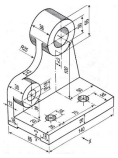
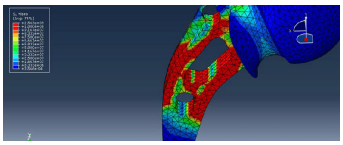
Practical Engineering Skills

CAD design



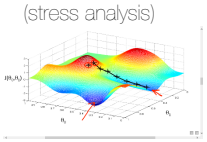
(engineering drawings)

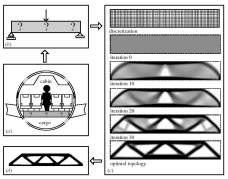
Finite Element Simulations



(stress analysis)

Gradient descent optimization
(TopOpt)





Altair

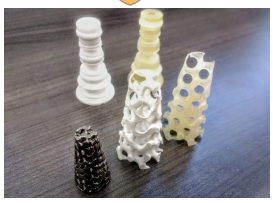
Additive Manufacturing
(future of industrial standards of manufacturing)

1

Mechanical Learning of Additive Manufacturing Parts

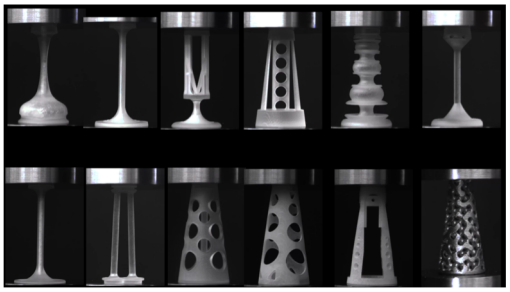
- Highlights of MATLS 2H04A (2018) – Structure Materials Design Project

McMaster University



Example of 3D printed parts
with different materials

Compression tests of students' designs
(video click to play: crushed samples will disappear)

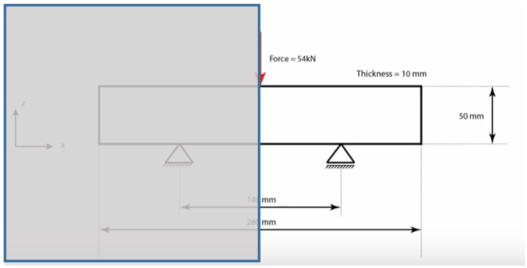


Sessional Instructor: Dr. Bosco (Hiu Ming) Yu, PhD
2018

2

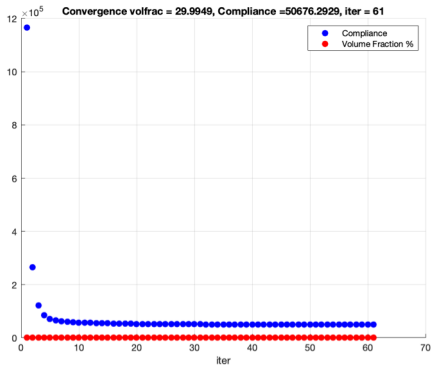
SMALL EXERCICE using top88.m

- Search the optimal 2D topology using symmetry
--> modify top88.m

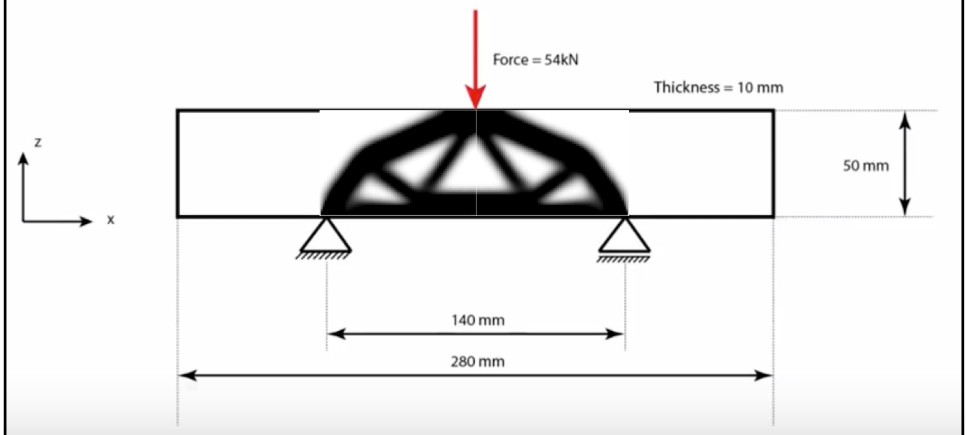


top88_ptBENDING(140, 50, 0.3, 3, 2, 2)

