Stress analysis for composite plate multibody system based on global-local higher order shear deformation theory

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Abstract

Laminated composite plate theories include the classical laminated plate theory, the first-order shear deformation theory, the global higher-order theory and the global-local higher shear deformation theory. Due to the neglect of the effects of transverse shear strains in the laminated plate based on the Kirchhoff assumption, the classical laminated plate theory is only proper for the very thin laminated composite plates. The first-order shear deformation theory (FSDT) has been attempted to take into account the effects of the transverse shear strain. However, these theories assume that the transverse shear strains are constant in the thickness direction, such that shear correction factors are considered to adjust the transverse shear stiffness. The accuracy of results obtained by the FSDT is mainly dependent on the shear correction factors. Although acceptable gross response and natural frequencies can be obtained, the shear stress results can not be accurately calculated by using FSDT.

In order to overcome the limitation of the classical laminated plate theory and the first-order shear deformation theory, the global higher-order plate theory (HSDT) has been developed. However, this theory is not of the layer-wise type, which does not satisfy the continuity conditions of transverse shear stresses between layers, and then a number of layer-wise plate models have been developed, which represent the zig-zag behavior of the in-plane displacement through the thickness. These models can provide accurate results of the displacement and stress at the expense of an increased number of unknowns with an increased number of layers. Because the number of variables depends on the number of layers, they are not computational efficient for laminated plates with large number of layers. The global-local higher-order shear deformation theory is composed of both global displacements and local displacements. The advantage of this theory is that by enforcing free conditions of the transverse shear stresses on the upper and lower surfaces, and displacements and transverse shear stresses continuity conditions at the interfaces, the number of unknowns can be reduced.

In this paper, the global-local higher-order shear deformation theory is extended to calculate the interlaminar stress of the laminated plate attached to a hub with rotational motion. The global-local 1,2-3 mode is employed in the formulation. In condition of satisfying the continuity of in-plane deformation and shear stress as well as the free conditions of the upper and lower surfaces, the number of the independent variables of each node is reduced to 13, which does not change with the number of plies. The displacement mode is then developed in rigid-flexible coupling dynamics for composite plate structure mutibody system, based on the hybrid coordinate formulation. By using the principle of virtual work, the dynamic equations for mutibody system are established which take into consideration the continuity of the interlaminar stress for laminated plate. Firstly, the results obtained by the global-local 1,2-3 displacement mode are compared with the exact solution in statics example to verify the accuracy of the global-local 1,2-3 displacement mode, through which the law that the interlaminar stress changes with thickness can be obtained, and then simulation example of a hub and laminated plate multibody system is used to show the difference results obtained by the present formulation, FSDT and HSDT to illustrate the necessity of considering the continuity of interlaminar shear stress.

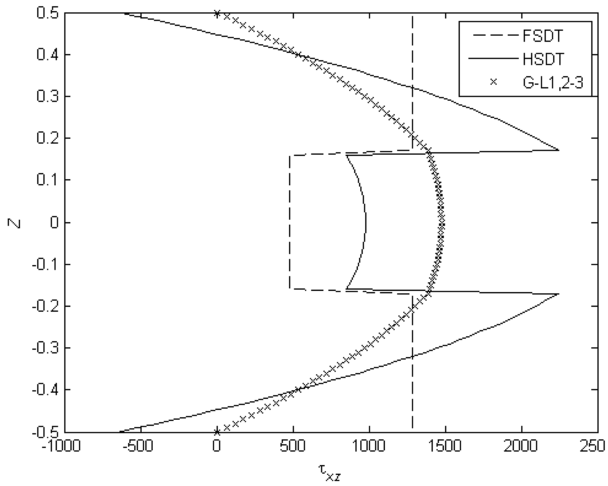

Figure 1: Comparison of shear stress results obtained by different models.

Figure 1 shows the transverse shear stress through the thickness of a laminated plate with three layers. Comparison of transverse shear stress results obtained by different models shows that the results obtained by the first-order shear deformation theory (FSDT) and the global higher-order plate theory (HSDT) can not satisfy the interlaminar stresses continuity conditions and transverse shear free conditions of upper and lower surfaces. The results obtained by the present formulation satisfy both the interlaminar stresses continuity conditions and transverse shear free conditions of upper and lower surfaces.

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