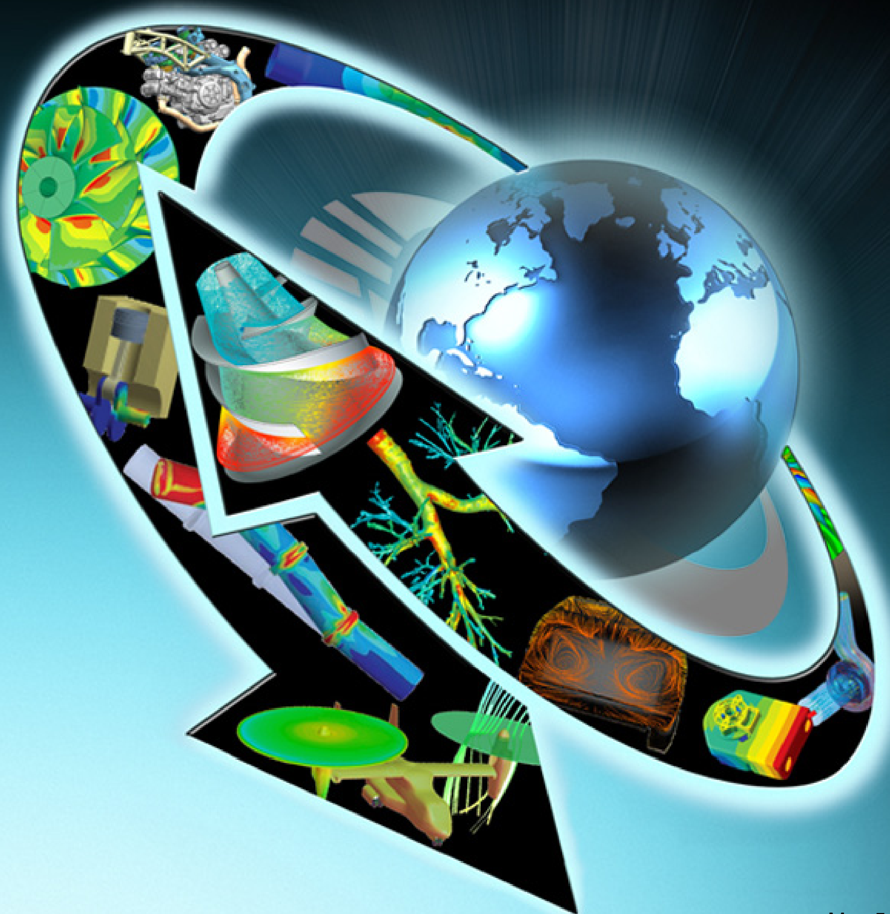
Workbench - Mechanical Introduction 12.0

Chapter 5

Vibration Analysis



Chapter Overview

- **In this chapter, performing free vibration analyses in Simulation will be covered. In Simulation, performing a free vibration analysis is similar to a linear static analysis.**
  - **It is assumed that the user has already covered Chapter 4 *Linear Static Structural Analysis* prior to this section.**
- **The following will be covered:**
  - **Free Vibration Analysis Procedure**
  - **Free Vibration with Pre-Stress Analysis Procedure**
- **The capabilities described in this section are generally applicable to *ANSYS DesignSpace Entra* licenses and above.**

Basics of Free Vibration Analysis

- For a free vibration analysis, the natural circular frequencies ω_i and mode shapes ϕ_i are calculated from:

$$\left([K]-\omega_i^2[M]\right)\{\phi_i\}=0$$

- **Assumptions:**
  - [K] and [M] are constant:
    - Linear elastic material behavior is assumed
    - Small deflection theory is used, and *no* nonlinearities included
    - [C] is not present, so damping is not included
    - {F} is not present, so no excitation of the structure is assumed
    - The structure can be constrained or unconstrained
  - Mode shapes {ϕ} are *relative* values, not absolute

A. Free Vibration Analysis Procedure

- **The free vibration analysis procedure is very similar to performing a linear static analysis, so not all steps will be covered in detail. The steps in blue italics are specific to free vibration analyses.**
  - **Attach Geometry**
  - **Assign Material Properties**
  - **Define Contact Regions (if applicable)**
  - **Define Mesh Controls (optional)**
  - ***Define Analysis Type***
  - **Include Supports (if applicable)**
  - ***Request Frequency Finder Results***
  - ***Set Frequency Finder Options***
  - **Solve the Model**
  - **Review Results**

