Ansys Mechanical Linear and Nonlinear Dynamics

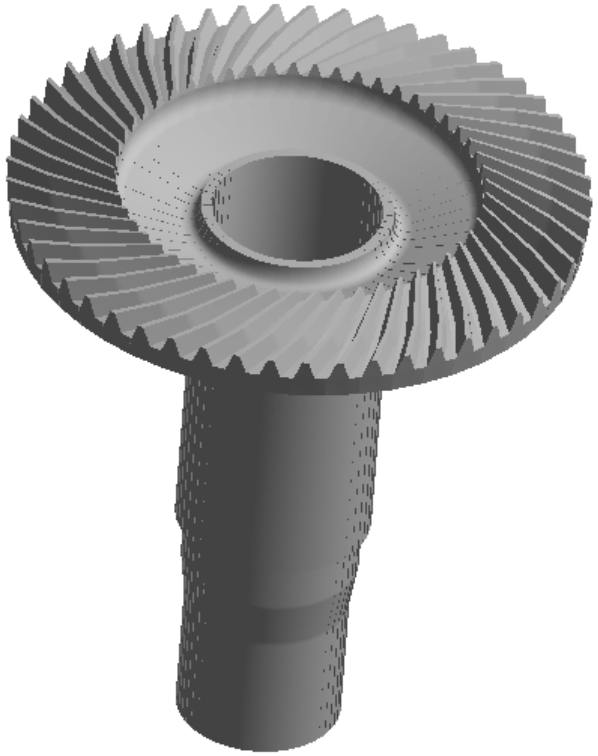
WS 04.1: Modal Cyclic Symmetry of Bevel Gear

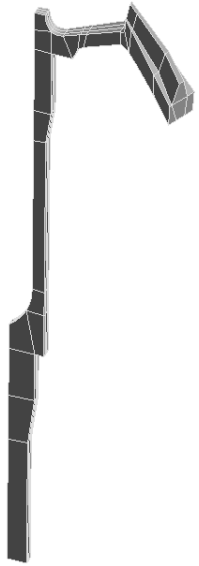
Release 2022 R2

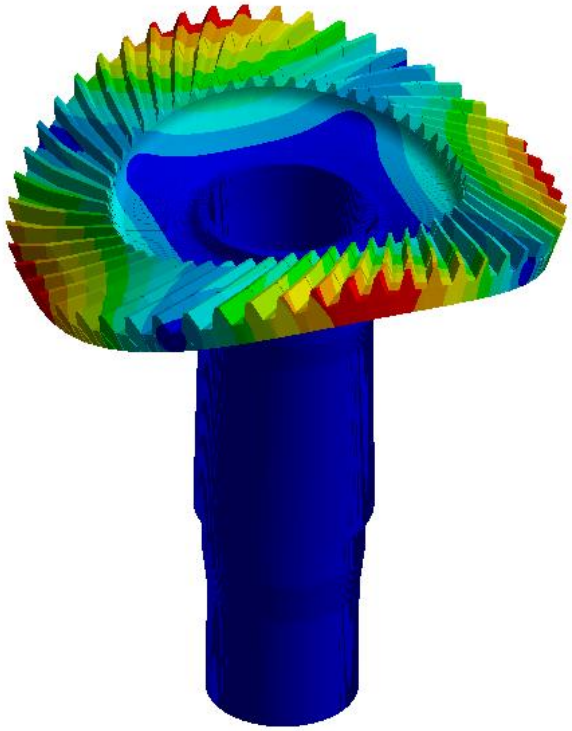
Please note:
- These training materials were developed and tested in Ansys Release 2022 R2. Although they are expected to behave similarly in later releases, this has not been tested and is not guaranteed.
- The screen images included with these training materials may vary from the visual appearance of a local software session.
- Although some workshop files may open successfully in previous releases, backward compatibility is somewhat unlikely and is not guaranteed.

Workshop 04.1 - Goals

- Our goal is to use cyclic symmetry to determine the first 6 natural frequencies and mode shapes for the bevel gear shown below.







Workshop 04.1 – Project Schematic

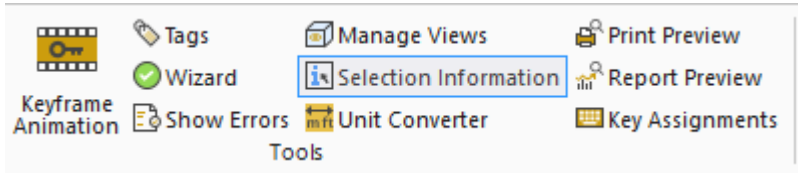
- Start a new Workbench session, and from the project schematic, insert a new Modal Analysis system.
- Import the Geometry file “**bevel_gear_solid**.stp”
- Edit the Model cell to open the Mechanical application
  - Units: U.S. Customary (in, lbm, lbf, °F, s, V, A)

