**ME 610 -- HW1B**

**Clamped-Clamped Beam using NASTRAN**

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**OBJECTIVE**

The objective of this assignment is to construct a simple FEM model of a clamped-clamped beam using NASTRAN, and then to validate the results analytically. Two models will be made, one with 15 elements and one with 30 elements. The beam has dimensions of 40’’ x 0.25’’ x 1’’ (l x h x w). The beam is constructed of aluminum, E=10^7 psi , .

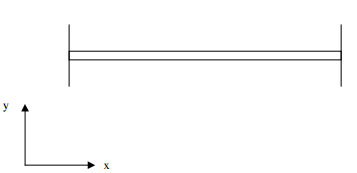
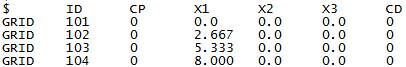


Figure 1- Model of the clamped-clamped beam.

**PROCEDURE**

NASTRAN was used to build the model. The nodes were equally spaced for both the 15 and 30 element models. For the bulk deck, the CBAR elements were made to align with the global coordinate system pictured above. Examples of the GRID, CBAR, PBAR and MAT1 commands for the bulk deck are shown below:







The model was constrained to motion in the x-y plane, with both its end nodes completely constrained. This was done by specifying the ASET and SPC1 commands in the ‘\*.dat’ file:





The next command is used to allow for imperial units.



The first 20 modes and frequencies were extracted from the models, along with the models corresponding mass and stiffness matrices. The modes and frequencies were calculated using MATLAB and the first 5 frequencies were compared.

The natural frequency was compared to the exact analytical solution, given by:

(1)

Where , and ,which is the mass per unit length. It was also compared to the natural frequency acquired by the Rayleigh quotient.

(2)

(3)

(4)

Where we are using an assumed shape of :

(5)

Which satisfies all 4 boundary conditions ().

When equation (5) is plugged into equations (2-4), we get:

(6)

**RESULTS**

Below are the tabulated results for the first 5 frequencies from the 15 and 30 element models, both for the NASTRAN and for the MATLAB calculations, along with the % difference between them. The %difference is relative to , as shown below (**all frequencies in Hz)**:

( 7 )

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Frequency # |  |  | % diff |  |  | % diff |
| 1 | 31.855 | 31.855 | 0.000 | 31.855 | 31.854 | 0.000 |
| 2 | 87.812 | 87.812 | 0.000 | 87.808 | 87.808 | 0.000 |
| 3 | 172.172 | 172.172 | 0.000 | 172.140 | 172.140 | 0.000 |
| 4 | 284.706 | 284.706 | 0.000 | 284.563 | 284.563 | 0.000 |
| 5 | 425.577 | 425.577 | 0.000 | 425.106 | 425.106 | 0.000 |

Table - Frequencies acquired via NASTRAN and MATLAB. No difference was found between them.

The table above shows that the eigensolver for NASTRAN and MATLAB yields the same results. The table below shows the % error when the frequencies are compared to the analytical solution (note the table has been shortened, since there is no difference between MATLAB and NASTRAN.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Frequency # |  |  | % error |  | % error |  | % error |
| 1 | 31.87 | 32.47 | 1.875 | 31.85 | -0.07 | 31.85 | -0.069 |
| 2 | 87.86 | - | - | 87.81 | -0.06 | 87.81 | -0.064 |
| 3 | 172.25 | - | - | 172.2 | -0.05 | 172.17 | -0.05 |
| 4 | 185.60 | - | - | 284.7 | 53.39 | 284.71 | 53.39 |
| 5 | 425.36 | - | - | 425.6 | 0.049 | 425.57 | 0.049 |

Table - Frequency error between the analytical frequencies and those found via NASTRAN/MATLAB.

Finally, the first 5 modes were plotted. The x-axis has been remapped to the physical location of the DOF.

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Figure - First 5 modes for both the 15 and 30 element beam.

