

## ABSTRACT

Turbomachinery blades are frequently subjected to gaseous or fluid impact in high-temperature aviation engines and power plants. Therefore, this blade material needs to be able to withstand impacts with high pressure and high velocity while being subjected to significant thermal loading. Nowadays, the development of diverse advanced materials with improved material properties is a major concern. Functionally graded material (FGM) is a high-tech composite material that is ideal for meeting this requirement. The application of FGM can avoid the frequent results of delamination, debonding, and fiber breakage in composite materials at very high temperatures. FGMs are composed of metal and ceramic constituents, with the metal part contributing to the material qualities of the FGM and the ceramic part providing protection against severe temperature and pressure. As a result, studying the free vibration characteristics of rotating turbomachinery blades built of FGMs under thermal gradient is quite important. Earlier the researchers have thought of the blades of turbomachinery as cantilevered twisted beams, however, this is quite inaccurate if the blade has a small aspect ratio, or if more than the first few frequencies and mode shapes are required. A beam representation totally eliminates chordwise bending modes. Other modes, particularly higher frequency modes, tend to be mixed rather than pure spanwise bending or torsion. A two-dimensional analysis is thus required for accurate description of such modes. A pretwisted conical shell having thickness variation along the longitudinal direction and cantilever boundary condition may be a better alternative. The twisted tapered conical shell made of FGM having some degree of porosity will make the model very practical and realistic.

The free vibration response of rotating pretwisted functionally graded (FG) conical shells in nonlinear thermal conditions is investigated using a finite element approach with the purpose of application in turbomachinery blades. The pretwisted conical shell with one metal and one ceramic constituent is functionally graded in its transverse direction with the aid of power, exponential, and sigmoid laws. In addition, the FG conical shell with one ceramic and two metal constituents is graded in both the thickness and longitudinal directions by following power-law function. Porosity distributions in FGMs can be categorized as even or uneven and temperature-dependent properties of materials are also functions of porosity distributions. The one-dimensional Fourier heat conduction equation is used to assess the nonlinear temperature distribution across the thickness of the FG conical shell. Finite element method (FEM) is introduced to discretise the conical shell in eight-noded isoparametric elements having seven degrees of freedom at each node. Two different mathematical models

based on trigonometric and polynomial higher order shear deformation theory is employed for evaluating element mass matrix, element stiffness matrices, and the equations of general dynamic equilibrium. Lagrange's equation is applied to kinetic and potential energy based formulations to derive the governing equation of motion of the cantilevered FG conical shell.

The mathematical analysis based on finite element formulations are employed to develop an in-house computer code to evaluate the natural frequencies of pretwisted porous FG conical shell in thermal environment. The results are validated with the available benchmark publications and the convergence study is also carried out to establish the exactitude of the model. A parametric study is explored to analyse the effect of porosity, power-law indexes, top surface temperature, pretwist angle, taper ratio and rotational speed on the natural frequency. The findings reveal that the porosity volume fraction has a significant influence on the natural frequency. The nonlinear temperature difference and pretwist angle both cause stiffness reduction to the FG conical shell upon increasing, whereas the presence of rotational speed inducts geometrical stiffness resulting in centrifugal stiffening. Moreover, mode shapes are developed to illustrate the modal displacements under the impacts of aforementioned parameters.