Summary

Topology optimization is a technique that finds the optimal layout of the structure within a specified design domain. 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.

The described process in this report is a topology optimization problem for three-dimensional continuum structures. The used approach is similar to the microstructure approach (material distribution). 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. The density of material is used as design variable between these limits. The design variables tend to attain one of their limiting values (1 or 0).

The purpose of this study was to develop a universal and efficient topology optimization script for Ansys, which can be used for each finite element model. The optimization script should not only be able to deal with different topology models, but also be capable of applying different methods of optimization and various types of volume reduction. The developed optimization script has been tested successfully for all topology optimization structures in this report. Only, a careful choice of optimization parameters is necessary in order to acquire the intended results.

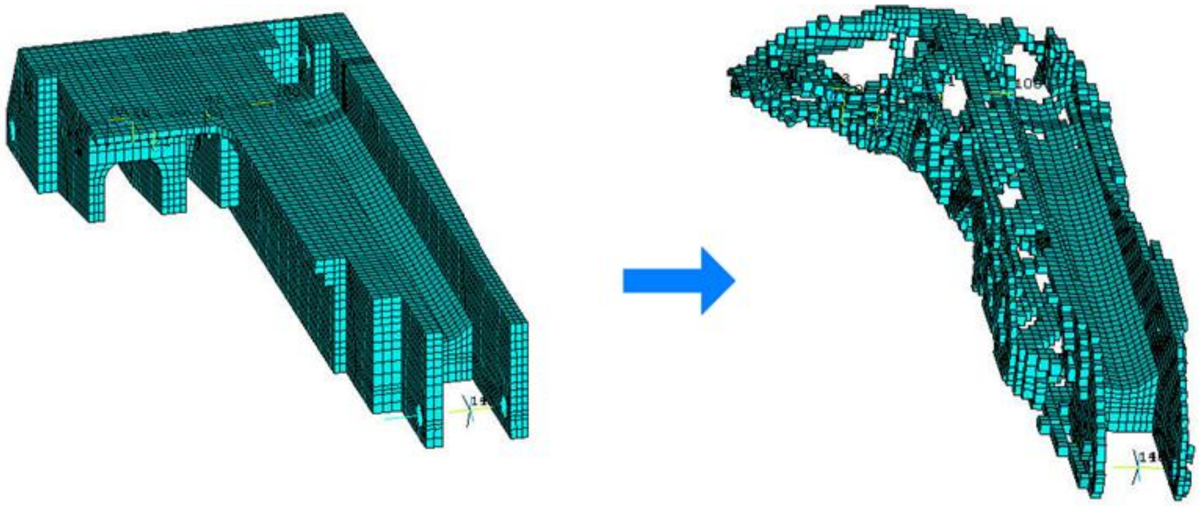

Figure 1 Transformation from initial design to optimal topology

One of the most important parameters is the method of optimization. The final optimal topology depends largely on this choice. The use of a strain energy based (stiffness) method is to be preferred because of better interpretable results. The considered examples showed that the strain energy based solutions have a lower mean compliance, and thus a larger stiffness. On the other hand, stress based solutions have a more uniform stress distribution.

This study showed that 15 iterations is usually sufficient to obtain a final structure. Optimization with more iterations, in case convergence is already reached, only costs extra calculation time, especially for models with a long calculation time.

When the process time is not really an issue or does not have priority, a large number of load cases is preferred due to the more realistic approach. When the process time is required to be as short as possible, a compromise might be found between the number of load cases (and thus indirectly the process time) and an acceptable optimal topology

The maximum allowable compliance and the intended minimum amount of mass reduction are of major importance to the choice of volume reduction. Only, when minimization of the compliance is equally or more important than minimization of the mass, it is adviceable to limit the amount volume reduction to about 0.80-0.85. Also, the product of the total compliance (stiffness) and total mass of the structure could be taken as benchmark for the performance of the optimization process. For the specific example of the cantilever beam (section 3.3.3), it was shown that a volume reduction of 0.88-0.90 leads to an optimum value for the volume reduction.

The method of volume reduction determines for a large part the development of the topology during the optimization process. A gradually reduction requires more iterations and thus more time before convergence occurs. When a choice has to be made between the different types of gradually reduction, type 3 (see section 3.4.4) obtains the best results. Considering the different properties of the structures obtained by the other methods of volume reduction, it can be concluded that direct reduction (type 0) has the most advantages.

The element size does not affect the symmetry of the structure. Both, for the large and for the small element size, the optimization process delivers symmetrical structures. Despite the benefits that a large element size has, such as a lower compliance and significant less computation time, a certain minimum element size is necessary. This particularly because of the read- and the usability of an optimal topology structure. Also, smaller element sizes deliver structures with a more uniform stress level.

The influence of the perimeter control was not examined in this report because of an extensive review about this subject in another study [5].

Recommended settings:

User defined parameters

Optimization method	Strain energy
Iterations	15
Volume reduction	0.85-0.90
Method of reduction	Direct (0)
Load cases	max
Penalty	3
Perimeter constraint	0

Recommendations:

- Development of a more time-efficient, universal perimeter control