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Thesis Title: "Automated Design of Structures subject to Stress, Displacement and Temperature Constraints"
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Abstract

A simultaneous automated design procedure, for obtaining minimum mass design of thermally cooled structures subjected to combined thermal and mechanical loading with strength, displacement, thermal, minimum and maximum size constraints, is described. The procedure is based on a mathematical programming method using the sequence of unconstrained minimization technique (SUMT). A cubic extended interior penalty function (CEIPF) formulation that is designed to minimize the error in the approximation to the Hessian matrix is presented. Several other approximation concepts and the computation of analytical derivatives of constraints are described. In conjunction with Newton's method these concepts help reduce computational time and increase the order of the structural design problem that can be solved. With the application of CEIPF, considerable saving in terms of number of analyses is obtained. A methodology is presented for resizing plate elements, which exhibit nonlinear dependence of stiffness properties on the resized dimensions. An efficient optimization program, developed in connection with present work for solving static structural design problems including bending and involving a large number of design variables, multiple constraints, and under several alternate loading environments are also discussed.
Five example problems are considered.

- The first three are chosen to demonstrate the application of cubic extended penalty function formulation in obtaining the minimum mass design with a small total number of analyses.
- The fourth optimization problem in chosen to demonstrate the simultaneous design procedures for the design of a thermally cooled with wing box.
- The fifth problem presents the application of mathematical programming procedures for resizing plate problems involving bending.

Objective

The present research effort is directed towards the advancement of the application of efficient optimization techniques to general structural design problems. Based on this general idea, the effort described herein reflects contributions in the following four major directions.

1. Developing of an Efficient and dependable optimization scheme.

The first objective is the development of an efficient optimization scheme using SUMT to be applied in conjunction with any second order methods like Newton. A cubic extended penalty function formulation, designed to minimize the errors in the approximate of the Hessian matrix, is introduced for that purpose. The advantages in the use of the present formulation over the quadratic extended penalty function (91) (when applied with Newton Method) with regard to providing better performance and in reducing the number of needed analyses for a converged design will be demonstrated.

2. Introduction of a Novel Design Concept to problems of thermal designs.

Structures subjected to severe thermal loading, often require thermal control devices like active cooling system or heat shields. The second objective here is to extend the design capabilities to such problems. This is accomplished here by introducing the concept of design variables controlling nodal temperature. Mass penalties associated with these design variables are used to represent the mass of the temperature reducing devices (measured usually in terms of cooling inventory mass or pumping penalties.)

3. Development of a General Purpose Finite Element Based Structural Optimization Package for the Design of Complex Structural Systems.

The third objective is to develop an efficient optimization package applicable to general structures where the features discussed as in the first two objectives will be incorporated. PARS (Program for Analyses and Resizing of Structures), is the outcome of the combined effort devoted independently towards generation of a <u>static optimization capability</u> for the minimum weight design of structures subjected to static constraints (stress, displacement, and thermal constraints) and a <u>flutter optimization capability</u> for the design subjected to flutter constraints. The development of flutter optimization package for PARS is based on the SPAR finite element program [113], a very efficient and flexible finite element code and an optimization procedures based on the application of an extended interior penalty function formulation with Newton's method.

4. Inclusion of a Plate Element Resizing Capability.

The last objective of the present work is to add the capability of resizing plate finite element to PARS. Present automated design codes such as ACCESS [88] are limited to three conventional elements namely bar, membrane and shear panel finite elements, which exhibit linear dependence of the stiffness matrix on element thickness. The inclusion of plate element during resizing which does not have this linear dependence enhances the generality of PARS. It also provides the capability to solve a new class of structural optimization problems involving bending predominance.