Author: John Singleton, Cornell University Problem Specification 1. Pre-Analysis & Start-Up 2. Geometry 3. Mesh 4. Physics Setup 5. Numerical Solution 6. Numerical Results 7. Verification & Validation Exercises Comments

# Pre-Analysis & Start-Up

## **Pre-Analysis**

The following equations give the frequencies of the modes and the mode shapes and are derived from Euler-Bernoulli Beam Theory.

$$\begin{split} w_n &= \alpha_n^2 \sqrt{\frac{EI}{ml^3}} \\ n &= 1, 2, 3, \dots \\ \alpha_n &= 1.875, 4.694, 7.855, \dots \\ m &= \rho V = \rho \cdot l \cdot h \cdot w \\ I &= \frac{w \cdot h^3}{12} \\ w_1 &= 1.875^2 \sqrt{\frac{70 \ E9 \ \frac{kg}{m \cdot s^2} \cdot \frac{0.346m \cdot (0.346m)^3}{12}}{\sqrt{2.7 \ E3 \ \frac{kg}{m^3} \cdot 4m \cdot 0.346m \cdot 0.346m \cdot (4m)^3}} = 111.7 \ \frac{rad}{s} = 17.8 \ Hz \\ w_2 &= 4.694^2 \sqrt{\frac{70 \ E9 \ \frac{kg}{m \cdot s^2} \cdot \frac{0.346m \cdot (0.346m)^3}{12}}{\sqrt{2.7 \ E3 \ \frac{kg}{m^3} \cdot 4m \cdot 0.346m \cdot 0.346m \cdot (4m)^3}} = 700.4 \ \frac{rad}{s} = 111.5 \ Hz \\ w_3 &= 7.855^2 \sqrt{\frac{70 \ E9 \ \frac{kg}{m \cdot s^2} \cdot \frac{0.346m \cdot (0.346m)^3}{12}}{\sqrt{2.7 \ E3 \ \frac{kg}{m^3} \cdot 4m \cdot 0.346m \cdot 0.346m \cdot (4m)^3}} = 1961.2 \ \frac{rad}{s} = 312.1 \ Hz \end{split}$$

$$\begin{split} y_i(x) &= \cosh(\frac{\alpha_i x}{L}) - \cos(\frac{\alpha_i x}{L}) - \sigma_i(\underline{\sinh}(\frac{\alpha_i x}{L}) - \sin(\frac{\alpha_i x}{L})) \\ \alpha_i &= 1.875, 4.694, 7.855, \dots \\ \sigma_i &= 0.73409, \ 1.018647, \ 0.9992245, \ \dots \end{split}$$

## Start ANSYS Workbench & Load Files

In this section we will launch ANSYS Workbench and then load the project file, "cantilever.wbpj" that was created in the "Cantilever Beam" tutorial.

Start > All Programs > ANSYS 12.1 > Workbench

### File > Open

Then choose the "cantilever.wbpj" file that you created in the "Cantilever Beam" tutorial.

### Management of Screen Real Estate

This tutorial is specially configured, so the user can have both the tutorial and ANSYS open at the same time as shown below. It will be beneficial to have both ANSYS and your internet browser displayed on your monitor simultaneously. Your internet browser should consume approximately one third of the screen width while ANSYS should take the other two thirds as shown below.