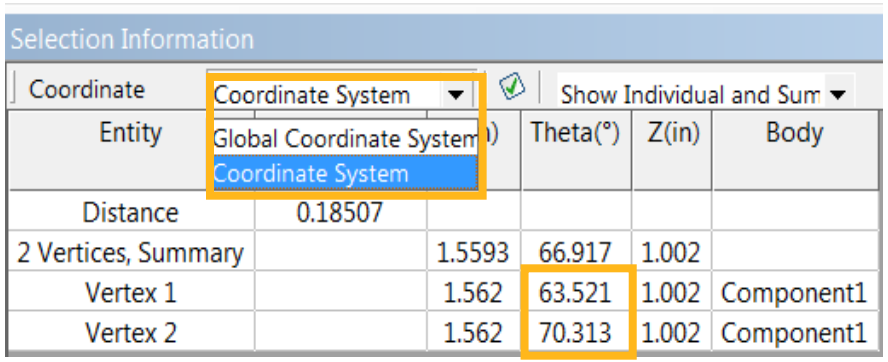
Workshop 04.1 – Local Coordinate System

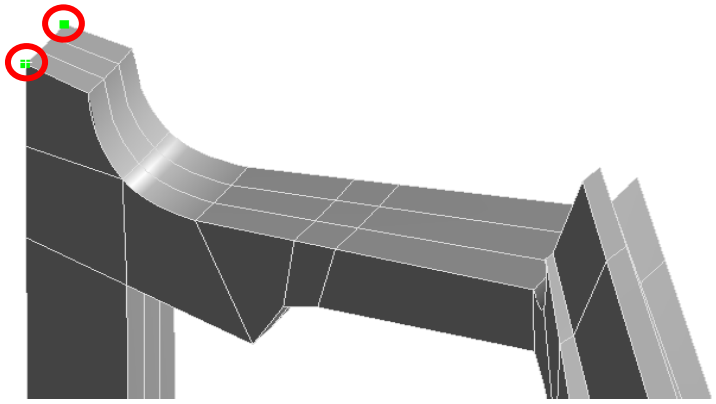
- The geometry consists of a single repeating tooth of the bevel gear
- Create a cylindrical coordinate system at the axis of symmetry to be used for the cyclic symmetry definition.
  - Define By Global Coordinates
    - Origin X = 0
    - Origin Y = 0
    - Origin Z = 0

Workshop 04.1 – Confirm Sector Angle

- Set the Selection Filter to Vertex.
- Select two vertices on opposing faces of the sector (the low and high sector boundaries)
- Use Selection Information on the Home tab of the Mechanical ribbon to enable the window.
  - Change the Coordinate System to the cylindrical system created previously
  - The vertices are a Theta(°) angle of 70.313 – 63.521 = 6.792° apart

