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On numerical analysis of composite and laminated cylinders of finite length subjected to partially distributed band load

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ABSTRACT

A simplified and accurate semi analytical – numerical model is presented here to investigate the behavior of cylinders of finite length subjected to partially distributed band load. A diaphragm supported laminated cylinder under symmetric load which is considered as a two dimensional (2D) plane strain problem of elasticity in (r, z) direction. The boundary conditions are satisfied exactly in axial direction (z) by taking an analytical expression in terms of Fourier series expansion. Fundamental (basic) dependent variables are chosen in the radial coordinate of the cylinder. First order simultaneous ordinary differential equations are obtained as mathematical model which are integrated through an effective numerical integration technique by first transforming the boundary value problem (BVP) into a set of initial value problems (IVPs). The proposed method is successful in handling the 2D and three dimensional (3D) elasticity problems involving wide range of loadings, material properties and mixed variables. For cylinders subjected to band load, the convergence study is carried out and presented for different harmonics. The numerical results obtained are also first validated with existing literature for their accuracy.

1. Introduction

A circular cylinder is such a structural element which is used extensively. Therefore, calculation of accurate state of stress in cylinder under various loading conditions is of considerable attention. The most studied stressed state is cylinder loaded with uniformly distributed pressure over it length. There is much less information for determination of state of stress in a zone of a circular area of its length. This makes the problem challenging to analyze. Before these cylinder devices are used in engineering design, it is very important that these are analyzed very accurately. For such a reason, present study focuses the analysis of composite and laminated cylinders subjected to band load using the simple yet accurate semi analytical cum numerical methodology. The uniqueness of this approach is: it first requires algebraic manipulation of basic elasticity equations like equilibrium, strain displacement and constitute equations. After this manipulation, this becomes the two point boundary value problem (BVP) which governs the behavior of finite length cylinder which is plane strain two dimensional problem in r, z plane and gives four first order simultaneous partial differential equations. Taking a clue from this development, an attempt is made here to extend the strategy of transforming the governing system of PDEs to a system of ODEs [1] for elastostatic problems; Preliminary involvement of such formulation for a class of classical shell problems is seen in the literature [2,3].

Recently [4,5], have obtained accurate stresses in laminated finite length cylinders subjected to thermo elastic uniformly distributed and sinusoidal load using similar numerical model. Also, with the same methodology, accurate numerical results for composite and sandwich narrow beams were obtained by Kant et al. [6]. Some of the literature pertaining to problem of a cylinder is described as follows. The classic problem of an infinitely long elastic cylinder of an isotropic material under internal and external pressure was analyzed first by Lame in 1847 given in Ref. [7] and by Lekhnitskii [8] for anisotropic and layered materials in his book. This particular problem has been studied by many during later years. Ref. [9] obtained stresses and displacements by the use of 3D elasticity theory and several shell theories in a long isotropic circular cylinder subjected to an axisymmetric radial line load externally and compared results with the shell theories of Love and Flugge. An elasticity solution by using a Love function approach for semi-infinite circular cylindrical shell subjected to a concentrated axisymmetric radial line load at the free end were presented in Ref.

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