A FOURIER-RELATED MULTI-SCALE ANALYSIS ON MEMBRANE WRINKLING: THEORETICAL STUDY AND NUMERICAL APPLICATIONS

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Summary Recently, a new macroscopic approach has been proposed to modelise membrane wrinkling. By using the technique of slowly variable Fourier coefficients, the microscopic models are transformed into macroscopic ones that offer several numerical advantages, for instance, it significantly decreases the computational cost and makes it easier to pilot the non-linear calculations. However, as a reduced model, the proposed Fourier macroscopic approach could not perfectly consider boundary effects. To overcome this difficulty, we proposed a bridging technique to couple microscopic model on the boundary and macroscopic model in the bulk. By using the above technologies, we studied the following instability phenomena: instability of beams on non-linear Winkler foundation, global-local-coupling instability of sandwich structures and wrinkling of tensile membranes.

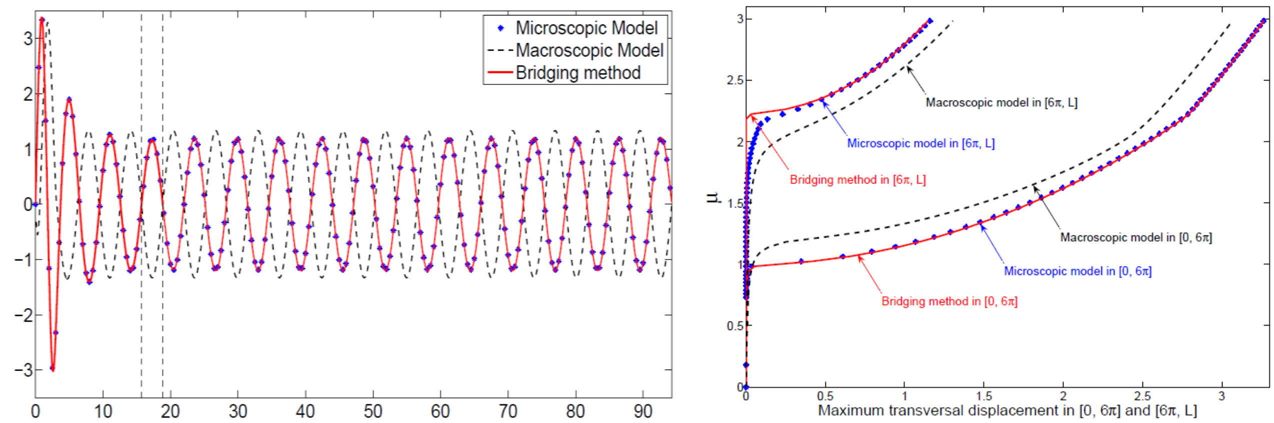
Introduction

Recently a new approach has been presented [1] that is based on the concept of Fourier series with slowly varying coefficients. By expanding the unknowns into Fourier series and evaluating only the Fourier coefficients, the computational efficiency improves a lot in contrast to microscopic models because envelopes vary much more slowly than instability patterns. Moreover, the use of harmonic functions allows one to select a priori the useful modal wavelength that makes it easy to pilot non-linear calculations. It has been established that the models obtained in this way are consistent with the Landau-Ginzburg technique, but they may remain also valid away from the bifurcation point and the coupling between global and local instabilities can be accounted for.
However, it's difficult to consider boundary effects in macroscopic models. To overcome this difficulty, we have introduced a bridging technique [2] to couple microscopic model on the boundary and macroscopic model in the bulk [3].

Numerical examples

In this paper, we present three instability examples: 1) Instability of a beam on Winkle foundation, 2) global buckling and local wrinkling of sandwich beam, 3) local wrinkling of biaxial load membranes.

A simply supported beam on Winkle foundation with a local defect near the boundary



(1-a) (1-b)

Fig. 1: Comparison between the microscopic model (723 DOFs), macroscopic model (33 DOFs) and bridging model (189 DOFs). In bridging model, the microscopic model is applied on the left and the coupling zone is between dot lines. 1-a) Instability patterns; 1-b) Bifurcation curves.