… Geometry and Point Mass

- **Modal analysis supports any type of geometry:**
  - **Solid bodies, surface bodies and line bodies**

- **The Point Mass feature can be used:**

  - **The Point Mass adds mass only (no stiffness) in a free vibration analysis.**
  - **Point Masses will *decrease* the natural frequency in free vibration analyses.**

- **Material properties: *Young's Modulus, Poisson's Ratio,* and *Density* are required.**

… Contact Regions

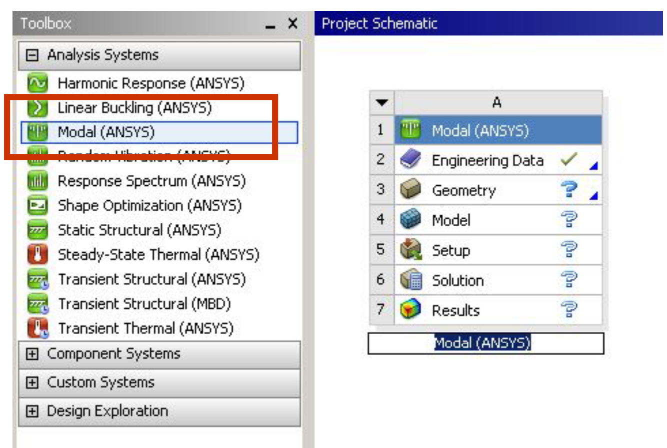
- **Contact regions are available in free vibration analyses. However, contact behavior will differ for the *nonlinear* contact types:**

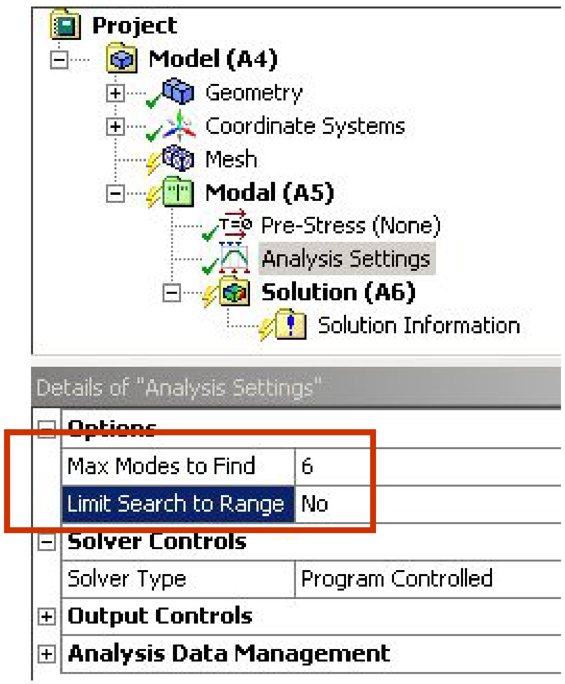
Contact Type	Static Analysis	Modal Analysis		
		Initially Touching	Inside Pinball Region	Outside Pinball Region
Bonded	Bonded	Bonded	Bonded	Free
No Separation	No Separation	No Separation	No Separation	Free
Rough	Rough	Bonded	Free	Free
Frictionless	Frictionless	No Separation	Free	Free

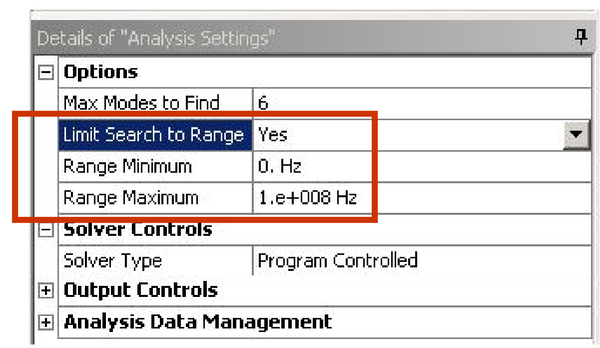
- **Contact free vibration analyses:**
  - ***Rough* and *frictionless:***
    - **will internally behave as *bonded* or *no separation***
    - **If a gap is present, the nonlinear contact behaviors will be free (i.e., as if no contact is present).**
  - ***Bonded* and *no separation* contact status will depend on the pinball region size.**

… Analysis Type

- Select "Modal" from the Workbench toolbox to specify a modal analysis system.
- Within Mechanical Analysis Settings:
  - Specify the number of modes to find: 1 to 200 (default is 6).
  - Specify the frequency search range (defaults from 0Hz to 1e+08Hz).