| State of Annual Annual Annual States in Annual An   | A VALUE AND A VALUE AN   |                              |
|---|--|------------------------------|
| In all the face desired link and  |  |                              |
| CALLY O IN A D marteria and descent to 100 has the  | Die gine, gine ginen. Onen, feinerer ginterbart Camitan Greefen  |                              |
| Games, a / Anaton, Games A. Games C. Grant A. ( )   | A REAL PROPERTY AND A REAL | · · · ·                      |
| AMPER 12 - Castillever Brane Model Analysis - Pre-Analysis &  | A DECEMBER OF A  | A Description                |
| Satty   | Automation I de spenson r. I de spenson r.   | · Income and the second      |
| A REAL OF THE REAL PROPERTY AND A REAL OF THE REAL PROPERTY AND A | a restance and   | a free books                 |
| 10.000 P  | And  | T the second                 |
|   | The second secon |                              |
| Author John Singleton and Republic Beckaram, Camel University   | Ref. Society (2011) (allow (allow first))  |                              |
| Esten lascitutor  | ** *usa #usa amma  |                              |
| C.Paulosijas & Barroy   | Taxant Rodyal (MC)   |                              |
| Lisense   | 🔹 yana yana teres  |                              |
| 1.84  | 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1  |                              |
| 1. Intel Prints   |  |                              |
| Lines   | a more sensitive   |                              |
| Contraction and Contraction   | Endersthein  |                              |
| Taxing .  | a total  |                              |
|   | <ul> <li>Naukits</li> </ul>  |                              |
|   | * ···  |                              |
| 1. Pre-dnatysis & Start-Up  | a tate tate  |                              |
| Response of Science Read Sciences   | a implement  |                              |
| The lateral is specially configured, to the over can have both the tabulat and  |  |                              |
| MOVE and our should be an international or our house and the last   |  |                              |
| should be seen about company approximate, one first of the second well when   |  |                              |
| ANOTS should also the she has been been as should be the  |  |                              |
|   |  |                              |
| Child Here for Hadre Resolution#  |  |                              |
|   |  |                              |
| The hosts as an angle mation is on an provide All and fail  |  |                              |
|   |  |                              |
|   |  |                              |
| Date Stee J. Covereits  | P and been   |                              |
| ha 🖌  | a me   | i der frame de ber inferenze |

**Click Here for Higher Resolution** 

If the monitor you are using is insufficient in size, you can press the Alt and Tab keys simultaneously to toggle between ANSYS and your internet browser.

# Modal (ANSYS) Project Selection

Left, click on *Modal ANSYS*, Modal (ANSYS), and drag it to the right of the "Cantilever" project. You should then see a red box to the right of the "Cantilever" project that says "Create standalone system" as shown below.



#### Higher Resolution Image

Now, release the left mouse button. Your Project Schematic window should now look comparable to the image below.



#### Higher Resolution Image

# Rename Modal (ANSYS)

Double click on Modal (ANSYS) and rename it to "Cantilever Modal".

| ۸        | CantilevNoModal - Workbench |           |                           |                   |      |  |           |   |
|----------|-----------------------------|-----------|---------------------------|-------------------|------|--|-----------|---|
|          | le View Tools Units Help    |           |                           |                   |      |  |           |   |
| 1        | New 📴 Open 🛃 Save 😹 Save    | e As      | Dimport Reconnect         | 2 Refresh Project | 🤊 u  | pdate Project  | () Projec |   |
| To       | show = X Pr                 | oject Sch | enatic                    |                   |      |  |           |   |
| 8        | Analysis Systems            |           |                           |                   |      |  |           |   |
| 0        | Bectric (ANSYS)             |           |                           |                   |      |  |           |   |
| 8        | Biplicit Dynamics (ANSYS)   |           | A                         |                   | •    | 8  |           |   |
| E        | Fluid Flow (CFX)            | 1         | Static Structural (ANSYS) |                   | 1 10 | Modal (ANS15)  |           |   |
| E        | Fluid Flow (FLUENT)         | 2         | Engineering Data          | × .               | 2 🦪  | Engineering Da   | ta 🗸      | 2 |
| 2        | Harmonic Response (ANSYS)   | 3         | Geometry                  | 1                 | 3 6  | Geometry   | ?         | 1 |
|          | Linear Buckling (ANSYS)     |           | a main                    |                   |      | and of the second secon | -         | 1 |
| E        | Magnetostatic (ANSYS)       | -         | Model                     | × .               |      | Model  | - r.      | • |
| <b>F</b> | Modal (ANSYS)               | 5         | 🙀 Setup                   | × .               | 5 🚯  | Setup  | - 7.      | 4 |
|          | Random Vibration (ANSYS)    | 6         | Solution                  | × .               | 6 6  | Solution   | 2         |   |
|          | Response Spectrum (ANSYS)   | 7         | Rep. //s                  | 1                 | 7 🗬  | Reads  | 2         | 1 |
| E        | Shape Optimization (ANSYS)  |           | - Heard                   | · ·               |      | Historia   |           | • |
|          | Static Structural (ANSYS)   |           | Cantilever                |                   |      | Cantilever Mod   | Sal.      |   |