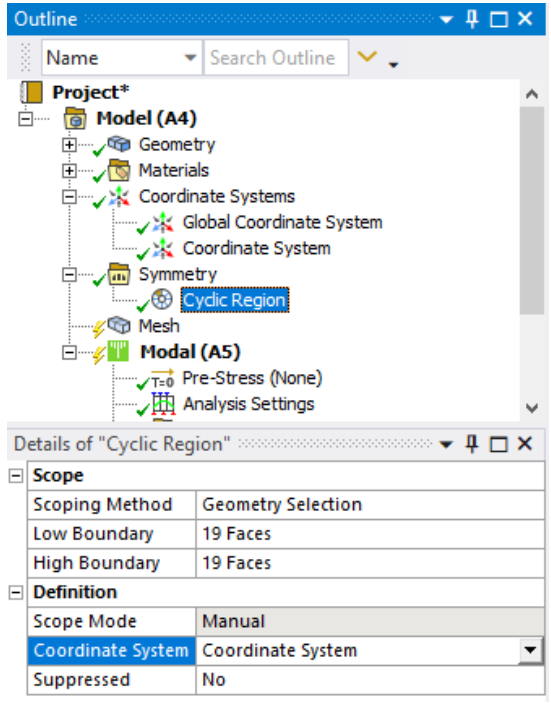


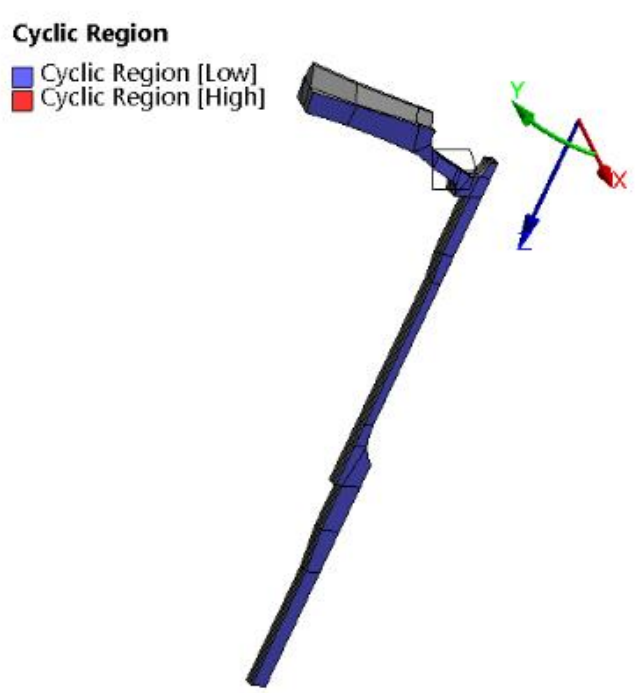


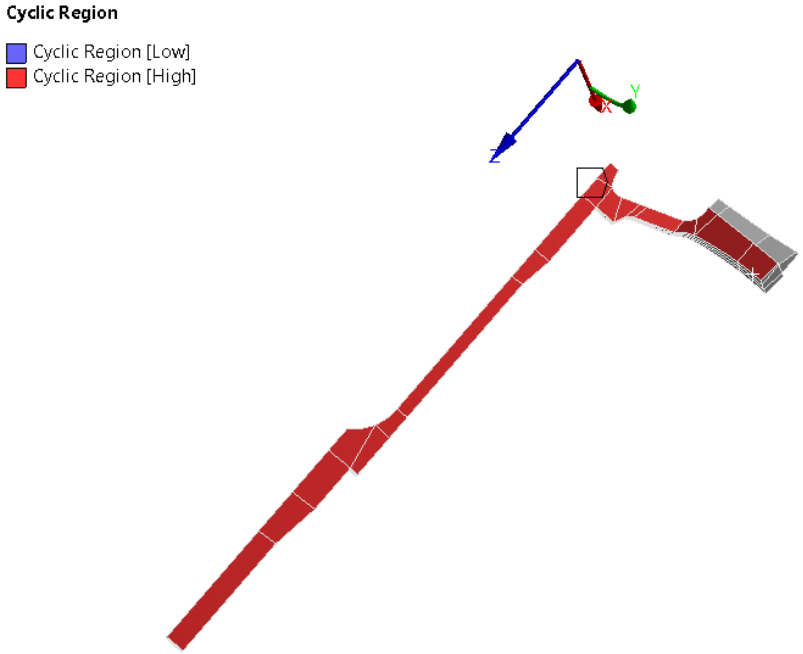


Workshop 04.1 – Define Symmetry

- From the Model branch, Insert Symmetry
- On the Symmetry branch, Insert Cyclic Region
  - Set Coordinate System to the cylindrical system created previously
  - There are 19 faces on the Low and High Sector Boundaries; select them by any convenient means (Hint: Extend Selection to Limits)