**APPENDIX A – MATLAB & NASTRAN**

**MATLAB**

close all; clc; clear all;

load('hw1binfo');

% E = 10^7;

% I = 0.001302;

% p = 0.098;

% l = 40;

% Physical info in metric

A = 0.00016129;

E = 6.894\*10^10;

I = 5.4193\*10^-10;

p = 2712.63;

l=1.016;

w1 = sqrt(((E\*I)/(3\*A\*p))\*((2\*pi)/l)^4)/(2\*pi);

lam = [ 4.73004074; 7.85320462; 10.9956079; 11.41371655; 17.2787597];

wans = (lam.^2./(2\*pi\*l^2)).\*(E\*I/(A\*p))^0.5;

phys15 = 0:(2+(2/3)):40;

phys30 = 0:(1+(1/3)):40;

[phi15,v15] = eig(K15,M15);

[phi30,v30] = eig(K30,M30);

wnMAT15 = sqrt(diag(v15));

wnMAT30 = sqrt(diag(v30));

[wnMAT15,w15ind] = sort(wnMAT15,'ascend');

[wnMAT30,w30ind] = sort(wnMAT30,'ascend');

wn15hrz = wnMAT15/(2\*pi);

wn30hrz = wnMAT30/(2\*pi);

figure; hold on;

% subplot(1,2,1);hold on;

plot(phys15 ,[ 0; phi15(1:2:end,1); 0],'rx-');

plot(phys30,[ 0; phi30(1:2:end,1); 0],'ko-');

title('Mode 1');

ylabel('Amplitude');

xlabel('Physical location of Node (in)');

legend('15 Element Model', '30 Element Model');

figure; hold on;

% subplot(1,2,2); hold on;

plot(phys15 ,[ 0; phi15(1:2:end,2); 0],'rx-');

plot(phys30,[ 0; phi30(1:2:end,2); 0],'ko-');

title('Mode 2');

ylabel('Amplitude');

xlabel('Physical location of Node (in)');

legend('15 Element Model', '30 Element Model');

figure; hold on;

% subplot(1,3,1); hold on;

plot(phys15 ,[ 0; phi15(1:2:end,3); 0],'rx-');

plot(phys30 ,[ 0; phi30(1:2:end,3); 0],'ko-');

title('Mode 3');

ylabel('Amplitude');

xlabel('Physical location of Node (in)');

legend('15 Element Model', '30 Element Model');

figure; hold on;

% subplot(1,3,2); hold on;

plot(phys15 ,[ 0; phi15(1:2:end,4); 0],'rx-');

plot(phys30 ,[ 0; phi30(1:2:end,4); 0],'ko-');

title('Mode 4');

ylabel('Amplitude');

xlabel('Physical location of Node (in)');

legend('15 Element Model', '30 Element Model');

figure; hold on;

% subplot(1,3,3); hold on;

plot(phys15 ,[ 0; phi15(1:2:end,5); 0],'rx-');

plot(phys30, [ 0; phi30(1:2:end,5); 0],'ko-');

title('Mode 5');

ylabel('Amplitude');

xlabel('Physical location of Node (in)');

legend('15 Element Model', '30 Element Model');

**Beam15.blk**

$

ASSIGN MASTER='beam15.MASTER'

ASSIGN DBALL ='beam15.DBALL'

$

ID BEAM,MODES

SOL 103 $ Normal modes - superelements

TIME 30 $ 30 CPU minutes

DIAG 8 $ Print matrix trailers

DIAG 20 $ Print database fetch/store messages

$

$

CEND

TITLE =FIXED-FIXED 15 ELE BEAM

SUBTITLE =FINITE ELEMENT MODEL (FEM)

