VIII International Conference on Marine Engineering
MARINE 2019

Homogenized and Non-Classical Beam Theories in Ship Structural Design – Challenges and Opportunities

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ABSTRACT

The presentation gives an overview of the recent developments on the application of homogenized, non-classical beam theories used to predict the micro- and macro- structural stresses in the design of marine structures. These theories become important when super-lightweight marine structures are being developed and one needs to computationally explore the design space also in regions where the length scales of openings are in the range of characteristic length of the beam or when we use lattice/frame-type of beams to reduce the weight of ship structures. The homogenization considers all steps of the derivation of the prevailing differential equations from kinematics to equilibrium with external loading. The resulting homogenised beam models are based on non-classical continuum mechanics that allow micro-rotation inside the beams. This added feature allows the treatment of size effects with great accuracy. The resulting analytical and finite element models have special features in terms of shape functions and iterative solutions in non-linear problems which we discuss in detail. The enhanced beam model enables accurate localization process that recovers the microstructural effects from the homogenized solution of the prevailing differential equations and is able to handle limit states of serviability (stiffness and vibrations) and ultimate strength (geometrical non-linearity). Moreover, we show applications to ultimate strength assessment of sandwich structures and describe where the beam and plate theories based on local continuum mechanics fail. The theory is validated by experiments and full 3D-FE-simulations on periodic beams and plates. The shortest beams tested have only 4-unit cell along their length, while the longest have 15. The theory converges to the physically correct solutions in the case of infinite and zero shear stiffness; especially the limit of zero shear stiffness is important as there the traditional Timoshenko beam theory fails to predict the response correctly. Lastly, we show the treatment of two-scale geometrical non-linearity and the power of the developed approach in terms of accuracy and speed.

REFERENCES

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