… Loads and Supports

- **Structural and thermal loads are not available in free vibration.**
- **Supports:**
  - **If no or partial supports are present, rigid-body modes can be detected and evaluated (modes will be at or near 0 Hz).**
  - **The boundary conditions affect the mode shapes and frequencies of the part. Carefully consider how the model is constrained.**
  - **The *compression only* support is a nonlinear support and should not be used in the analysis.**

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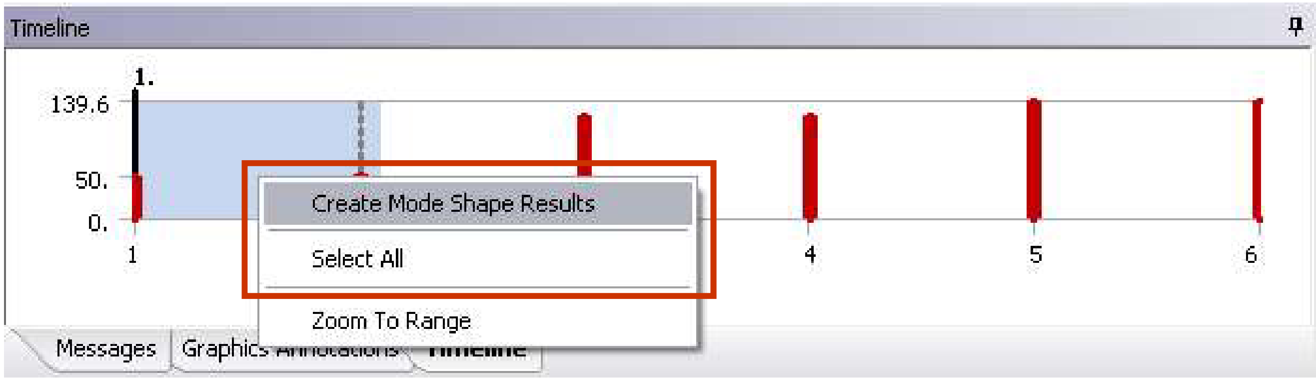
… Requesting Results

- **Solve the model (no results need to be requested).**
- **When complete, the solution branch will display a bar chart and table listing frequencies and mode numbers.**

