

## Design Optimization

By Zafer Gürdal\* and Uwe Schramm<sup>+</sup>

Introduction of the methods of mathematical optimization into structural design in the early 1960's started a new era in automating engineering design. Since then, significant research in both the optimization methods and their implementations, and advances in numerical analysis techniques led to increased use of structural and engineering optimization in product design and development. Some of this increase can be attributed to widespread use of Finite Element Method (FEM) that can be used for efficient analyses of the structure/product on faster and faster computers and parallel processing machines. With the use of efficient sensitivity analysis, novel approximations, and fast reanalysis techniques, it is now possible to size structures modeled by millions of degrees-of-freedom linear FEM models using tens of thousands of design variables and constraints, and/or design their shapes and topologies.

The course is designed in two parts. The first part is an introduction to mathematical and algorithmic aspect of optimization and will start with a definition of the elements of structural optimization, along with a brief historical perspective. After introducing various algorithms for one and N-dimensional function minimization, concepts behind N-dimensional constrained optimization algorithms will be discussed. For design problems with costly analyses, computation of derivatives will be discussed next. This part will be finalized with a discussion of approximation and fast reanalysis techniques. The second part of the course concentrates on practical applications of Structural Optimization starting with a review of software implementations, and the role of optimization in design engineering. A number of applications from diverse field of engineering design will be presented.

\* Professor,  
Departments of Aerospace and Ocean Engineering  
Virginia Tech, Blacksburg, VA 24061  
Phone (540) 231-5905  
zgurdal@vt.edu

<sup>+</sup> Director of Engineering,  
Product Manager Optimization Products  
Altair Engineering Inc., Irvine, CA 92612  
Phone (949) 221-0936  
schramm@altair.com

# DESIGN OPTIMIZATION

By Zafer Gürdal and Uwe Schramm

## OUTLINE

### I – INTRODUCTION TO STRUCTURAL OPTIMIZATION

1. Elements of Problem Formulation
  - Design Variables, Objective Function, and Constraints
  - Standard Formulation and Special Cases
  - Graphical Representation
  - Potential Pitfalls in Optimization Formulation
  - Multiobjective Formulations
2. Optimization Algorithms
  - One-Dimensional Minimization
  - N-Dimensional Minimization
  - Constrained Minimization
3. Sensitivity Derivatives
  - Finite Difference
  - Analytical/Semi analytical Derivatives
4. Approximations
  - Local Approximations
  - Global Approximations
5. Fast Reanalysis Techniques

### II – PRACTICAL APPLICATIONS OF STRUCTURAL OPTIMIZATION

1. Review of Optimization Methods
  - Approximation Methods
  - Software Implementation
2. Optimization in the Design Process
  - Topology Optimization
  - Topography Optimization
  - Size and Shape Optimization
3. Optimization of Problems with Non-linear Physics
  - Contact problems
  - Crashworthiness
  - Sheet Metal Forming
  - Multi-disciplinary problems
4. Manufacturing Considerations in Structural Optimization
  - Topology Optimization
  - Topography Optimization
  - Weld Optimization
  - Layout of Automotive Structures
  - Casting Design