Higher Resolution Image

# **Engineering Data**

In this section we will input the properties of aluminum (as defined in the the Problem Specification) in to ANSYS. First, double click Engineering Data,

Engineering Data , in the "Cantilever Modal" Project. Next, click where it says "Click here to add a new material" as shown in the image below.

| They Coen I Save I                                       | Save As |                                   | 2     | lefes | h Prod | iect 🥑 Update Project 🕻 Return to Project   | 60                    |
|--|---------|-----------------------------------|-------|-------|--------|---|-----------------------|
| tottos _ X   | 0,tire  | Filter                            | ĩ     |       |        |   | - 1                   |
| B Physical Properties                                    | •       | A                                 | 8     | (     |        | D   |                       |
| B Linear Elastic   | 1       | Data Source                       | 1     | Leo   | tion.  | Description   |                       |
| 🚰 Instrupt Dastity                                       | 2       | 🛷 Engineering Data                |       | 82    |        | Contents filtered for Model (ANSHS).  |                       |
| Orthotropic Elastidy                                     | 3       | General Materials                 |       | 1     |        | General use material samples for use in vario   | vs an                 |
| Anisotropic Distody     B. Funanimental Grass Grain Data | 4       | General Non-linear Materials      | ō     | 14    |        | General use material samples for use in non-  | for use in non-linear |
| B Hyperelastic   | 5       | Explicit Materials                | ٦     | ×.    |        | Material samples for use in an explicit analy   |                       |
| E Plasticity   | 6       | Huperelastic Materials            |       | 2     |        | Material stress-strain data samples for curve fit   |                       |
| 8 Life   | 7       | Magnetic 8-H Curves               |       | 2     |        | 8-H Curves amples specific for use in a magnetic  |                       |
| B Strength   | 8       | 8 🍲 Favorites                     |       |       |        | Quick access list and default items   | -                     |
|  | ×       | 1                                 |       | х.    |        |   |                       |
|  | Outine  | of Schematic 82: Engineering Data |       |       |        |   | - 3                   |
|  |         | A                                 |       | 8     | с      | D   |                       |
|  | 1       | Contents of Engineering Data      | Þ     | 12    | 5      | Description   |                       |
|  | 2       | C Haterial                        |       |       |        |   |                       |
|  | 3       | 🗣 Studural Stel                   |       | þ     | ÷      | Fatigue Data at zero mean stress comes from<br>1998 ASME BPV Code, Section 8, Div 2, Table<br>5-110-1 |                       |
|  |         | (lick here to add a new ma        | haris |       | _      |   |                       |

### Higher Resolution Image

Next, enter "Aluminum" and press enter. You should now have Aluminum listed as one of the materials in table called "Outline of Schematic B2: Engineering Data", as shown below.

| Outine | of Schematic 82: Engineering Data |   |     |  |
|--------|-----------------------------------|---|-----|--|
| -      | A                                 | в | с   | D  |
| 1      | Contents of Engineering Data 🔒    | 8 | s., | Description  |
| 2      | Material                          |   |     |  |
| 3      | Structural Steel                  |   | ē   | Fatigue Data atzero mean stress comes from<br>1998 ASME BPV Code, Section 8, Div 2, Table<br>5-110.1 |
| - 4    | y 🖗 Aluminum                      |   |     |  |
| •      | Click here to add a new material  |   |     |  |

Higher Resolution Image

Then, (expand) Linear Elastic, as shown below.

| 🔥 CantilevNoModal - Workbench   |  |  |  |  |  |  |  |  |
|---------------------------------|--|--|--|--|--|--|--|--|
| File View Tools Units Hel;      |  |  |  |  |  |  |  |  |
| 🎦 New 💕 Open 🛃 Save 📓           |  |  |  |  |  |  |  |  |
| Toolbox _ X                     |  |  |  |  |  |  |  |  |
|                                 |  |  |  |  |  |  |  |  |
| Linear Elastic                  |  |  |  |  |  |  |  |  |
| 🚰 Isotropic Elastidty           |  |  |  |  |  |  |  |  |
| 🔁 Orthotropic Elasticity        |  |  |  |  |  |  |  |  |
| 🔁 Anisotropic Elasticity        |  |  |  |  |  |  |  |  |
| Experimental Stress Strain Data |  |  |  |  |  |  |  |  |
| Hyperelastic     ■              |  |  |  |  |  |  |  |  |
|                                 |  |  |  |  |  |  |  |  |
| E Life                          |  |  |  |  |  |  |  |  |
|                                 |  |  |  |  |  |  |  |  |