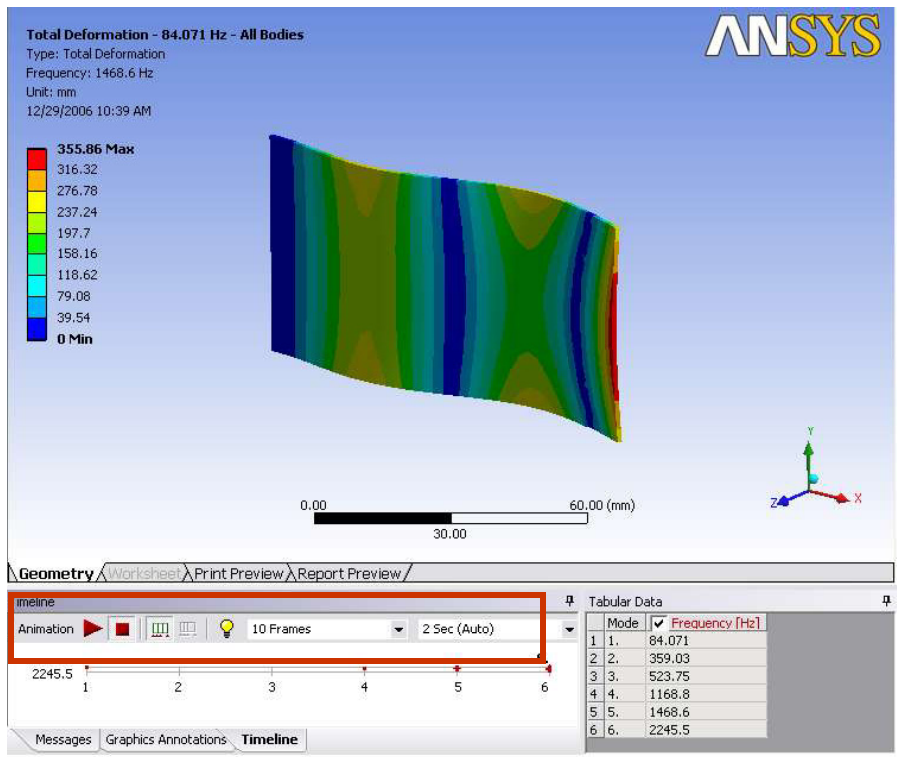


	Mode	Frequency [Hz]
1	1.	50.998
2	2.	51.378
3	3.	121.71
4	4.	122.22
5	5.	138.7
6	6.	139.6

- **Request specific mode shapes to be displayed by RMB (can select all frequencies if desired).**
- **This will insert the “Total Deformation” results for the requested mode shapes.**

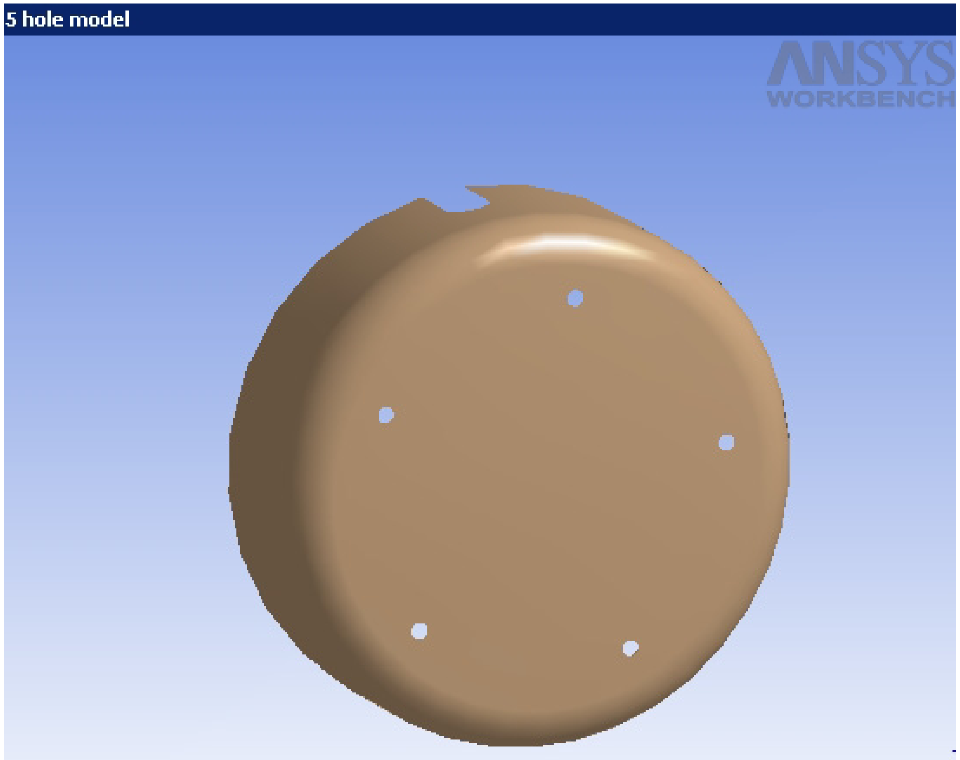
… Reviewing Results

- **Mode shapes:**
  - **Because there is no *excitation* applied to the structure, the mode shapes are *relative* values associated with free vibration.**
  - **The frequency is listed in the Details view of the result being viewed.**
  - **The animation toolbar from the timeline tab below the graphics window can be used to help visualize the mode shapes.**



B. Workshop 5.1 – Free Vibration

- **Workshop 5.1 – Free Vibration Analysis**
- **Goal:**
  - **Investigate the vibration characteristics of motor cover design shown here manufactured from 18 gauge steel.**



