ABSTRACT

A twisted cantilever plate whose mid-surface is a right helicoid, is a structural element of considerable technical significance. Extensive practical uses of pretwisted plates can be found e.g., in turbomachinery, impeller and fan blades, marine propellers and windmills. In a weight sensitive application composite materials are advantageous because of their light weight, high stiffness and strength. Turbomachinery blades with low aspect ratio are idealized as rotating pretwisted cantilever plates. A profound understanding of the dynamic behaviour of composite pretwisted plates requires close attention in order to ensure safety of operation. Accordingly, the present work is aimed at investigating some aspects of the dynamic behaviour of composite pretwisted rotating plates such as free vibration, transient dynamic and associated failure characteristics.

A nine-noded three-dimensional degenerated composite shell element is developed for the present finite element formulation. The effects of transverse shear deformation and rotary inertia are also included. The direct Gauss quadrature integration scheme is used through the element thickness to account for the change in material properties from layer to layer within the element. The associated finite element code is accordingly modified for accurate computation of transverse shear stresses by employing a finite difference scheme to the stress equilibrium equations. The general dynamic equilibrium equation is derived by employing Lagrange's equation of motion and the investigation is carried out for moderate rotational speeds for which the Coriolis effect is negligible. A trigonometric increment of pretwist angle along the plate length is considered and the cubic polynomial approximation is assumed for pretwist angle along each elemental length. The finite element codes are developed for free vibration analysis, transient dynamic analysis due to low velocity impact and failure analysis of laminated composite pretwisted rotating plates. The modified Hertzian contact law is utilized to compute the contact force between the impactor and the laminated plate. The strength-of-material type failure criteria are adopted for the analyses and the total ply discount approach is used as the stiffness reduction model. These computer codes are utilized to generate numerical results. The static equilibrium equations and the generalized eigenvalue problem are solved

by Gauss elimination technique and subspace iteration algorithm, respectively. Newmark's time integration scheme is used for solving the time dependent equations of the plate and the impactor. The present finite element modelling is validated after performing a suitable convergence study and verification of the results with those existing in the open literature.

The vibration characteristics of laminated composite cantilever plates with exponentially varying thickness, and variable chordwise width are investigated for nonlinear pretwist. The results are primarily obtained for graphite-epoxy plates and they present the concise study of the influence of parameters such as rotational speed, fibre orientation, thickness ratio, aspect ratio, width to thickness ratio, angle of twist, skew and precone angles on the natural frequencies. Numerical solutions are obtained for transient response and stresses of laminated composite pretwisted rotating plates subjected to low velocity normal and oblique impact at the centre. Parametric studies are conducted to investigate the effects of angle of twist, rotational speed, laminate configuration, span to thickness ratio, precone angle and oblique angle on the impact response of graphite-epoxy composite pretwisted rotating plates. The numerical results are generated for predicting the first occurrence of ply failure and the post first-ply failure response of graphite-epoxy composite pretwisted rotating plates subjected to low velocity normal impact at the centre. The first-ply failure strengths of graphite-epoxy composite pretwisted rotating plates are also determined due to a centre point transverse load. The impact failure analyses and failure load computations are carried out in respect of pretwist angles, rotational speeds and laminate configurations. The results are discussed in detail and conclusions highlighting the important findings are made. The scope for future research in the area is also identified.