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Efficient robust shape optimization of imperfection sensitive structures using a second-order approximation of the variance.

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Design optimization is an emerging field in engineering as it allows reducing cost and environmental impact. Deterministic optimizations however tends to provide designs that are sensitive to deviation from the nominal configuration (i.e. load orientation, geometry, material properties ...). Especially structures that are prone to buckling, the optimal design can differ significantly from a design that is found under consideration of uncertain imperfection [1]. Various methods aim at optimizing designs that are not sensitive to imperfections, such as robust design optimization [2]. Here, a typical objective is to minimize the mean value and standard deviation of the objective function [2, 3].

Various methods are available for the determination of mean value and standard deviation. The Monte Carlo method is very accurate at the cost of high computation time. The First-Order Second-Moment method (FOSM) is based on a first-order Taylor series. It requires significantly less computation time at the cost of lower accuracy [3]. In certain situations, the FOSM approach fails to provide a robust design [4]. Alternatively, the Second-Order Fourth-Moment method (SOFM) can be employed, which is based on a second-order Taylor series. It is more accurate than FOSM, but it requires the Hessian of the objective function. The derivative of the robust objective hence even includes the third derivatives of the objective function. This computational cost for determining there derivatives scales quadratically with the number of random parameters [5].

In this presentation, the SOFM method is used in a more efficient way. The Hessian is approximated by the symmetric rank one update and the derivative of the robust objective is separated into expensive and cheap parts. The expensive part is approximated using the good Broyden method and the cheap part is calculated analytically. In order to improve the convergence of the Hessian, the imperfections are constructed in a way that the covariance matrix has low rank. The potential of this method is demonstrated for various benchmark examples, including snap-through-problems.

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