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Prediction of vibration response of functionally graded sandwich plates by zig-zag theory

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Abstract. This study is aimed to accurately predict the vibration response of two types of functionally graded sandwich plates, one with FGM core and another with FGM face sheets. The gradation in FGM layer is quantified by exponential method. An efficient zig-zag theory is used and the zigzag impacts are established via a linear unit Heaviside step function. The present theory fulfills interlaminar transverse stress continuity at the interface and zero condition at the top and bottom surfaces of the plate for transverse shear stresses. Nine-noded C-0 FE having 8DOF/node is utilized throughout analysis. The present model is free from the obligation of any penalty function or post-processing technique and hence is computationally efficient. Numerical results have been presented on the free vibration behavior of sandwich FGM for different end conditions, lamination schemes and layer orientations. The applicability of present model is confirmed by comparing with published results. Several new results are also specified, which will serve as the benchmark for future studies.

Keywords: finite element analysis; functionally graded material; sandwich plates; zig zag theory

1. Introduction

To withstand harsh environmental conditions, design requirement of incompatible properties like toughness and hardness, high melting point and strength, etc. at one place, generated a need of developing composite materials. Alloys have distinct material combinations, but alloying materials of different melting points is a difficult and impossible task (EI-Galy 2019). So, laminated composites (LC) which are a layer-by-layer combination of more than one material were developed. These were tested for thermo-mechanical loads and found to be good in withstanding stress conditions, having only drawback of material de-bounding at the interfaces (Garg and Chalak 2019). At the joining lamina, material properties were wide apart, so materials behaved differently (elongation) to the temperature elevation resulting in failure. To comply with stress failure at interfaces, functionally graded material (FGM) having a regular variation of material property was developed. The concept was applied firstly in 1984 for designing a thermal barrier in Japan (Koizumi 1997). FGM provides a way of controlling the material response by suitably choosing and varying material property. Different manufacturing methods of FGM are discussed by Owoputi (2018).

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