Various Methods for Structural Optimization Problems with Industrial Applications

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ABSTRACT

We consider an industrial application consisting of the mass minimization of a frame in an injection moulding machine. This frame has to compensate the forces acting on the mould inside the machine and has to fulfill certain critical constraints. The deformation of that frame with constant thickness is described by the plain stress state equations for linear elasticity. If the thickness varies then we use a generalized plain stress state with constant thickness in the coarse grid elements. These direct problems are solved by an adaptive multigrid solver.

The mass minimization problem leads to a constrained minimization problem for a non-linear functional which will be solved by some standard optimization algorithm which requires the gradients with respect to design parameters.

For the shape optimization problem, we assume that the machine components consist of simple geometrical primitives determined by a few design parameters. Therefore, we calculate the gradient in the shape optimization by means of numerical differentiation which requires the solution of approximately 4 direct problems per design parameter. The adaptive solver guarantees the detection of critical regions automatically, and ensures a good approximation to the exact solution of the direct problem.

A different strategy has been implemented for optimal sizing problems. Here, we have to handle hundreds of varying thickness parameters in the optimization problem which makes numerical differentiation non-competitive. The first approach to calculate the gradient quite fast consists in using Automatic Differentiation (AD) of our direct problem solver. This approach works fine for direct solvers for the direct problem but requires huge memory and disk capabilities to handle iterative, and especially adaptive solvers. The other approach consists in writing the total derivative of the functional and get many partial derivatives by solving only one adjoint problem by means of our adaptive solver. Unfortunately, one may have to handle and implement huge expressions for other partial derivatives so that this approach is only useful for rather simple functionals.

The best solution seems to be the combination of AD and the adjoint method such that derivatives with respect to the differential equations will be handled by the adjoint method and all remaining derivatives by AD. Using this hybrid technique instead of a pure AD approach we achieved an acceleration by factor 4. The optimal sizing can also be used for finding an initial guess for the shape optimization.

REFERENCES

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