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Topology optimization of Thin-walled beam structures

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This paper presents a recent progress made in the design of thin-walled closed beams by the topology optimization method. The specific model in consideration is a ground-beam model, but the major achievement made in this study is the first implementation of a higher-order beam theory in simulating structural responses of thin-walled closed beams for topology optimization. Among others, the present investigation shows that only if one employs the present formulation based on a higher-order beam theory that is capable to represent cross-sectional deformations not included in the Euler or Timoshenko beam theory, the optimization result can be acceptable especially in torsion-dominant loading cases.

The physical aspects of the higher-order beam theory are such that sectional deformations such as warping and distortion, not considered in the existing beam theories, can be expressed by the theory. Thereby, the flexibility of beams, especially flexibilities at beam joints, are correctly represented. In the implementation of the beam-ground topology optimization based on the higher-order beam theory, there arises a big issue in field-variable matching at the connecting locations of ground beams; when sectional deformation-related kinematic variables are also included as the degrees of freedom in addition to the usual Timoshenko kinematic variables, these variables do not simply transform to the vector rule at a beam joint. Thus, how this issue can be addressed is presented in this study. Finally, there is also an issue related to the modelling of the existence of a beam through a continuous density variable defined in each and every beam because of the difficulty arising from the complexity coming from the joint matching condition mentioned above. Therefore, a method to overcome the issue has been developed and the details will be given. Several numerical examples are considered in this study to demonstrate the validity and effectiveness of the present new formulation.

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