The University of Iowa
College of Engineering
53:236 Optimization of Structural Systems
Spring Semester 2002

Assignment #7: **Due: 4/24/02**

Assignment:

Upon completing Assignment #6, you have a program which given micro-structural design parameters (a, b, θ), computes the set $(\mathbf{C}, \frac{\partial \mathbf{C}}{\partial a}, \frac{\partial \mathbf{C}}{\partial b}, \frac{\partial \mathbf{C}}{\partial \theta})$. The objective of this assignments is to use this program in implementing the homogenization-based continuum structural topology optimization formulation of Bendsoé and Kikuchi.

One slight change you should note is that each element will have three design variables (a,b,c) rather than (a,b,θ). This so that all of the design variables can be variables on the same closed interval [0,1]. The variables c and θ are related as follows: $\theta = \frac{\pi}{2}c$.

Overview of Assignment

When this multi-part assignment is completed, you will have a functioning software package of three integrated pieces:

a. SLP is the optimization driver which will call BESTOP with designs **b**, expecting to obtain function values and their design derivatives in return. **You will not need to make any changes to this program.**

b. BESTOP will receive the design vector **b** from the optimization driver, and it will then convert these into elastic moduli for individual finite elements in the analysis model. These elastic moduli will need to be written into a file called “MATERIAL.data”. BESTOP will then execute FENDAC which will read this file to obtain stiffness properties for each element. After execution is complete, BESTOP will read the resulting displacement field $\mathbf{u}(\mathbf{b})$ from the file “des.results”. BESTOPwill then compute the necessary function values (strain energy and global solid volume fraction) and their design derivatives. This information will be transferred conveyed back to the optimization program SLP. You will need to make a few changes to BESTOP and these will be discussed below.

c. FENDAC will serve as the analysis program. When it receives elastic moduli from BESTOP it will then solve the linear elastic structural analysis problem and write the displacement solution $\mathbf{u}(\mathbf{b})$ in the ASCII results file “des.results” which will in turn be read by BESTOP. **You will not need to make any changes to FENDAC . In addition, FENDAC should be run in standard execution mode without doing any sensitivity analysis for evaluation of topology functionals.**

Details on BESTOP modifications

BESTOP already does many of the tasks mentioned above in (b), so you will only need to make a few changes. In fact, all of your modifications to BESTOP will be contained within a single file (or subroutine) called plane.f

During each design iteration, BESTOP calls this routine a number of times to do different tasks. You need to be concerned with the following three:

ie = 1 During this stage, design BESTOP reconstructs the element connectivity data, and given the design variables for each element, it prints the elasticity tensor **C** to the FENDAC input file file "MATERIAL.data". You will need to provide the code for computing elasticity tensors and writing the results into "MATERIAL.data".

ie = 14 During this task, the displacement vector **u** and the adjoint displacement vector $\mathbf{u}^a = -\frac{1}{2}\mathbf{u}$ are passed to this subroutine. You will need to add the coding to compute both

$$\mathcal{F}_E(\mathbf{b}) \qquad \text{and} \qquad \frac{d\mathcal{F}_E}{d\mathbf{b}} = \int_{\Omega_s} \boldsymbol{\epsilon}^a : \frac{\partial \boldsymbol{\sigma}}{\partial \mathbf{b}}\, d\Omega_s.$$

For each finite element "i" you will compute the gradient and then assemble the result into the global design gradient vector which is a real array of dimensions "grad(3,numel)".

ie = 15 During this task, the objective is to compute both:

$$< \phi_{\text{solid}} >= \frac{1}{V}\int_{\Omega_s} \phi_{\text{solid}} d\,\Omega_s \qquad \text{and} \qquad \frac{d < \phi_{\text{solid}} >}{d\mathbf{b}}.$$

Again, your sensitivity results will go into the same global design gradient array "grad(3,numel)".

<u>More Details</u>

- It is recommended that you start out solving a very small problem involving only four elements. The starting FENDAC data file "des.data" and the starting BESTOP data file "bestop.data" for this problem are provided in the directory "/usr/ui/class/examples/cee5330/53_236/hw7".
- To make your own version of BESTOP you can copy the files "plane.f" and "makefile" from the directory "/usr/ui/class/examples/cee5330/53_236/hw7". After modifying the file "plane.f" you only need to type "make" to compile it and create the new executable BESTOP .
- BESTOP already does the following things which you will not need to concerned with:
  - it reads the current design **b** from the file "DESIGN" created by SLP;
  - it executes FENDAC and reads **u**(**b**) from "des.results";
  - it writes the objective function to file "OBJECTIVE", the constraint function value to "CONSTRAIN" and their respective gradients to files "OBJGRAD" and "CONGRAD";