Project 3 Documentation

**Problem**

In this project, the 88 line MATLAB code for topological optimization will be modified to solve a structural optimization problem with different boundary and loading conditions. The optimization problem aims to minimize the compliance or deflection of a rectangular structure while meeting a volume constraint and equality condition. The structure is divided into square elements all with the same element stiffness matrices. Each element has a density that can range from 0 to 1.

*where,*

*c(x) is the compliance,*

*U is the global displacement,*

*K is the global stiffness matrix,*

*V(x) is the material volume,*

*V0 is the design domain volume,*

*f is the volume fraction,*

*F is the force vector, and*

*xe is the density of an element*

**Support and Loading Conditions**

Shape, square

Description automatically generatedShape

Description automatically generated with low confidence

Dimensions:122 by 40 elements

Supports: (1) Fixed support on left side, (2) Rolling support at bottom center

Forces: (1) to simulate a distributed load, a 1N force was applied at 2/3 the length of the structure, (2) 1N force at the bottom right corner

% DEFINE LOADS AND SUPPORTS

F = sparse([2\*(nely+1)\*((2/3)\*(nelx+1))-(2\*nely),2\*(nely+1)\*(nelx+1)], …

[1 2],[-1 -1],2\*(nely+1)\*(nelx+1),2); %force on top at 2/3L and bottom right

% F = sparse(2\*(nely+1)\*(nelx+1),1,-1,2\*(nely+1)\*(nelx+1),1); % 1 Force

U = zeros(2\*(nely+1)\*(nelx+1),2);

fixeddofs = union([1:2\*(nely+1)],[((nelx/2)+1)\*(nely+1)]); %left side fixed, rolling bottom center

alldofs = [1:2\*(nely+1)\*(nelx+1)];

freedofs = setdiff(alldofs,fixeddofs);

**Material Properties**

%% MATERIAL PROPERTIES

E0 = 2; % Modulus of Elasticity for Low Alloy Steel = 2.0\*10^11 Pa Source:AmesWeb

Emin = 1e-9; % Minimum E assigned to void regions to prevent singularities

nu = 0.3; % Poisson's ratio for steel

**Results**

Optimized structure for various prescribed volumes:

V(x)/V0 =

**f = 0.25 f = 0.5**

Shape, rectangle

Description automatically generated with medium confidence**A picture containing graphical user interface

Description automatically generated**

**f = 0.6 f = 0.7**

**A black and white flag

Description automatically generated with medium confidenceA black and white flag

Description automatically generated with medium confidence**

When f = 0.7, the optimized structure does not provide a meaningful position as seen by the blurry region. This can somewhat be improved by reducing the filter radius at the cost of increased computation time for each iteration. Although slightly improved, the solution is not practical for manufacturing. Additionally at a certain point, the checkerboard pattern will emerge which is a mathematically sound, but impractical solution.

f = 0.7 after reducing the filter radius from 3 to 2:

A black and white striped flag

Description automatically generated with medium confidence

f = 0.7 after reducing the filter radius to 1.5:

A black and white striped flag

Description automatically generated with low confidence

f = 0.7 after reducing the filter radius to 1:

A picture containing text, clipart, vector graphics, screenshot

Description automatically generated

*Note: The sensitivity filter (not the density filter) was used for the above simulations.*