Summary

Topology optimization is a technique that finds the optimal layout of the structure within a specified design domain. Substantial efforts and progress have been made in the development of topology optimization procedures and methods in recent years. The interest in this subject increased enormously, particularly since the publication of Bendsøe and Kikuchi (1988). There are several strategies for topology optimization, which use is often problem dependent. Topology optimization is most valuable as preprocessing tool for sizing and shape optimization. The appropriate topology of a structure in the conceptual or preprocessing phase is generally the most decisive factor for the efficiency of a new product.

Two types of topology optimization exist: discrete and continuous. For discrete structures, the optimum topology problem consists of determining the optimum positions, number and common connectivity of the structural members. In topology optimization of continuum structures, the shape of internal and external boundaries and the number of inner holes are optimized simultaneously. Roughly two classes of approaches can be distinguished, the Material- or Micro-approaches and the Geometrical- or Macro-approaches. In the Microstructure-approach, it is common to use a fixed finite element mesh to describe the geometry and the mechanical response fields within the entire allowed design domain. Containing whether each element should contain material or not is what the optimization consists, the so-called 0-1 problem, where 1 represents solid material and 0 void or very weak material. A well-known example of the microstructure (density-) approach is the SIMP model. The macrostructure techniques assume that the structure or component consists of solid, isotropic or anisotropic material. Within the Macrostructure-approach, the topology of a solid design domain can be changed in two ways; growing or degenerating material, or by inserting holes. One of the most explored macro-structure approaches is the Evolutionary Structural Optimization method (ESO).

Many different types of methods exist in the field of topology optimization, but not all the methods are also explored for three-dimensional topology optimization. Of course, every method has its advantages and disadvantages, and is more applicable for one or the other optimization problem. Therefore, there is not one method that is best suitable for all the various optimization problems. Topology optimization result could be a gray level image in discrete finite elements, which may cause difficulties in interpreting the topologies from a design point of view. Three-dimensional topology optimization results especially are difficult to interpret. For that reason a smooth, checkerboard free and clear topology that is possibly useful for later design stages, as interpreting into CAD models, has priority. Another important requirement is that the method is suitable for multi-objective optimization and is capable of solving problems within an admissible computation time. The methods that satisfy these demands quit well and are widely used in the field of topology optimization are the Simplified Isotropic Material with Penalization (SIMP) model, the Bi-Directional Evolutionary Structural Optimization (BESO), the level set method and the (two stage adaptive-) genetic algorithm.

The relatively new and unknown, but promising topology optimization methods are the generalized Cahn-Hilliard model, which is capable of multi-material optimization, the Topological-Shape Sensitivity Method, the Ant Colony Optimization (ACO), the Hybrid Cellular Automaton method (HCA) and the FETI-DP method.

A difficulty of topology optimization software is that commercial optimization software development has a different set of goals and constraints than the development of academic or industrial research codes. Commercial software has to contain a wide range of analysis options and should be able to handle large, real, industrial analysis models. For the different users of the software, the codes must perform in a robust way. Academic codes are often experimental in nature and do not care about issues such as ease of use, documentation and robustness. Proving a certain point of view is mostly the main goal of the development of academic codes. Although topology optimization can be and already is integrated into existing CAD and CAE environments, some key issues are still unsolved and need attention from an academic point of view.

Further investment in research into the well known and the relatively new methods will lead in the future to better and more useful results for industrial application.