Now, (Double Click) Isotropic Elasticity. Then set Young's Modulus to 70e9 Pa and set Poisson's Ratio to 0.35, as shown below.

| Properties of Outline Row 4: Aluminum 📃 🚽 |                         |                                       |      |  |  |
|---|-------------------------|---------------------------------------|------|--|--|
| •   | A                       | 8                                     |      |  |  |
| 1   | Property                | Value                                 | Unit |  |  |
| 2   | 🖻 🔀 Isotropic Elasticty |                                       |      |  |  |
| 3   | Derive from             | Young's Modulus and Poisson's Ratio 📼 |      |  |  |
| 4   | Young's Modulus         | 7E+10                                 | Pa 🔹 |  |  |
| 5   | Poisson's Ratio         | 0.35                                  |      |  |  |
| 6   | Bulk Modulus            | 7.7778E+10                            | Ра   |  |  |
| 7   | Shear Modulus           | 2.5926E+10                            | Pa   |  |  |

Higher Resolution Image

Next, (expand) Physical Properties, as shown below.

| 🔥 CantilevNoModal - Workbench     |  |  |  |  |  |  |  |
|-----------------------------------|--|--|--|--|--|--|--|
| File View Tools Units Hel         |  |  |  |  |  |  |  |
| 🎦 New 💕 Open 🛃 Save 📓             |  |  |  |  |  |  |  |
| Toolbox _ X                       |  |  |  |  |  |  |  |
| Physical Properties               |  |  |  |  |  |  |  |
| 🔁 Density                         |  |  |  |  |  |  |  |
| 🔁 Isotropic Secant Coefficient of |  |  |  |  |  |  |  |
| 🔁 Orthotropic Secant Coefficient  |  |  |  |  |  |  |  |
| 🔁 Isotropic Instantaneous Coeff   |  |  |  |  |  |  |  |
| 🔁 Orthotropic Instantaneous Coe   |  |  |  |  |  |  |  |
| 🚰 Constant Damping Coefficient    |  |  |  |  |  |  |  |
| 🔁 Damping Factor (β)              |  |  |  |  |  |  |  |
|                                   |  |  |  |  |  |  |  |
|                                   |  |  |  |  |  |  |  |
|                                   |  |  |  |  |  |  |  |
|                                   |  |  |  |  |  |  |  |
| ⊞ Life                            |  |  |  |  |  |  |  |
|                                   |  |  |  |  |  |  |  |

Now, (Double Click) Density. Then, set Density to 2,700 kg / m^3 , as shown below.

| Properties of Outline Row 4: Aluminum |                        |                                       |         |   |  |
|---------------------------------------|------------------------|---------------------------------------|---------|---|--|
| -                                     | A                      | 8                                     | с       |   |  |
| 1                                     | Property               | Value                                 | Unit    |   |  |
| 2                                     | 🔁 Density              | 2700                                  | kg m^-3 | • |  |
| 3                                     | 🖻 🔛 Isotropic Elastidy |                                       | ĺ       | _ |  |
| 4                                     | Derivefrom             | Young's Modulus and Poisson's Ratio 💌 |         |   |  |
| 5                                     | Young's Modulus        | 7E+10                                 | Pa      | • |  |
| 6                                     | Poisson's Ratio        | 0.35                                  |         |   |  |
| 7                                     | Bulk Modulus           | 7.7778E+10                            | Pa      |   |  |
| 8                                     | Shear Modulus          | 2.5926E+10                            | Pa      |   |  |

Higher Resolution Image

Now, the material properties for Aluminum have been specified. Lastly, (Click) Return To Project, Return to Project

### Save

Save your project now and periodically, as you work. ANSYS does not have an auto-save feature.

### Go to Step 2: Geometry

Go to all ANSYS Learning Modules