C. Free Vibration with Pre-Stress

- **In some cases, one may want to consider *prestress effects* when performing a free vibration analysis.**
  - **The stress state of a structure under constant (static) loads may affect its natural frequencies such as a guitar string being tuned.**

$$[K]\{x_o\}=\{F\}$$

A linear static analysis is performed

$$[\sigma_o]\rightarrow[S]$$

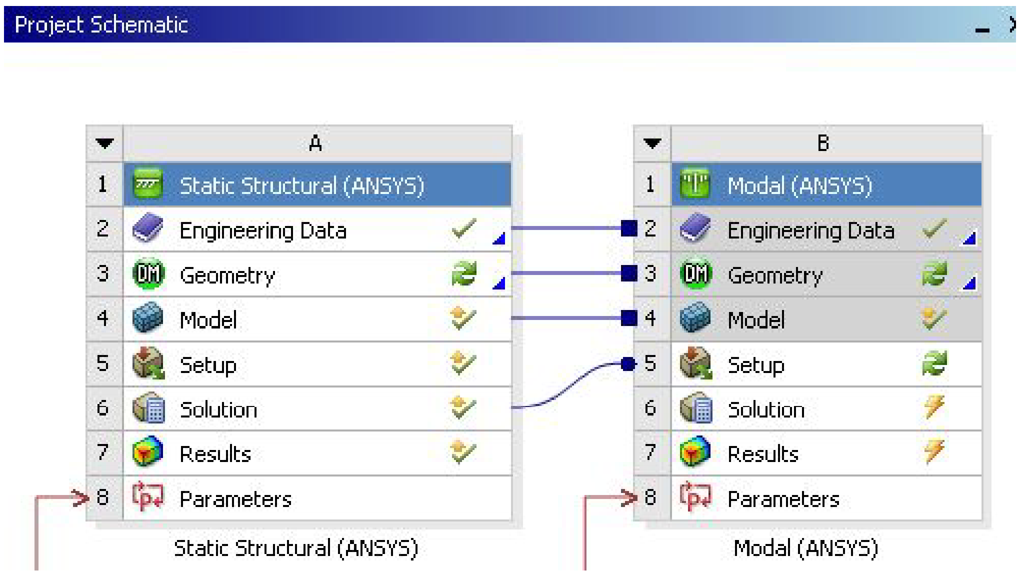
A stress stiffness matrix is calculated from the structural analysis

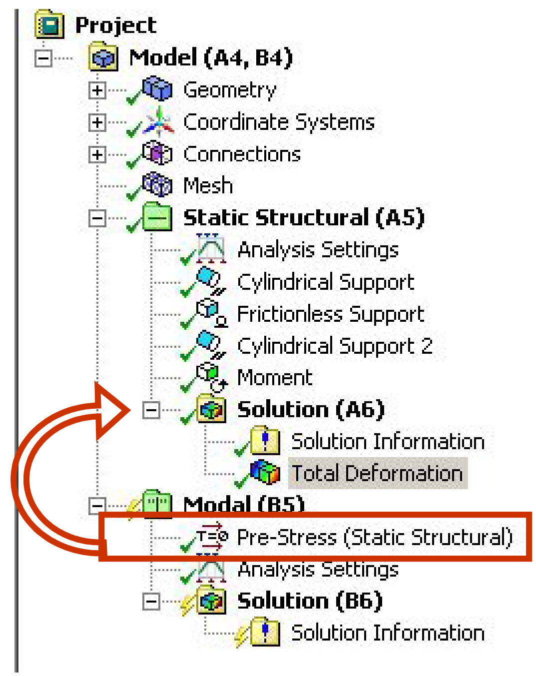
$$\left([K+S]-\omega_i^2[M]\right)\{\phi_i\}=0$$

The original free vibration equation is modified to include the [S] term

… Procedure w/ Pre-Stress Effects

- **Setup a pre-stressed modal analysis by linking a static structural system to a modal system (<u>at the solution level</u>) in the project schematic.**

