International Journal of Scientific Modern Research and Technology
(Volume: 4, Issue: 3, Number: 4)
ISSN: 2582-8150

Analysis of Graded Tapered Shaft Using Stress Analysis

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Abstract- Present work deals with the study of stresses developed in tapered functionally graded (FG) shaft system under both thermal and mechanical environment for three nodded beam element by using Timoshenko beam theory. The temperature distribution in radial direction is assumed based on one dimensional steady state temperature field by Fourier heat conduction equation without considering heat generation. Temperature dependent material properties are varied along the radial direction using power law gradation. Tapered FG shaft consists of rigid disk attached at its centre and shaft is mounted on two flexible bearings acts as spring and damper, inner radius of the tapered shaft is varying in x direction keeping thickness of hollow tapered shaft is constant. For the present analysis the Mixture of Stainless steel (SUS304) and Aluminum oxide (Al2O3) are considered as inner and outer surface material of the FG shaft. Three dimensional constitutive relations are derived based on first order shear deformation theory (FSDT) for Timoshenko beam element considering rotary inertia, strain and kinetic energy of shaft and gyroscopic effect.

Keywords: (FGMs), Power law index, Tapered shaft, (TBT), FEM,

I. INTRODUCTION

Composite materials are materials, composed of two or more fundamental materials with different properties, when combined to get a material with different properties than that of individual constituents. Composite material structures are more frequently used in engineering fields as their high strength to weight ratio and high stiffness to weight ratio is basically favorable for material selection. Main disadvantage with composite material is, weakness in interface between neighboring layers, which is popularly known as delamination phenomenon that may cause structural failure. To overcome this problem, a new class of material presented, named as Functionally Graded Materials (FGMs). FGMs are recognized as, whose material properties are varying in certain direction and thus overcome interface weakness. FGMs are defined as, the materials whose volume fractions of two or more materials are varied continuously along certain direction to attain required purpose. FGMs provide better material response and excellent performance in thermal environments like thermal barrier and space application, where it is used to protect space shuttle from heat generated during re-entry to Earth's atmosphere by modeling ceramic material at outer surface metal at inside surface.

II. PREVIOUS WORK

Schmauder et al. [2020] investigated mechanical behavior of ZrO2/NiCr 80 20 compositions FGMs are analyzed and compared with experimental results. And also found that new parameter matricity controls the stress level of composite, globally and also locally. analyzed time dependent heat conduction in no homogeneous FGMs. Laplace transforms technique is used to solve initial boundary value problem. Results obtained for finite strip and hollow cylinder having exponential variation of material properties.

Shao et al. [2019] presented stress analysis of FG hollow circular cylinder in combined mechanical and thermal environment by considering linearly increasing temperature. Temperature dependent material properties are considered and solution for ordinary differential equations are solved by Laplace transforms technique.

Farhatnia et al. [2018] presented stress distribution for composite beam having FGM in middle layer. Temperature dependent material properties are considered for uniform temperature gradient. Presented nonlinear analysis of FGMs in thermal environment by changing material variation parameter, aspect ratio, and boundary condition re analyzed with higher order displacement model. Nonlinear simultaneous equation is obtained by Navier's method and equations are solved by Newton Raphson iterative method.

Abotula et al. [2017] studied stress field for curving cracks in FGMs for thermo-mechanical loading. Using strain energy density criterion effect of curvature parameters, temperature gradients on crack growth directions, non-homogeneity values are found and discussed. Studied parametric study of FGM plate by varying volume fraction distribution and boundary conditions. Static analysis of FGM plate has studied by sigmoid law and compared with literature.

III. METHODOLOGY

Finite element analysis is to find field variables at each nodal point by approximate analysis, taking nodes within the elements. These variables is a function of values at nodal points of the element, this function is called as interpolation function or shape function. In present model three node one dimensional Timoshenko beam element is considered having six degrees of freedom at each node. Lagrangian interpolation function is used to approximate the displacement fields rotating shaft.

IV. CONCLUSIONS

Three nodded Timoshenko beam element has been implemented for modelling and analysis of FG tapered shaft by taking into account of structural damping and hysteretic damping in temperature environment. the temperature distribution is assumed based on one Dimensional steady state temperature field by using Fourier heat conduction equation without considering heat generation. Temperature dependent material properties are established by taking different power law index value.

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