A CLOSED-FORM SOLUTION FOR THE POSTBUCKLING BEHAVIOUR OF COMPOSITE PLATE STRIPS UNDER INPLANE SHEAR LOAD

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In this contribution, the postbuckling behaviour of rectangular orthotropic composite laminated plates under inplane shear (see fig. 1, left) is treated in a closed-form analytical manner. The analysis approach presumes an infinitely long plate strip. Identical shape functions are employed for both the bifurcational buckling shape and the postbuckling deflections. The considered structural situation is representative for a skin section in a composite aircraft fuselage. Concerning the boundary conditions of the longitudinal plate edges, two sets of boundary conditions are considered, namely a plate with simply supported edges, and a plate with fully clamped edges (fig. 1, right).

The analysis approach is based on the two coupled partial Kármán-type differential equations that describe the postbuckling behaviour in terms of the postbuckling deflections and Airy’s stress function and that take initial plate imperfections into account. These differential equations result firstly from the requirement for compatibility of the membrane strains, and secondly from the requirement for out-of-plane equilibrium of a deflected plate element. Based on rather simple shape functions for the buckling shapes and postbuckling deflections of imperfect plates (see fig. 2 for an exemplary shape function), the compatibility
equation can be fulfilled explicitly. The equilibrium condition does not allow for an explicit solution so that it is fulfilled in an integral sense using a Galerkin-formulation. The analysis approach eventually allows for a closed-form representation of all state variables of the postbuckled imperfect plates. A comparison with nonlinear finite element calculations (see fig. 3 for some sample results) shows that the presented analysis approach enables an assessment of the postbuckling behaviour of imperfect composite plates up to load levels as they are relevant in aircraft engineering practice. This allows for a substitution of time-consuming full-scale nonlinear finite element calculations at least in the stages of preliminary design or in the framework of optimization procedures.

Figure 2: Buckling shape of a simply supported plate (so-called SS-plate) under inplane shear load.
Figure 3: Results for the postbuckling deflections of perfect and imperfect aluminum and orthotropic laminated composite SS-plates.