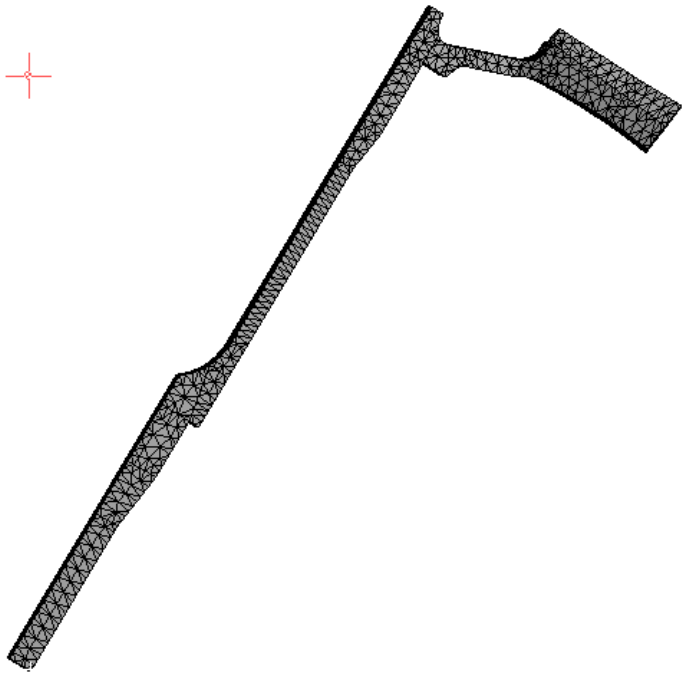






Workshop 04.1 - Mesh

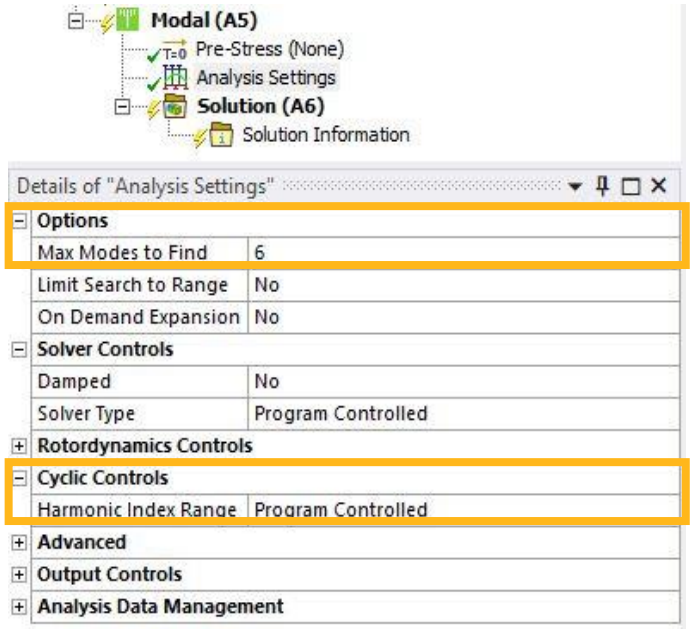
- The Cyclic Region symmetry definition previously defined will attempt to match the mesh on the low and high sector boundaries, thus no special mesh controls are required for symmetry.
- Set a global element size to 0.1 inch and generate the mesh.



Workshop 04.1 – Analysis Settings

- Our goal is to find the first six modes of the bevel gear. Since we are conducting a cyclic symmetry solution, we're actually solving for the first six modes of each harmonic index.
- Recall that the sector angle was shown to be $\alpha = 6.792°$. Thus there are N = 360°/6.792°=53 sectors and k = (N-1)/2 = (53-1)/2 = 26 harmonic indices.
- Solving for 6 modes in each of 26 harmonic indices will result in 156 modes, plus 6 modes for harmonic index 0.

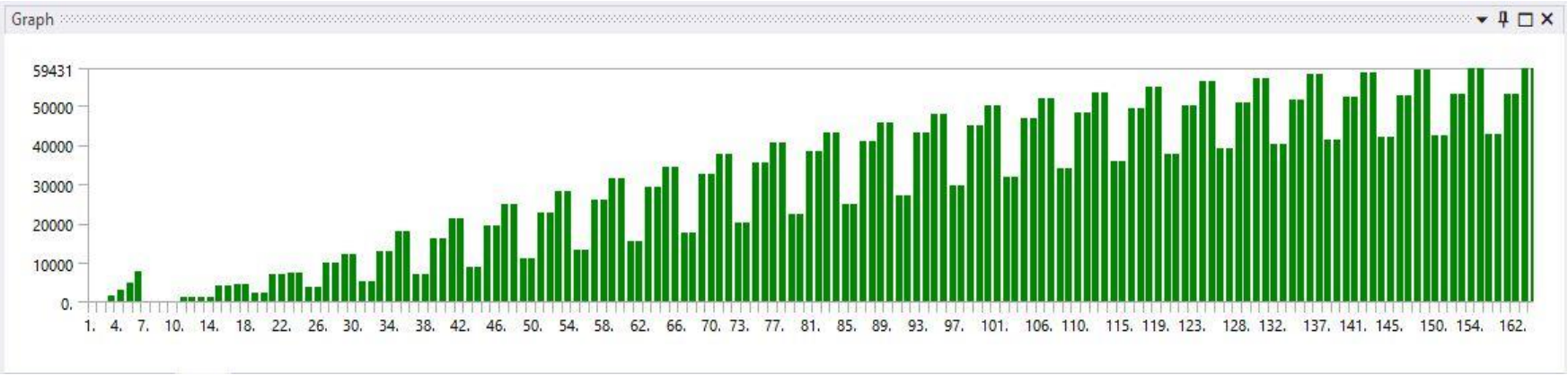
  - Accept the "Program Controlled" option for Harmonic Index Range, resulting in 6 modes for each harmonic index.
  - Solve the model.



Workshop 04.1 – Post Processing

- The solution takes approximately 2 minutes on a dual core machine with 32GB RAM.
- When finished, click on the Solution Branch and inspect the Graph and Tabular Data views.
- The Graph shows frequency versus harmonic index, and the Tabular Data is sorted by harmonic index.