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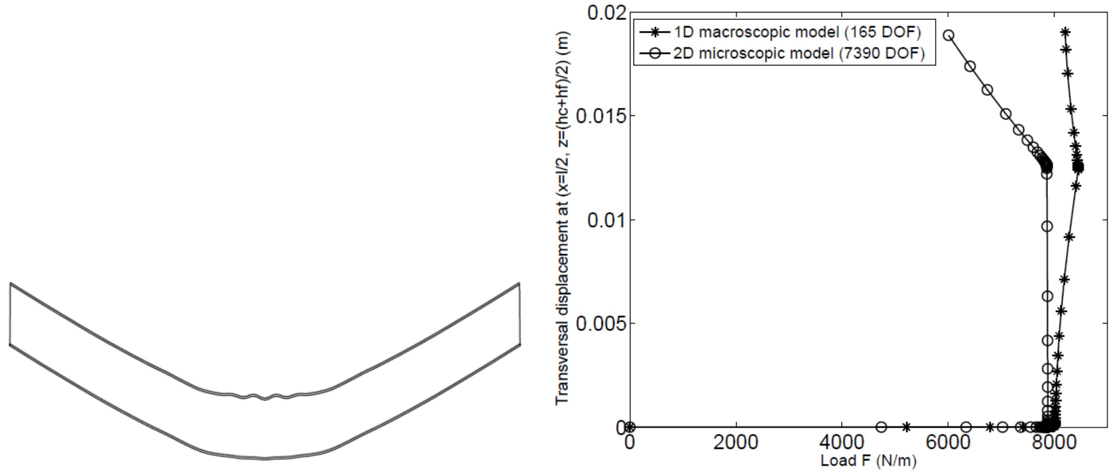
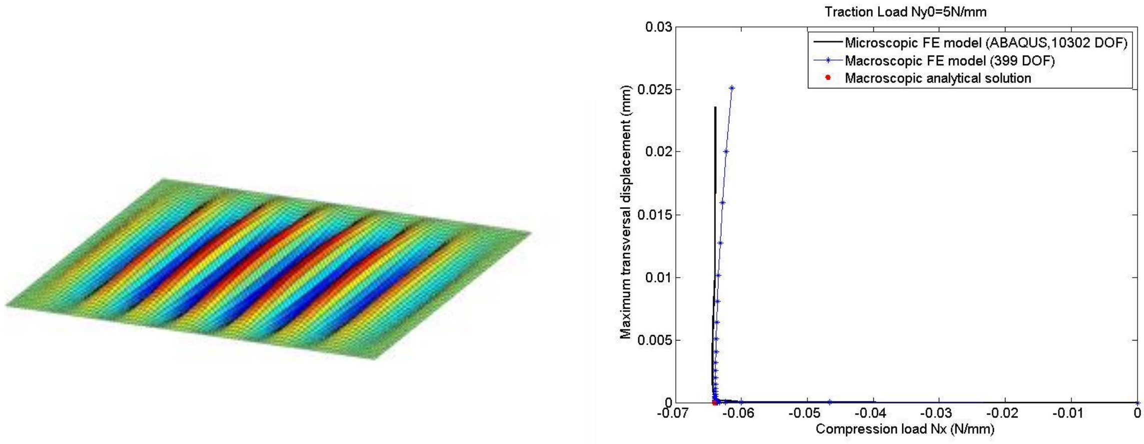
Global-local-coupling instability phenomena of a sandwich beam



(2-a) (2-b)

Fig. 2: Comparison between the 2D sandwich model and 1D macroscopic model. 2-a) Instability pattern obtained by 1D macroscopic model; 2-b) Bifurcation curves

Local wrinkling of biaxial load membranes



(3-a) (3-b)

Fig. 3: Comparison between the 2D macroscopic model and ABAQUS shell model. 3-a) Instability pattern obtained by macroscopic model; 3-b) Bifurcation curves

CONCLUSIONS

This paper applies the technique of slowly variable Fourier coefficients and the bridging technique to different instability phenomena. The computational efficiency and reliability are significantly improved in contrast to traditional models, especially treating with high wavenumber instability phenomena. At the same time, these techniques show a powerful ability to analyze almost all the instability problems with periodic spacial displacement field.

References

[1] Damil N. and Potier-Ferry M.: Influence of local wrinkling on membrane behaviour: a new approach by the technique of slowly variable Fourier coefficients. *Journal of the Mechanics and Physics of Solids* 58(8):1139–1153, 2010.

[2] Ben Dhia H. and Rateau G.: The Arlequin method as a flexible engineering design tool. International Journal for Numerical Methods in Engineering 62:1442-1462, 2005.

[3] Hu H., Damil N. and Potier-Ferry M.: A bridging technique to analyze the influence of boundary conditions on instability patterns. Journal of Computational Physics 230(10):3753–3764, 2011.