HOMOGENIZATION OF SANDWICH PLATES WITH CORRUGATED CORES FOR COUPLED SHEAR - TORSION PROBLEM

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Abstract:
The orthotropic sandwich plates such as corrugated cardboards are largely used in the packaging, naval and aeronautic fields. This kind of plates can be considered as 3D structures and modelled with shell elements, but the 3D modelling is too tedious and time-consuming. The homogenization allows one to obtain 2D equivalent homogenous plates so makes the modelling much more efficient. We should determine the equivalent global rigidities representing the relations between the generalised deformations and the resultant forces.

Many studies have been carried out on the homogenization models of corrugated cardboards [1-4]. Most of them were concentrated on the extension and bending. Several works were carried out on the transverse shear. There is nearly no work on the torsion of the sandwich plates. Because of the complicated geometry and boundary conditions, it is difficult to calculate the torsion rigidity even numerically. For the torsion problem of a gridworks, Timoshenko et al. have proposed an equivalent homogenous plate [5]. Inspiring from their model, we have presented an original model for the torsion problem of corrugated cardboards [6]. The basic idea is to decompose the torsion of the orthotropic plate into two beam torsions.

In this paper, we will extend this model to more complicated corrugated cardboards which are composed of 3 flat facings and 2 corrugated cores. The torsion curvature is equally decomposed into 2 torsion rates in the CD and MD directions (Cross and Machine Directions). In each direction, the torsion rigidity is calculated by the beam theory. We demonstrate the following relation between the plate torsion rigidity and the beam ones:

\[ D_{xy} = \frac{1}{L} \frac{\int G J_t}{4B J_0} \frac{G J_t}{G J_t} \]  
(L : length of the plate in x, B : width in y)

In a sandwich plate with a single core, the CD section can be considered as a closed thin wall beam section whose torsion rigidity can be calculated by the Bredt theory. But in a sandwich plate with double corrugated cores, we find that the two cores and the intermediate facing play an important role. Our new model consists in taking the two external flat facings as a closed thin wall section and taking the three internal layers as another closed section (Fig. 1). The superposition of these two torsion rigidities gives the torsion rigidity of CD section.

The torsion rigidity of the section MD is difficult to determine analytically. Our numerical calculations have shown that this rigidity is very small comparing to that of CD so negligible in equation (1). Thus the torsion rigidity can be analytically determined.
For a section non symmetrical through the thickness, the shear centre is not situated on the mid-surface. This leads to a coupling between the in-plane shear and torsion. In our study, we calculate these two rigidities at the shear centre without coupling, then make a transformation of variables to obtain their rigidities with respect to the mid-surface.

The global rigidities obtained by our homogenization model is introduced into the “User’s subroutine Ugens” of Abaqus for the efficient simulation of complex sandwich structures. The lateral buckling of a plate in corrugated cardboard is simulated in two manners: 3D simulation by shell elements (Fig. 2); or discretization of its mid-surface by the plate elements using our H-model. The comparison will show the efficiency and accuracy of the H-model.

REFERENCES