Note: your result magnitudes may vary slightly throughout this workshop due to mesh and software release differences

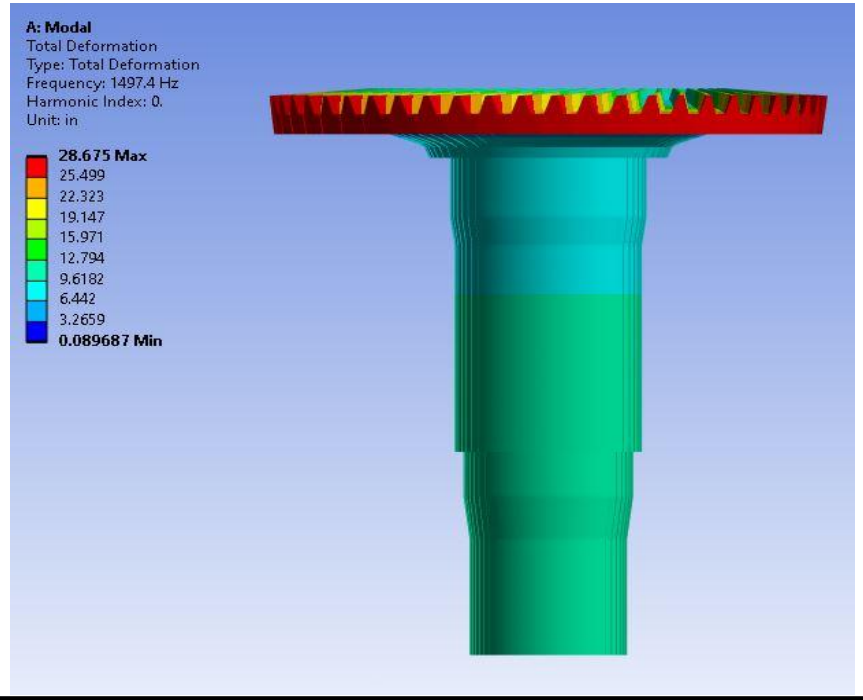


Tabular Data

	Mode	Harmonic Index	Frequency [Hz]
1	1.	0.	0.
2	2.	0.	4.4919e-003
3	3.	0.	1497.4
4	4.	0.	3074.6
5	5.	0.	4589.9
6	6.	0.	7780.6
7	1.	1.	0.
8	2.	1.	0.
9	3.	1.	3.9372e-003
10	4.	1.	4.2184e-003
11	5.	1.	1001.6
12	6.	1.	1001.6
13	1.	2.	1056.1
14	2.	2.	1056.1

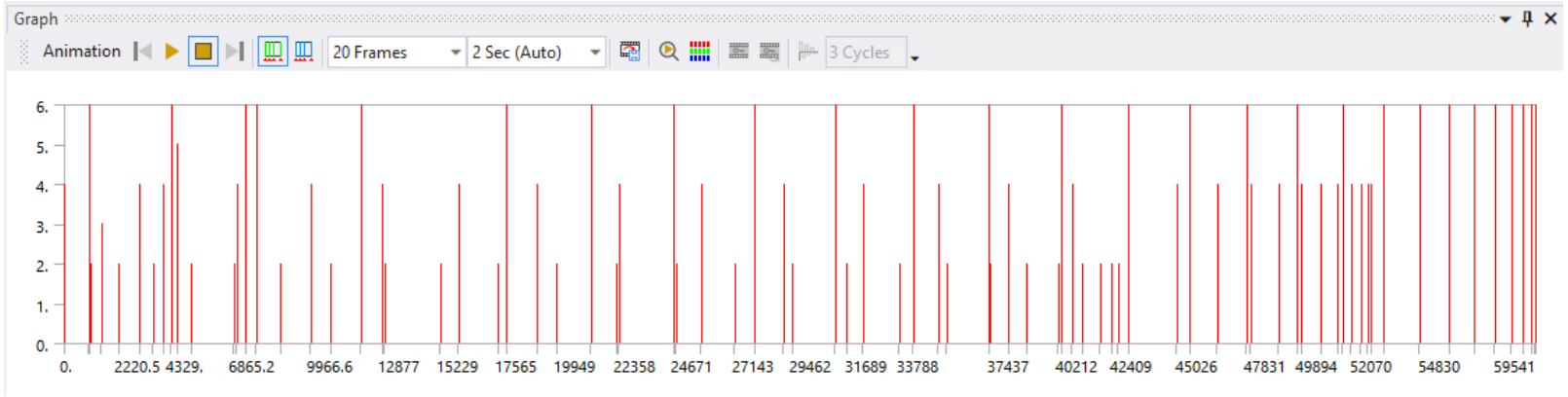
Workshop 04.1 – Post Processing

- There are 6 zero (or near-zero) modes due to the absence of supports on the bevel gear.
- Select the first non-zero mode (mode 3, harmonic index 0) from the Tabular Data and Create Mode Shape Results
- Confirm this to be a “breathing mode” by animating results from the Graph view.