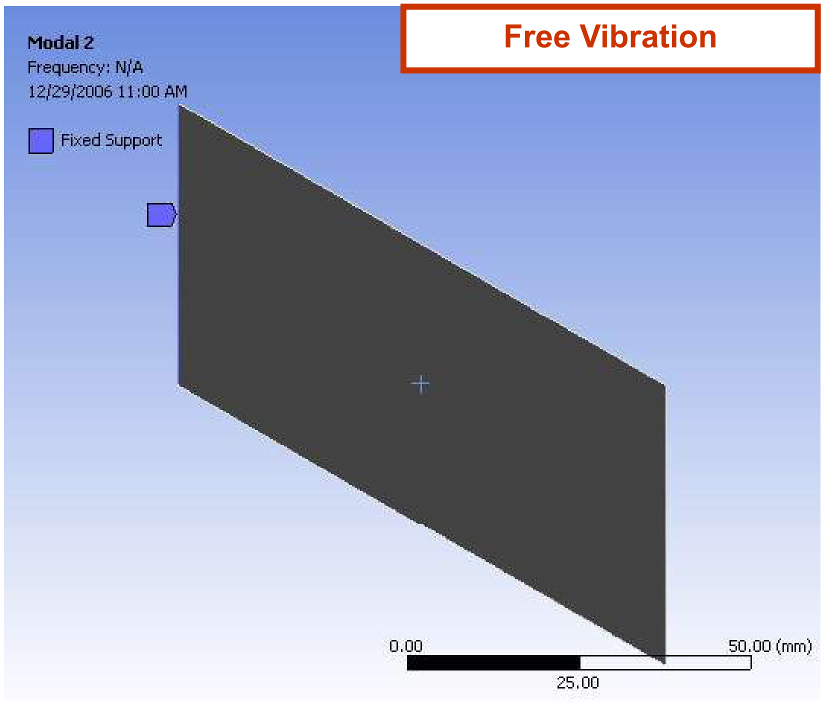


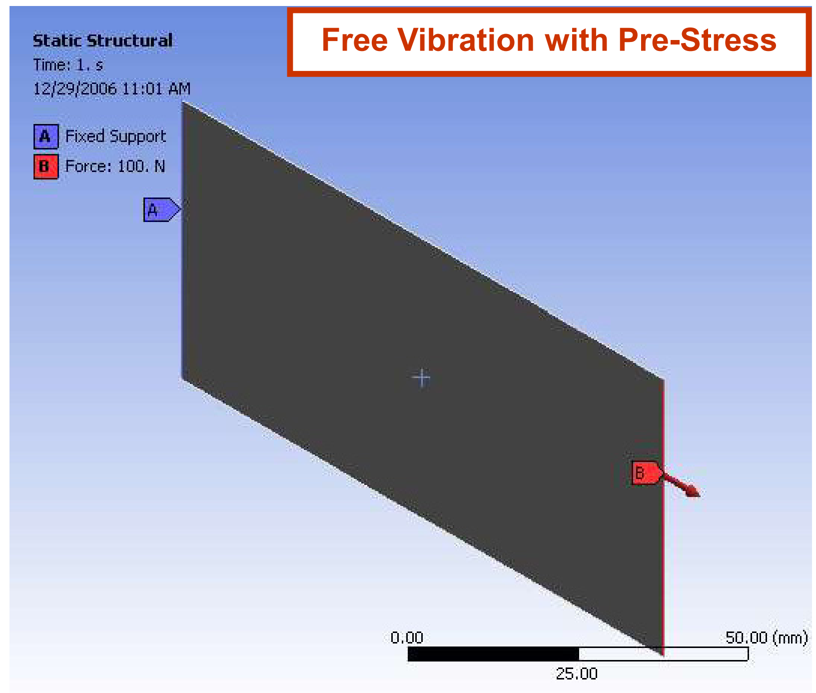


- **Notice in the modal branch, the structural analysis result becomes an initial condition.**

