International Journal of Solids and Structures 48 (2011) 1034–1043

Contents lists available at ScienceDirect

International Journal of Solids and Structures

journal homepage: www.elsevier.com/locate/ijsolstr

Effect of multiple localized geometric imperfections on stability of thin axisymmetric cylindrical shells under axial compression

Limam Ali [a], El Bahaoui Jalal [b], Khamlichi Abdellatif [b,*], El Bakkali Larbi [b]

[a] Laboratory of Civil and Environmental Engineering, National Institute of Applied Sciences at Lyon, Albert Einstein Avenue, Villeurbanne 69662, France

[b] Modelling and Simulation of Mechanical Systems Laboratory, Faculty of Sciences at Tetouan, University Abdelmalek Essaadi, BP. 2121, M'hannech 93002, Tetouan, Morocco

ARTICLE INFO

Article history:
Received 31 March 2010
Received in revised form 25 August 2010
Available online 16 December 2010

Keywords:
Stability
Buckling
Shells
Finite element method
Localized imperfections
Analysis of variance

ABSTRACT

Stability of imperfect elastic cylindrical shells which are subjected to uniform axial compression is analyzed by using the finite element method. Multiple interacting localized axisymmetric initial geometric imperfections, having either triangular or wavelet shapes, were considered. The effect of a single localized geometric imperfection was analyzed in order to assess the most adverse configuration in terms of shell aspect ratios. Then two or three geometric imperfections of a given shape and which were uniformly distributed along the shell length were introduced to quantify their global effect on the shell buckling strength. It was shown that with two or three interacting geometric imperfections further reduction of the buckling load is obtained. In the ranges of parameters that were investigated, the imperfection wavelength was found to be the major factor influencing shell stability; it is followed by the imperfection amplitude, then by the interval distance separating the localized imperfections. In a wide range of parameters this last factor was recognized to have almost no effect on buckling stresses.

1. Introduction

Thin shells are used in many fields of civil and mechanical engineering such as structural components: silos, tanks. Whatever the manufacturing process is used for these structures, the final geometry is never perfect. Geometrical defects disturb always the ideal desired nominal form of the assembled shell. Control and optimization of manufacturing processes of shells make it certainly possible today to decrease imperfections amplitudes, but they could never eliminate them completely. Even if, at first guess, the geometry seems to be perfect, precise measurements enable to detect always small geometric imperfections with magnitudes having in general the same order of scale than shell thickness.

During their service life, shell structures may be subjected to various kinds of loadings, such as axial compression, external/internal pressure, flexure or torsion. For cylindrical shells under axial compression, stability is an important design factor, (Gaylord and Gaylord, 1984; EN 1993-1-6, 2007; EN 1993-4-1, 2007). Calculation of the buckling load as it could be affected by the presence of various kinds of geometric imperfections constitutes an essential task. The European standard on shell buckling (ENV 1993-1-6, 2007) and the recent ECCS Recommendations on Stability of Shells (2008) require that when a geometrically nonlinear shell analysis with explicit representation of imperfections is used for design, a range of potentially damaging imperfection forms should be explored.

Several studies have been reported in the literature which deals with the effect of imperfections on buckling strength of thin shell structures. Arbocz and Babcock (1969) have studied experimentally buckling of cylindrical shells subjected to general imperfections. They have shown that huge reduction of the buckling critical load could be obtained. Koiter (1982) has given a review study about the effect of geometric imperfections on shell buckling strength. Other extensive investigations have considered the problem of shell buckling where analysis of the effects of distributed or localised imperfections on reduction of the buckling load has been performed (Yamaki, 1984; Arbocz, 1987; Bushnell, 1989 and Godoy, 1993). Kim and Kim (2002) have considered a generalised initial geometric imperfection having a modal superposition form. By using Donnell shell theory, (Donnell, 1934, 1976), they have studied the buckling strength of cylindrical shells and tanks subjected to axially compressive loads on soft or rigid foundations, they have found that the buckling load decreases significantly as the amplitude of initial geometric imperfection increases.

The above mentioned references have assessed, in all cases, that imperfections reduce drastically the buckling load of elastic cylindrical shells when subjected to axial compression. The obtained reduction depends on the nature of initial geometric imperfection that was considered. In general, reduction of the buckling load was

* Corresponding author.
E-mail addresses: ali.limam@insa-lyon.fr (L. Ali), jalalpc2@yahoo.fr (E.B. Jalal), khamlichi7@yahoo.es (K. Abdellatif), elbakkali@fst.ac.ma (E.B. Larbi).

0020-7683/$ - see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ijsolstr.2010.12.007