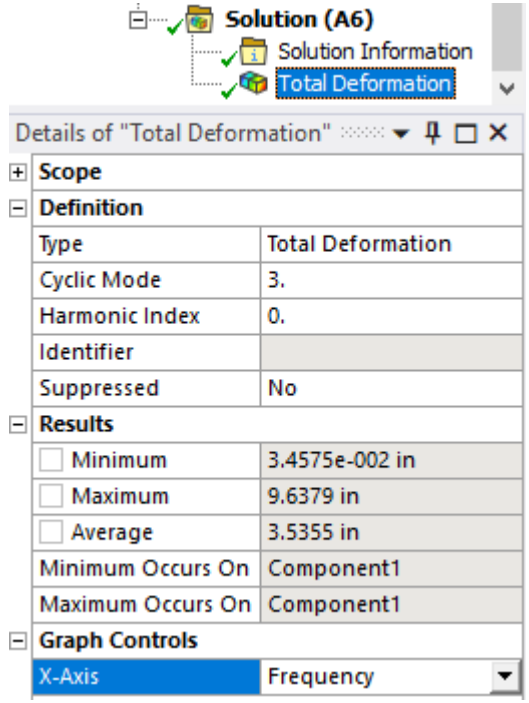


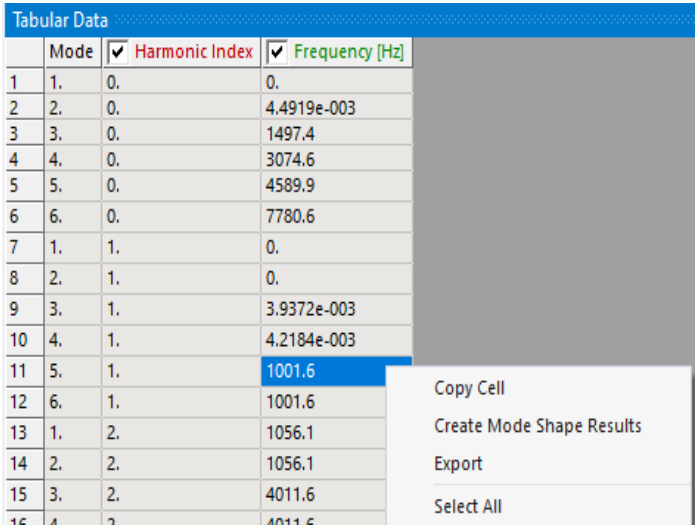
Workshop 04.1 – Post Processing

- Use the X-Axis Graph Controls in the Details view of Total Deformation to sort modes by Frequency value.
- The Graph view now displays Frequency along the X-Axis, with Harmonic Index along the Y-Axis.



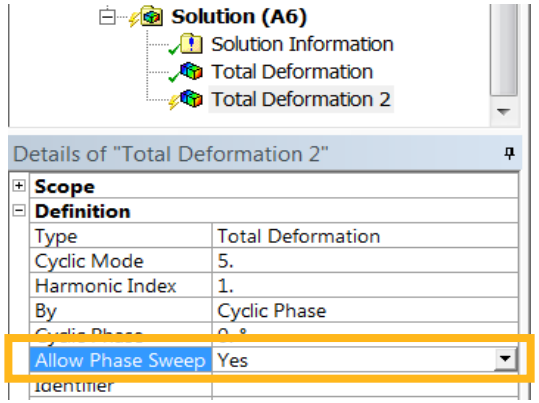
- From the Tabular Data view, select the lowest non-zero mode couplet and create mode shape results and evaluate (mode 5 from harmonic index 1).

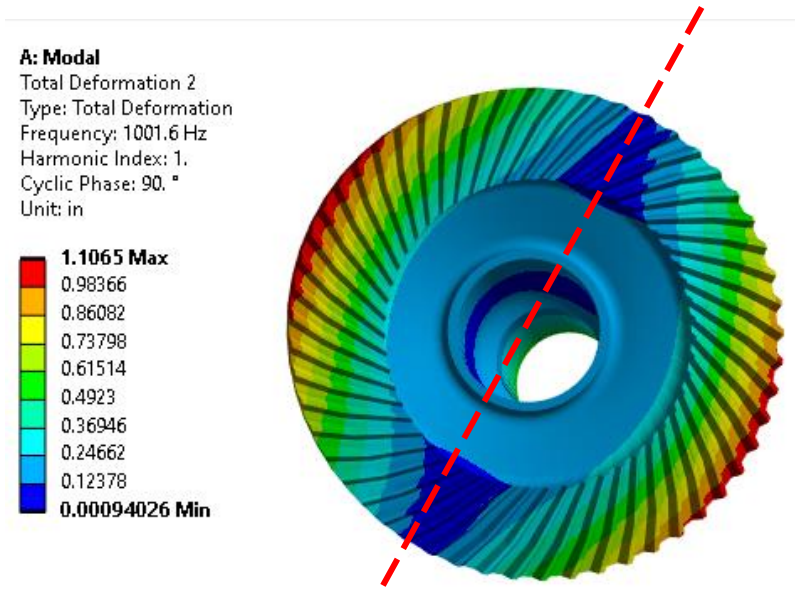




Workshop 04.1 – Post Processing

- This mode exhibits a single nodal diameter.
- In the Details view Allow Phase Sweep calculations and evaluate results once again.



