024 - Computational formulations involving shell and other thin-walled structures

024 - 024 - Session 1: Computational formulations involving shell and other thin-walled structures

No: 911

Title: Weight Reduction of Corrugated Board under Preservation of Buckling Strength

Abstract: Boards made from corrugated paper offer very good weight specific stiffness and strength properties, because they implement the efficient sandwich construction principle in terms of thin sheets of paper. Therefore, they are used in large volumes for packaging purposes, an application which places high demands on the strength of the employed corrugated board containers.

The wide-spread use of corrugated paper suggests that even a small reduction of the weight per unit area of the board can lead to significant cost savings. This is the motivation for proposing a numerical procedure for the reduction of the weight of a given corrugated board design while preserving its buckling strength.

Corrugated board is a sandwich structure consisting of a wavy core called flute and face sheets called liners. It is prone to buckling both on the global level of the box walls and the local level of liner and/or flute. Global buckling of box walls can be avoided by prescribing a minimum effective bending stiffness which is strongly influenced by the overall thickness of the board. Local buckling of the flute, the cross-section of which is described by a sinus function here, can be prevented by adapting the wave length to amplitude ratio favorably, or by increasing the thickness of the flute paper. Local buckling of the liners can be delayed by increasing the thickness of the liner paper and by reducing the free width between the bonding lines between liners and fluting. It has to be noted that changes to the fluting or the liner may also influence the mode of interaction between those components.

The above-mentioned parameters can be varied by means of algorithms for constrained optimization in order to come up with a design that is lighter than the original one, but shows the same buckling strength. The difficulty herein lies in the determination of the effective buckling strength of corrugated board with respect to local buckling, because neither a closed form analytical expression for the critical loads of the fluting is available, nor can the interaction of fluting and liners be described in a straightforward manner. The generally orthotropic nature of paper complicates matters further.

In this paper, semi-analytical and numerical methods are employed for predicting the effective buckling strength of corrugated board. A periodic finite shell element unit cell model is employed for the discretization of a periodic board section. By application of appropriate periodicity boundary conditions, the effective mechanical behavior of a theoretically infinite board can be predicted within the limits of linear shell theory.

Embedding this model into numerical optimization procedures opens up the possibility of reducing the area-specific weight of the board by modifying the governing geometrical parameters while enforcing the constraints on the bending stiffness and the local buckling strength. The application of the proposed optimization scheme to a specific kind of corrugated board in order to determine if there is potential for weight-reduction is successful. The resulting set of geometrical parameters describes a modified design of corrugated paper with the same buckling strength, but an area-specific weight that is reduced by more than 18% with respect to the original design. The improved corrugated board shows simultaneous buckling of fluting and liners under a compressive membrane load along the generatrix of the flute.

Comments:

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