2Outputs



Outputs

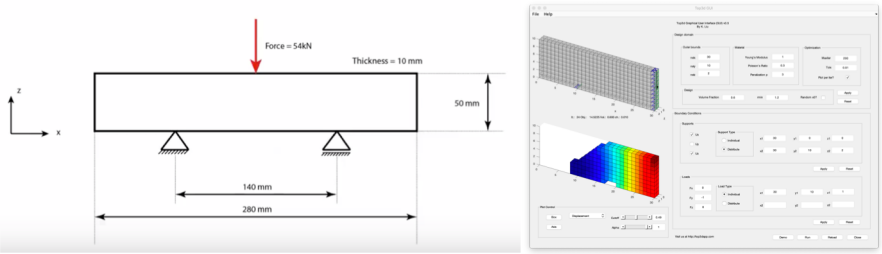



```
%%%% AN 88 LINE TOPOLOGY OPTIMIZATION CODE Nov, 2010 %%%%
function x=top88(nelx,nely,volfrac,penal,rmin,ft)
%% MATERIAL PROPERTIES
E0 = 1;
Emin = 1e-9;
nu = 0.3;
%% PREPARE FINITE ELEMENT ANALYSIS
A11 = [12  3 -6 -3;  3 12  3  0; -6  3 12 -3; -3  0 -3 12];
A12 = [-6 -3  0  3; -3 -6 -3 -6;  0 -3 -6  3;  3 -6  3 -6];
B11 = [-4  3 -2  9;  3 -4 -9  4; -2 -9 -4 -3;  9  4 -3 -4];
B12 = [ 2 -3  4 -9; -3  2 -9 -2;  4  9  2  3; -9 -2  3  2];
KE = 1/(1-nu^2)/24*([A11 A12;A12' A11]+nu*[B11 B12;B12' B11]);
nodenrs = reshape(1:(1+nelx)*(1+nely),1+nely,1+nelx);
edofVec = reshape(2*nodenrs(1:end-1,1:end-1)+1,nelx*nely,1);
edofMat = repmat(edofVec,1,8)+repmat([0 1 2*nely+[2 3 0 1] -2 -1],nelx*nely,1);
iK = reshape(kron(edofMat,ones(8,1))',64*nelx*nely,1);
jK = reshape(kron(edofMat,ones(1,8))',64*nelx*nely,1);
% DEFINE LOADS AND SUPPORTS (HALF MBB-BEAM)
F = sparse(2,1,-1,2*(nely+1)*(nelx+1),1);
U = zeros(2*(nely+1)*(nelx+1),1);
fixeddofs = union([1:2:2*(nely+1)],[2*(nelx+1)*(nely+1)]);
alldofs = [1:2*(nely+1)*(nelx+1)];
freedofs = setdiff(alldofs,fixeddofs);
%% PREPARE FILTER
[58 unmodified lines hidden]
  %% PRINT RESULTS
  fprintf(' It.:%5i Obj.:%11.4f Vol.:%7.3f ch.:%7.3f\n',loop,c, ...
    mean(xPhys(:)),change);
%
%
%
%
%
%
%
%
%
%
  %% PLOT DENSITIES
  colormap(gray); imagesc(1-xPhys); caxis([0 1]); axis equal; axis off; drawnow;
%
end
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
[26 unmodified lines hidden]
```

```
%%%% AN 88 LINE TOPOLOGY OPTIMIZATION CODE Nov, 2010 %%%%
%example top88_joseph(140, 50, 0.3, 3, 2, 2)
function x=top88_ptBENDING(nelx,nely,volfrac,penal,rmin,ft)
close all
%% MATERIAL PROPERTIES
E0 = 210e3;
Emin = 1e-9;
nu = 0.3;
thickness=10;
Force_amplitude=54e3;
%% PREPARE FINITE ELEMENT ANALYSIS
A11 = [12  3 -6 -3;  3 12  3  0; -6  3 12 -3; -3  0 -3 12];