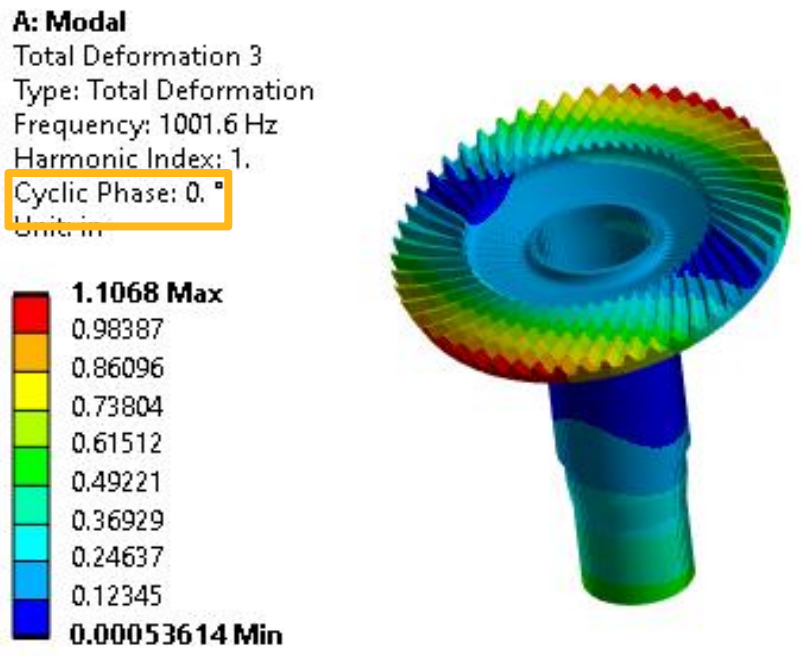


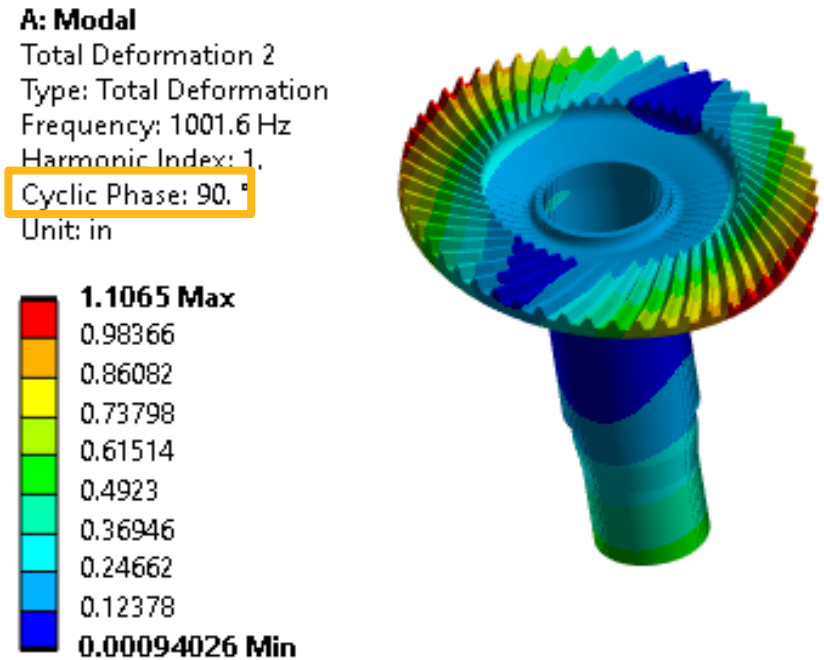
Scope	
Definition	
Type	Total Deformation
Cyclic Mode	5.
Harmonic Index	1.
By	Cyclic Phase
Cyclic Phase	90. °
Allow Phase Sweep	Yes
Identifier	
Suppressed	No
Results	
Minimum Value Over Phase	
Minimum	4.0128e-004 m
Cyclic Phase	40. °
Maximum Value Over Phase	
Maximum	0.88901 m
Cyclic Phase	90. °

