing.

As the unique restriction in the case of flexure tests is related to the vertical displacement at supports, membrane axial and shear deformations are allowed in the case that coupling effects generate them. Then, axial and in-plane shear forces do not appear if friction effects are neglected and reactions have only vertical component at supports. These vertical reactions are related to bending and twisting moments that in a general multidirectional laminate are associated to all type of deformations. In a first approach, it is assumed that the contact between specimen and supports occurs at four corner points. In that case the problem is statically indeterminated of first degree.

The complementary strain energy that corresponds to a multidirectional laminate has been determined including out-of plane shear and hygrothermal effects, in terms of force and moment resultants per unit length. It is worth noting that even in the linear elastic case, complementary energy and strain energy are different due to hygrothermal terms.

In the particular case of a flexure test, complementary strain energy is obtained as a function of applied force, redundant unknown \( X \) and hygrothermal effects. Applying Engesser’s second theorem the redundant unknown \( X \) can be obtained. This force has physical
meaning only when it is positive. Equating $X$ to 0, it is obtained the limit condition for specimen to lift-off at supports. In this case the problem is statically determinated and specimen is supported at two diagonally opposed points, as shown in Figure 1.

Displacement field can be obtained by applying Engesser’s first theorem. In order to obtain moment derivatives, the configuration of Figure 1 is adopted as basic system for applying unit loads.

In the configuration of Figure 1 the determination of moments and shear forces can be carried out by simple static considerations. Thus, in-plane and out of-plane stresses coming form Laminated Plates Theory including shear effects can be determined.

REFERENCES

