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Shape optimization method for crashworthiness design based on Equivalent Static Loads concept

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Abstract

Shape optimization of parameterized thin shell structures is increasingly considered by automotive industry in order to face nonlinear dynamics problems like crashworthiness. Since the number of shape parameters is important, around 100 CAD parameters for the firsts 100mm of the front side member, traditional multidisciplinary optimization methods such as metamodeling techniques become less efficient due to expensive calculation times (e.g. crashworthiness time calculation of a full vehicle: around 20h/16 processors).

A way to get around the problem is to switch to gradient methods where the number of parameters has a reduced effect on the optimization cost. However, shape sensitivities are often hard and costly to calculate for highly nonlinear problems.

Inspired by the Equivalent Static Loads Method [1,2], we defined linear static problems, equivalent to the nonlinear dynamic problem under quasi-static and quasi-proportional loadings (reversibility) hypotheses [3], on which we perform a shape sensitivity analysis. After linking sensitivity maps with CAD parameters, gradients are used as descent directions for the nonlinear objective function. We applied successfully the method to two test cases: minimization of a nodal displacement and maximization of the energy absorbed by a part of a thin shell beam. Both correspond to crashworthiness specifications: minimize the penetration into the passenger compartment and ensure a good behaviour of the crash scenario.

Because the calculation of the descent direction is inexpensive, this new optimization method allows doing crashworthiness optimization studies with a large number of parameters. This approximated gradient could also be used to improve metamodeling methods.

References

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