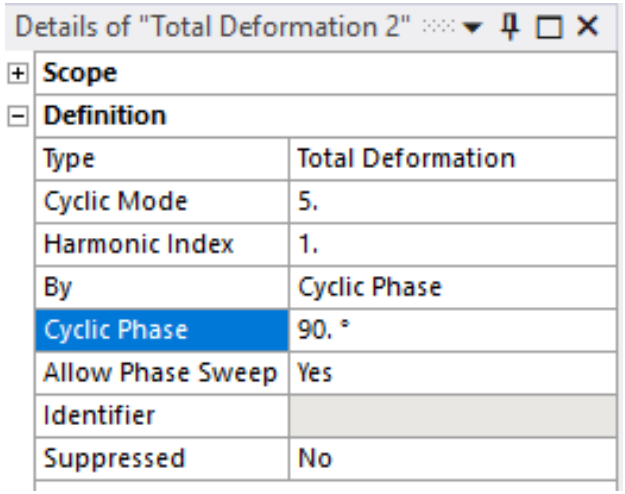
- The details view now displays information about minimum and maximum deformation values and their associated phase angle.
- Although deformation magnitudes are relative, this information can be used to determine phase angles for which stress may be a maximum.

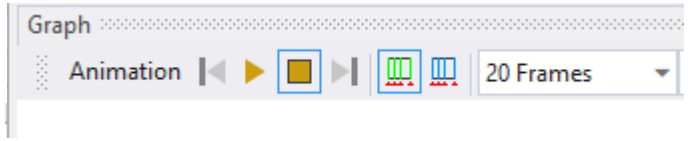
Workshop 04.1 – Post Processing

- Evaluate the Total Deformation for Mode 5 of Harmonic Index 1 at a 90° cyclic phase angle.
  - Note: position of nodal diameter rotates by 90°









- Animate the “traveling wave”.

Workshop 04.1 – Post Processing

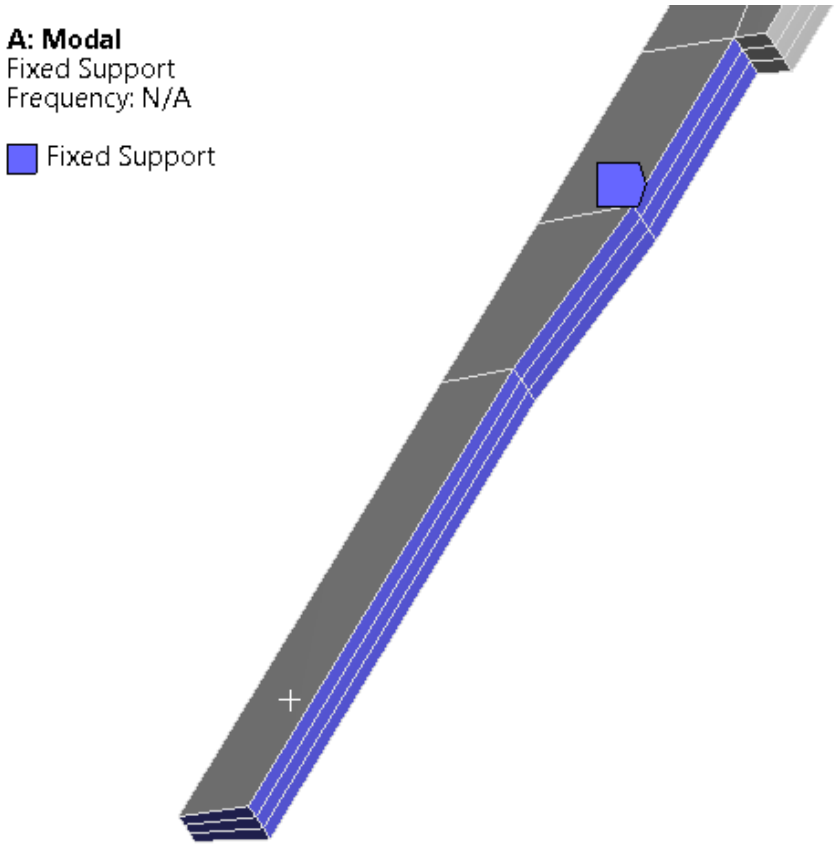
- Continue to post process frequency couplets at various harmonic indices, noting when possible the appearance of nodal diameters and using the phase sweep to locate critical phase angles.

Tabular Data

	Frequency [Hz]	Mode	Harmonic Index
1	0.	1.	0.
2	0.	1.	1.
3	0.	2.	1.
4	3.9372e-003	3.	1.
5	4.2184e-003	4.	1.
6	4.4919e-003	2.	0.
7	1001.6	5.	1.
8	1001.6	6.	1.
9	1056.1	1.	2.
10	1056.1	2.	2.
11	1497.4	3.	0.
12	2220.5	1.	3.
13	2220.5	2.	3.
14	3074.6	4.	0.
15	3599.1	1.	4.
16	3599.1	2.	4.
17	4011.6	3.	2.
18	4011.6	4.	2.
19	4329.3	5.	2.
20	4329.3	6.	2.

Workshop 04.1 – Post Processing

- Go Further! Add a fixed support at the base of the bevel gear and rerun the modal analysis, noting changes in behavior of the model.



End of presentation