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Analysis of a Graded Tapered Shaft Design: An Assessment

Akshay Anand[1], N. V. Saxena[2]
[1]Rsearch Scholar, [2]Assistant Professor
[1,2]Dept of ME, MIT, Bhopal, India

Abstract- Rotor dynamics mostly used to analyze the performance of a turbine shafts, jet engine to auto engines and computer storage disks. Basically Rotor dynamics deals with rotor and stator. Rotating part in mechanical devices are called rotors, which are supported on bearings, thus shaft rotate freely about its axis. Laminated composite materials contains of several layers of different fiber reinforced materials, bonded together to get the required properties like strength, stiffness, coefficient of thermal expansion, damping and wear resistance. By changing lamina thickness, material properties and stacking sequence preferred properties of the material can be achieved. As composite materials gives high stiffness to weight ration and high strength to weight ratio, which motives to use in weight sensitive structures. These kinds of structures carry improvement of their structural functions especially in aircraft and space applications.
Keywords: Rotor Dynamics, Jet Engine, Thermal.

1. 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.

Because of high strength, stiffness and low density material characteristics, brings an idea for replacing conventional metallic shafts with FGMs rotor shaft in many application areas like design of spinning components such as driveshaft in automobiles, jet engines and helicopters, turbine shafts and other rotating machineries. Composite materials have been validated both numerically and experimentally in rotor dynamics applications. Along with this various new advanced composite materials and material models for rotor shaft has been developed by researchers.

2. RELATED 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.

Kursun et al. [2016] presented stress distribution in a long hollow FG cylinder under thermo mechanical environment. By using infinitesimal deformation theory, solution for displacement model is found. Reveals effect of thermo mechanical coupling in FGMs plays an important role. Using von Karman theory, fundamental equation for shallow shells is obtained. Material properties and thermo mechanical stress field are determined.

3. PROBEM IDENTIFICATION

1. Many problems arise for traditional materials and composite materials can be significantly solved by using FGM.
2. Gradual variation of material properties in FGMs gives better stability. This new class of materials and their gradual changes in properties are used to design many components and applicable to many areas.
3. To study stresses developed in tapered shafts made of FGMs.

4. RESEARCH OBJECTIVES

Main objectives of present work has been laid down here,

1. Study of Material modeling for tapered FG shaft based on power law gradation. Modeling of temperature dependent material properties for FG shaft.
2. To study effect of Variation of mechanical properties with respect to temperature and power law indexes along radial direction.
3. To study stresses developed in tapered shafts made of FGMs. & Comparative study between tapered FG shaft and tapered Stainless Steel shaft.
3. To study the stresses developed both in thermal and mechanical environment for different speed, varying power law index value for FGM.

5. CONCLUSIONS

Due to the broad and rapidly developing field of FGM, these conclusions cannot encompass all significant directions, trends, and needs. Nevertheless, they reflect some of the observations of the authors based on the published research and their own analysis of the subject. Higher order shear deformation theory may be used to get precise results in case of thick beams. The most commonly used models for most of the literature that express the variation of material properties in FGMs is the power law distribution of the volume fraction. In practice, turbo-machinery blades are pre-twisted rotating blades. Hence the dynamic stability analysis of rotating pre-twisted blades may be undertaken as a future work of research. Moreover, the tapered beams can be considered for their parametric instability analysis. The study of dynamic stability of FGM beams considering material nonlinearity may be undertaken as a future work of research. Moreover, higher order stretching strain may be considered to include geometric nonlinearity. The problem that has to be addressed includes analysis of system under electro-thermo- mechanical environment as future work. The results obtained need to be verified with experimental results. Therefore experimental analysis of dynamic stability of functionally graded material beams may be taken as a future work in order to validate the used computational method and obtained theoretical results.

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