A12 = [-6 -3  0  3; -3 -6 -3 -6;  0 -3 -6  3;  3 -6  3 -6];
B11 = [-4  3 -2  9;  3 -4 -9  4; -2 -9 -4 -3;  9  4 -3 -4];
B12 = [ 2 -3  4 -9; -3  2  9 -2;  4  9  2  3; -9 -2  3  2];
KE = thickness*1/(1-nu^2)/24*([A11 A12;A12' A11]+nu*[B11 B12;B12' B11]);
nodenrs = reshape(1:(1+nelx)*(1+nely),1+nely,1+nelx);
edofVec = reshape(2*nodenrs(1:end-1,1:end-1)+1,nelx*nely,1);
edofMat = repmat(edofVec,1,8)+repmat([0 1 2*nely+[2 3 0 1] -2 -1],nelx*nely,1);
iK = reshape(kron(edofMat,ones(8,1))',64*nelx*nely,1);
jK = reshape(kron(edofMat,ones(1,8))',64*nelx*nely,1);
% DEFINE LOADS AND SUPPORTS (HALF MBB-BEAM)
F = Force_amplitude*sparse(2,1,-1,2*(nely+1)*(nelx+1),1);
U = zeros(2*(nely+1)*(nelx+1),1);
fixeddofs = union([1:2:2*(nely+1)],[(nelx+2)*(nely+1)]);
alldofs = [1:2*(nely+1)*(nelx+1)];
freedofs = setdiff(alldofs,fixeddofs);
%% PREPARE FILTER
  %% PRINT RESULTS
  fprintf(' It.:%5i Obj.:%11.4f Vol.:%7.3f ch.:%7.3f\n',loop,c, ...
    mean(xPhys(:)),change);
figure(2)
hold on
plot(loop,c,'bo','MarkerFaceColor','b')
plot(loop,mean(xPhys(:))*100,'ro','MarkerFaceColor','r')
% plot(outeriter,(1+GKSl)*VM1,'ko','MarkerFaceColor','k')
title([' Convergence volfrac = ',num2str(mean(xPhys(:))*100),', Compliance =',num
grid on
legend('Compliance','Volume Fraction %')
xlabel('iter')
  %% PLOT DENSITIES
    figure(1)
  colormap(gray); imagesc(1-xPhys); caxis([0 1]); axis equal; axis off; drawnow;
  print(['DZ_it',num2str(loop,'%3d')],'-dpng')
end
%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

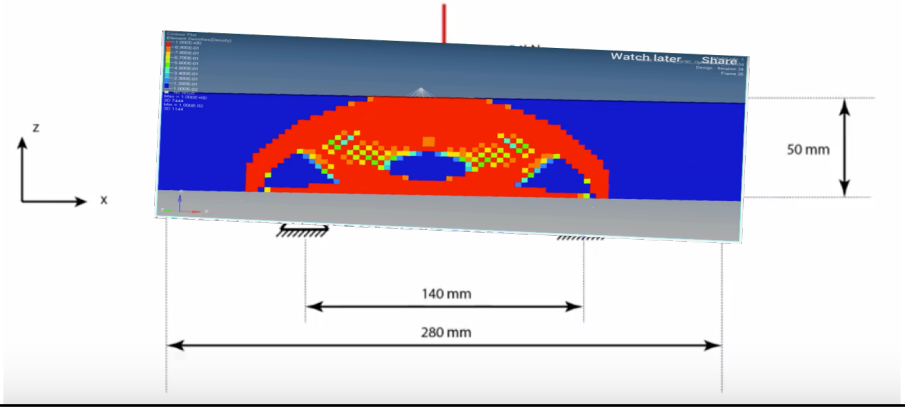
SAME EXERCICE using top3D

- https://top3dapp.com
- Search the optimal 3D topology using symmetry



A regarder … avant le 9…
OptiStruct

https://altairuniversity.com/13907-topology-optimization-tutorial-3-point-bending-of-a-beam-1d-



Bring your laptop with ALTAIR suite

https://altairuniversity.com/altair-student-edition-limitations/