IVE: A new method for stress evaluation during topology optimization

Henrik Svärd,
KTH Royal Institute of Technology, Sweden
Scania, Södertälje, Sweden

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Abstract

Much research in the field of topology optimization has in the later years been focused on efficient solution techniques for problems involving stress constraints. Although not yet fully developed, several methods exist to take stresses into account when optimizing a structure, both using local stress constraints and aggregated stress measures. However, one fundamental problem not exhaustively studied is how to correctly calculate stresses in the non-smooth structures that arise during topology optimization. The jagged structural boundary leads to artificially high stresses in the finite element solution, which may lead the optimizer to solutions that, when smoothed, are not optimal.

This talk presents a new method for evaluating stresses during topology optimization. The new method, Interior Value Extrapolation, IVE, exploits the fact that in the interior of the structure, the artificial stresses caused by the jagged structural boundary vanish, and as a result, the stresses calculated for the interior are more accurate than those calculated for the boundary. In order to eliminate the influence of the artificial stresses present at the boundary, the proposed method is based on extrapolating stress results for the boundary from results in the interior of the structure, resulting in a more stable and accurate stress measure.

The extrapolation of stresses from the interior to the boundary of the structure may be conducted in a number of ways. In this work, evaluating the stresses at points along a line pointing inwards from the element is proposed. A functional is fitted to the stresses along this line, and a stress value for the boundary element is estimated by extrapolating this functional. A fast method for calculating an approximate normal at each boundary element during a topology optimization process is also proposed.

To compare the accuracy of the extrapolation technique to a conventional stress calculation, a number of geometries are simulated, for which the stresses are known. It is shown that the new stress evaluation technique is more accurate than a conventional stress calculation, and that the impact of the jagged edges of the mesh is drastically reduced.

Finally, optimization examples are solved using the new stress evaluation process. The results are compared to an optimization using a conventional stress evaluation, and it is shown that nontrivial changes in the optimization result can occur when the stress evaluation is improved.

In conclusion, the proposed method for stress evaluation during topology optimization offers a significant improvement over existing methods in terms of accuracy, and is also shown to give rise to different structures.