Accepted Manuscript

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PII: S0045-7825(15)00174-7
DOI: http://dx.doi.org/10.1016/j.cma.2015.05.008
Reference: CMA 10621

To appear in: *Comput. Methods Appl. Mech. Engrg.*

Received date: 10 October 2014
Revised date: 2 May 2015
Accepted date: 6 May 2015

Optimal shape design of axisymmetric structures subject to asymmetric loading

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Abstract

This article describes an efficient method for the shape optimization of axisymmetric structures under asymmetric loads. Our method employs the semi-analytical method for both the primal and adjoint sensitivity analyses to convert the three-dimensional problem into a more manageable two-dimensional problem. By using the Kronecker product and the matrix and vector representations of fourth- and second-order tensors respectively, we obtain finite element formulas for the primal and sensitivity analyses that are succinct, can be readily programmed, and accommodate different element orders and topologies with minimal changes to the code. Instead of imposing local stress constraints on the surface of the component, as it is often done in shape optimization methods that update the design by deforming the mesh, we employ the stress p-norm over the body to approximate the maximum stress–a technique we borrow from recent developments in topology optimization. By doing this, we need not track stresses at specific locations of the body surface, nor impose many local stress constraints. To assess the procedure, the shape of axisymmetric cantilevers subject to a variety of loadings is optimized to minimize their mass subject to von Mises stress constraints; these designs are compared to analytical solutions obtained from beam theory. We also present a shaft shoulder design example

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