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Quasi-periodic excitation in a delaminated composite beam

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Abstract

In this paper the effect of quasi-periodic excitation was investigated on the dynamic stability of a delaminated composite beam. The quasi-periodic excitation was obtained by combining a longitudinal harmonic excitation with a random like transverse, in which case the the simplest approximation is the desired one. The mechanical model of the structure was created using the Euler-Bernoulli beam theory combined with possibility of axial deformation. The beam was discretized using the finite element method and stability charts for the global structure were determined using the largest Lyapunov characteristic exponent. The amplitude and frequency of the time dependent longitudinal force and displacement excitation, the length of the delaminated part and the amplitude of the beam end corresponding to the first mode shape were examined on the dynamic stability regions of the constrained mode model. The results were compared with the case when there is no transverse excitation using Bolotin's harmonic balance method. It was found that in case of small beam end amplitudes the results of the two methods is in good accordance.

Keywords: delamination, quasi-periodic, largest Lyapunov characteristic exponent

1. Introduction

Composite structures can be found in many fields of engineering, such as civil, mechanical and aerospace. Due to their heterogeneous structure the total or partial failure modes which occur in these designs are more diverse compared to the metal structures. One of the most common defect is delamination which may arise from fabrication imperfections or service time loadings. The presence of delamination may significantly change its integrity and mechanical properties such as stiffness and strength which in turn will affect the free and forced vibration characteristics of the structure. One of the first mechanical models for analysing the free vibration problem of split beams was introduced in [1]. The model contained four Timoshenko beams connected at the delamination tips, but the analytical model was missing a crucial element, the coupling of the transverse and longitudinal effects at the delamination tips which lead to significant discrepancy in the natural frequencies compared to the experimental results. The coupling effect was implemented by Wang et al. in [2] where the shapes and natural frequencies were computed. Hitherto the models which were later titled as free mode models produced unacceptable deformed shapes such as interpenetration of the top and bottom delaminated beam part and natural frequencies most frequently in case of unsymmetrical delamination. To avoid this unwanted phenomenon in [3] a constrained mode model was developed in which the transverse displacement of the delaminated portion is assumed to be identical. It was found that despite the artificial increase of stiffness introduced by the constrained mode the natural frequencies are much closer to the experimental results and the interpenetration of the top and bottom beams is avoided based on the constrained mode assumption [4]. By Della and Shu further investigations have been made in [5] where non-dimensional parameters have been introduced to study the free vibration characteristics of bimaterial beams.

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