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Influence of the initial imperfection on the non-linear buckling response of FGM truncated conical shells

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ABSTRACT

Non-linear buckling analyses of imperfect functionally graded truncated conical shells with simply supported boundary conditions and subjected to an axial compressive load have been presented in this work. The material properties of functionally graded shells are assumed to vary continuously through the thickness of the shell. The non-linear prebuckling deformations and initial geometric imperfections of an FGM truncated conical shell are both taken into account. The fundamental relations, modified Donnell type non-linear stability and compatibility equations of an imperfect FGM truncated conical shell are obtained and are solved by superposition and Galerkin methods, and the upper and lower critical axial loads has been found analytically. The numerical illustrations concern the non-linear buckling response of FGM truncated conical shells with different values of truncated conical shell parameters, initial imperfections and compositional profiles. Comparing the results of this study with those in the literature validates the present analysis.

1. Introduction

The buckling phenomenon of imperfect shells is one of the most challenging problems of the theory of elastic stability. It is now generally recognized that initial geometric imperfections play a dominant role in reducing the buckling load of certain structures. As is well known, an axially compressed thin shell is highly imperfection sensitive in this context (see, for example, the surveys [1–4]). A very useful bibliography can be found in these works.

The effects of geometric imperfections on the non-linear behavior of isotropic-homogeneous cylindrical shells have been thoroughly analyzed by a number of researchers. For example, the influence of geometric imperfections on the vibration frequencies and buckling loads of circular cylindrical shells under axial load were examined by Refs. [5–13]. As a common structure, the truncated conical shell has been widely applied in many fields such as space flight, rocketry, aviation, submarine technology, etc. The non-linear stability analyses of such shells are very important for their applications, and have been of considerable research interest in recent years. More research papers on the non-linear buckling and postbuckling behaviors of perfect homogeneous conical shells can be found in literature [14–21]. While the non-linear buckling behavior of perfect (with the initial imperfections disregarded) conical shells was extensively studied, its imperfect counterpart has so far, to the best of the authors' knowledge, attracted less interest [22–25]. However, all of these studies have been concerned with homogeneous materials.

A relatively new class of inhomogenous composite materials known as "functionally graded materials" (FGMs) first developed by the Japanese in the late 1980s is characterized by the smooth and continuous change of the mechanical properties from one surface to the other, Koizumi [26]. Due to its superior thermo-mechanical properties, FGMs have found extensive applications in various industries. Substantial research works have been done on the FGMs, Obata and Noda [27], Praveen and Reddy [28], Suresh and Mortensen [29] and Müller et al. [30].

Previous studies show that geometric nonlinearity plays and initial imperfections a significant role in the buckling behavior of homogenous shells. As the geometrical nonlinearity and initial imperfections is taken into account in the governing equations of inhomogenous shells, unpredictable behaviors may be occur. Therefore, it is of vital importance to study the influence of initial imperfections on the non-linear response of FGM shells. Limited works have been developed in buckling analysis of imperfect FGM structures. Most of these studies have been concerned with imperfect FGM plates and cylindrical shells. Shen [31] presented a static postbuckling analysis for imperfect FGM cylindrical shells with piezoelectric actuators subjected to axial compression in thermal environments. Mirzavand et al. [32] investigated the effect of imperfections on thermal buckling of functionally graded cylindrical shells. Shariat et al. [33] studied buckling of imperfect functionally graded plates under in-plane compressive loading. Huang and Han [34,35] studied buckling of perfect and imperfect functionally graded cylindrical shells under axial compression.

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