LABEL =NORMAL MODES ANALYSIS

$

ECHO = UNSORT $ Print unsorted bulk data deck

$

SEALL = ALL $ Required for SOL 103

SUPER = ALL $ Required for SOL 103

$

SPC = 10 $ Constrain to plane motion

METHOD = 70 $ First 20 modes

$

DISP(PLOT) = ALL $ Recover but do not print mode shapes

$

BEGIN BULK

$

$

$ PARAMETER CARDS

$ ---------------

$

PARAM AUTOSPC YES

PARAM GRDPNT 0

PARAM USETPRT 0

PARAM WTMASS .00259

PARAM COUPMASS1

PARAM POST 0

$

$

$ COMPUTE EIGENVALUES USING THE LANCZOS METHOD

$ --------------------------------------------

$

$ SID F1 F2 ND

EIGRL 70 20

$

$ SPECIFY ASET DOF

$ ----------------

$ C GID1 "THRU" GID2

ASET1 26 102 THRU 115

$

$ CONSTRAIN OUT-OF-PLANE MOTION

$ -----------------------------

$ SID C GID1 "THRU" GID2

$ SID C GID1 GID2

$ SID C GID1 GID2

SPC1 10 123456 101 116

$

$

$ BEAM BULK DATA

$ --------------

$

INCLUDE 'beam15.blk'

$

ENDDATA

**Beam15.dat**

$ GRID POINTS

$ -----------

$

$ 2 3 4 5 6 7 8 9

$

$ ID CP X1 X2 X3 CD

GRID 101 0 0.0 0.0 0.0 0

GRID 102 0 2.667 0.0 0.0 0

GRID 103 0 5.333 0.0 0.0 0

GRID 104 0 8.000 0.0 0.0 0

GRID 105 0 10.66 0.0 0.0 0

GRID 106 0 13.33 0.0 0.0 0

GRID 107 0 16.00 0.0 0.0 0

GRID 108 0 18.66 0.0 0.0 0

GRID 109 0 21.33 0.0 0.0 0

GRID 110 0 24.00 0.0 0.0 0

GRID 111 0 26.66 0.0 0.0 0

GRID 112 0 29.33 0.0 0.0 0

GRID 113 0 32.00 0.0 0.0 0

GRID 114 0 34.66 0.0 0.0 0

GRID 115 0 37.33 0.0 0.0 0

GRID 116 0 40.00 0.0 0.0 0

$GRID 117 0 2.786 0.0 0.0 0

$GRID 118 0 2.960 0.0 0.0 0

$GRID 119 0 3.135 0.0 0.0 0

$GRID 120 0 3.309 0.0 0.0 0

$GRID 121 0 3.483 0.0 0.0 0

$GRID 122 0 3.657 0.0 0.0 0

$

$ BAR ELEMENTS

$ ------------

$ 2 3 4 5 6 7 8 9

$

$ EID PID GA GB X1 X2 X3

CBAR 101 100 101 102 0.0 1.0 0.0

CBAR 102 100 102 103 0.0 1.0 0.0

CBAR 103 100 103 104 0.0 1.0 0.0

CBAR 104 100 104 105 0.0 1.0 0.0

CBAR 105 100 105 106 0.0 1.0 0.0

CBAR 106 100 106 107 0.0 1.0 0.0

CBAR 107 100 107 108 0.0 1.0 0.0

CBAR 108 100 108 109 0.0 1.0 0.0

CBAR 109 100 109 110 0.0 1.0 0.0

CBAR 110 100 110 111 0.0 1.0 0.0

CBAR 111 100 111 112 0.0 1.0 0.0

CBAR 112 100 112 113 0.0 1.0 0.0

CBAR 113 100 113 114 0.0 1.0 0.0

CBAR 114 100 114 115 0.0 1.0 0.0

CBAR 115 100 115 116 0.0 1.0 0.0

$CBAR 116 100 116 117 0.0 1.0 0.0

$CBAR 117 100 117 118 0.0 1.0 0.0

$CBAR 118 100 118 119 0.0 1.0 0.0

$CBAR 119 100 119 120 0.0 1.0 0.0

$CBAR 120 100 120 121 0.0 1.0 0.0

$CBAR 121 100 121 122 0.0 1.0 0.0

$

$ BAR PROPERTIES

$ --------------

$ 2 3 4 5 6 7 8 9

$ ID MAT A I1 I2 J

PBAR 100 100 0.25 1.30E-3 2.08E-2 4.38E-3

$ ID E G NU RHO

MAT1 100 10E6 .33 0.098