Submitted abstract for the 10th World Congress on Structural and Multidisciplinary Optimization,
in Orlando-Florida, May 19-24, 2013

Hierarchical topology and shape optimization of crash-loaded profile structures

Christopher Ortmann, Axel Schumacher, University of Wuppertal, Faculty D – Mechanical Engineering, Group for Optimization of Mechanical Structures, Germany

In many areas of the structural design methods for topology optimization are applied very successfully but up to now the topology synthesis of crash-loaded structures is difficult. Responsible for this are among others the nonlinearities occurring during a crashworthiness problem such as large displacements and rotations, contact and nonlinear, velocity-dependent material behavior taking into account failure models. Furthermore the huge number of design variables, the existence of bifurcation points and the costly determination of sensitivity information cause problems.

One approach to overcome these problems for the optimization of profile cross-sections is the method of Graph- and Heuristic-based Topology Optimization (GHT) [1], which separates the optimization problem into an outer optimization loop for the topology optimization and an inner optimization loop for the shape and sizing optimization. In the outer optimization loop heuristics (rules) derived from expert knowledge modify the topology and the shape of the structure based on the results of finite element crash simulations. In the inner optimization loop the automatically generated shape and sizing parameters of the structure are optimized with mathematical optimization methods. The two optimization loops are hierarchically nested in each other following the concept of the Bubble Method [2].

During the complete optimization procedure the three-dimensional structure is abstracted by a planar mathematical graph. Hereby the geometric optimization problem is reduced to a two-dimensional one, although the structure itself and all performed finite element simulations are three-dimensional. All changes of the structure are performed to the graph representation and the graph is the basis for the automatic generation of finite element models for the finite element crash simulations. Algorithms of the mathematical graph theory are used to modify the graph representation of the structure and to monitor the adherence of manufacturing constraints.

The application examples include academic structures and industrial structures of the automotive industry.

The complex process of developing heuristics for the topological changes of the structure is discussed in another submitted independent contribution [3].

References

[1] Ortmann, C.; Schumacher, A.: "Graph and heuristic based topology optimization of crash loaded structures", to appear in Journal of Structural and Multidisciplinary Optimization, 2013

[2] Eschenauer, H.; Kobelev, V.; Schumacher, A.: "Bubble method for topology and shape optimization of structures", J Struct Optim 8 : 42-51, 1994

([3] Schumacher, A.; Ortmann, C.: "Rule generation for optimal topology changes of crash-loaded structures" 10th World Congress on Structural and Multidisciplinary Optimization, Orlando-Florida, May 19-24, 2013)

Keywords

Topology optimization - Crashworthiness - Rule-based approach - Heuristic approach - Graph theory - Expert knowledge - Optimization in nonlinear dynamics