

# Topology optimization of beam structures

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## INTRODUCTION

An engineer, who is designing structures, is always trying to design a structure with the highest possible stiffness to weight ratio. For beam structures the objective is to maximize the stiffness for a prescribed amount of material. To do so a program using the Finite Element Method (FEM) is designed, with the possibility of using simple beam elements and Timoshenko beam elements. The Timoshenko beam theory is used to allow for transverse shear deformation. The two beam theories are compared to each other and to solutions obtained using truss elements, to examine, which effect beam bending has on the structure. A further expansion of the program is the implementation of the topology optimization theory for beam structures.

## TOPOLOGY OPTIMIZATION

The method that is used is to lower the density of the elements that has no or close to zero stress in the element, and recalculate the structure, until the optimized solution is made. A detailed explanation on topology optimization can be found in Bendsøe and Sigmund (2003). The simplified flow chart for topology optimization is:

- Set the initial material distribution and the total material volume
- Loop over a defined number of iterations
  - Solve the finite element problem
  - Compute design sensitivities and update design
  - If difference between new and old density is small, break loop.
- End loop

The optimization, using the FEM program, of beam structures can help the engineer to design a structure that has the stiffness for a prescribed amount of material. If an engineer has to find the optimum solution of a structure by using a design domain of  $10 \times 10$  nodes by examining all possibilities, it would will be an unrealistic task, do the number of elements in the domain.

The reduction of material in the structure means that less energy and waste of the resources of the Earth will be used on producing the structure. If a vessel or container, which uses beams in the structure, will be using less energy of moving itself, and therefore can transport more goods and lower the  $CO_2 / (kg \cdot km)$  - value.

## CONCLUSION

The use of topology optimization can help the engineer to design a structure which has the highest stiffness by using a defined amount of material. The correct boundary conditions should be set for a given problem, and the FEM program made in this project has only the possibility to examined one load condition.

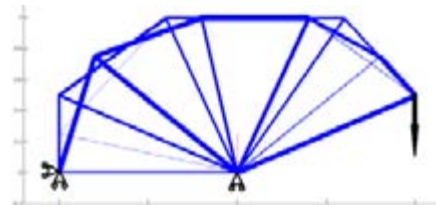


Figure 1, Optimized structure, A. Hamdan (2012)