… Example w/ Pre-Stress Effects

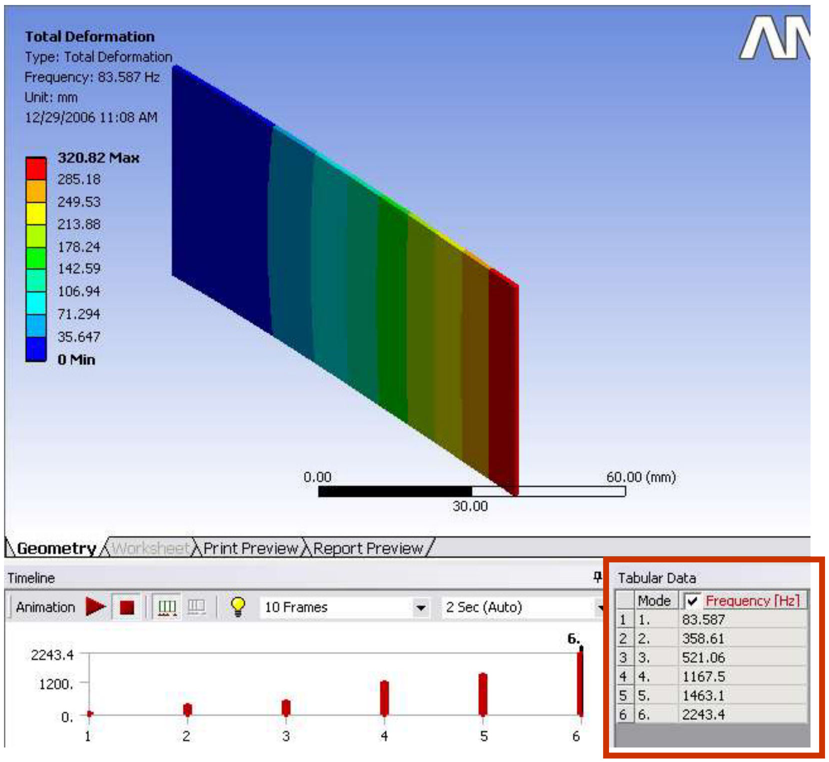
- **Consider a simple comparison of a thin plate fixed at one end**
  - **Two analyses will be run – free vibration and free vibration with pre-stress effects – to compare the differences between the two.**





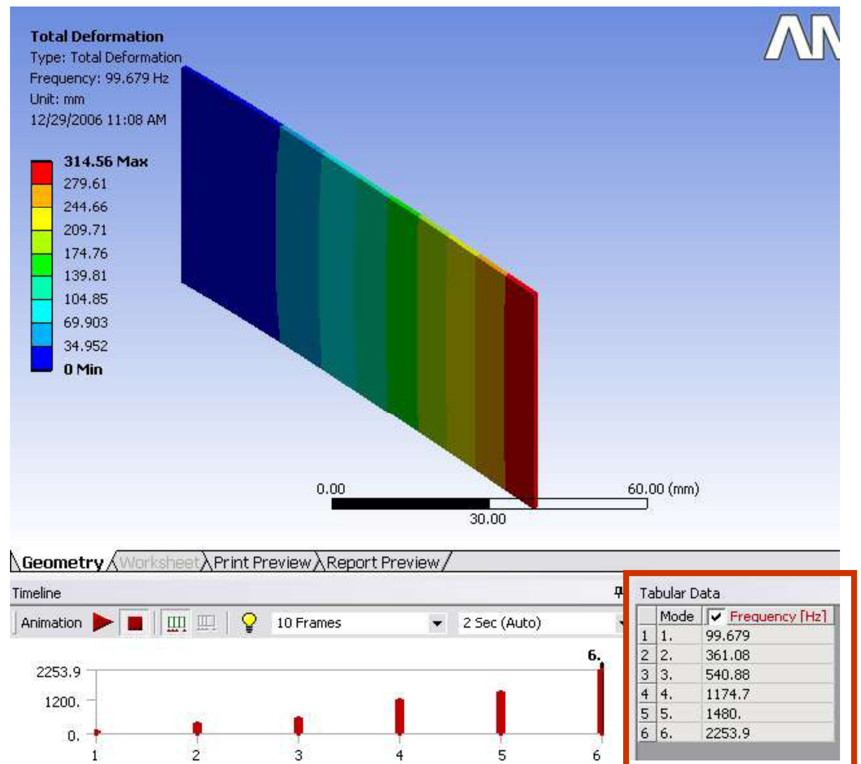
… Example w/ Pre-Stress Effects

- **In this example, with the applied force, a tensile stress state is produced which increases the natural frequencies.**



Free Vibration

1st mode frequency: 83.587 Hz



Free Vibration with Pre-Stress

1st mode frequency: 99.679 Hz

D. Workshop 5.2 – Prestressed Modal

- **Workshop 5.2 – Prestressed Modal Analysis**
- **Goal: simulate the modal response of the tension link (shown below) in both a stressed and unstressed state.**