XLRotor Tutorial

This tutorial will quickly lead you through a complete rotordynamic analysis. We'll create a shaft model from scratch, attach some bearings, and perform a critical speed and imbalance response analysis. We won't explore every feature of XLRotor, but we will cover the basics.

XLRotor Tutorial Part 2.pdf Click this link to learn more about imbalance response analyses.

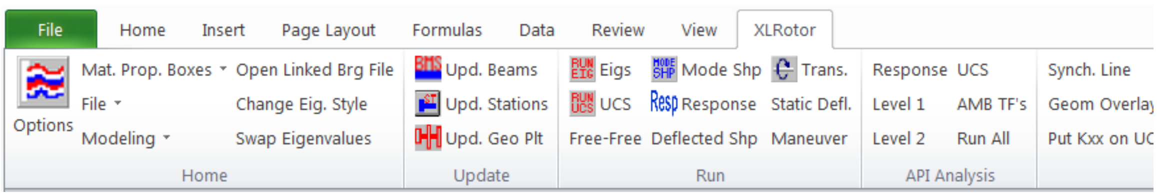
XLRotor Tutorial Part 3.pdf Click this link to learn about torsional analysis with XLRotor.

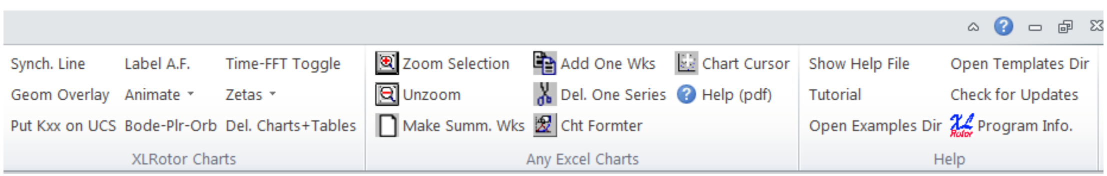
XLRotor Tutorial Part 4.pdf Click this link to learn about singular value analysis with XLRotor.

XLRotor Tutorial Part 5.pdf Click this link to learn about torsional analysis of reciprocating machines.

The XLRotor User Interface

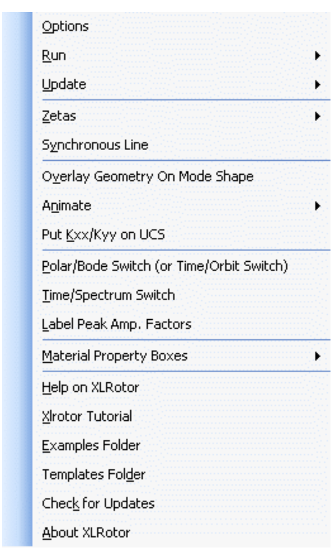
When an XLRotor file is open Excel, the XLRotor ribbon tab should be visible in the Excel ribbon (Excel versions 2007 and later only).

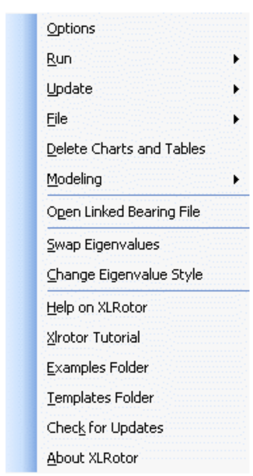


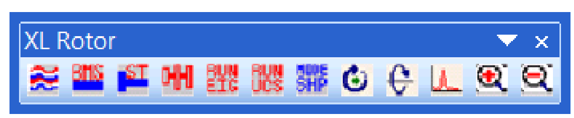


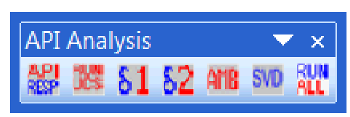
Every feature of XLRotor is accessible via the ribbon tab shown above.
In Excel version 2003 and earlier, XLRotor uses a pull down menu and several custom toolbars.

Worksheet menu ***Chart menu*** ***Toolbars***

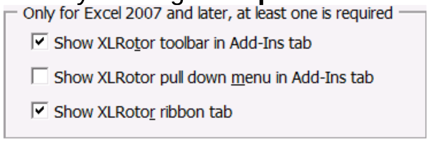


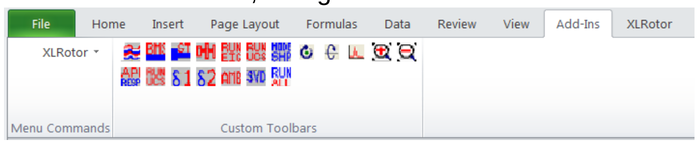






In Excel 2007 and later, the XLRotor menus and toolbars can be displayed on the **Add-Ins** tab of the Excel ribbon by clicking the **Options** button on the XLRotor ribbon, and go to the **Others** tab.

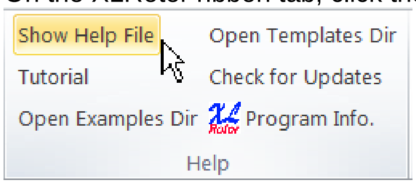




Accessing Online Help

The XLRotor online documentation is context sensitive. There are multiple ways to view the help file.

- Pressing **Control-F1** at any time will bring up the XLRotor help file, and it should display a help topic relevant to what you are currently doing.
- In any of XLRotor's dialog boxes, click the dialog's Help button.
- On the XLRotor ribbon tab, click the button for ***Show Help File.***

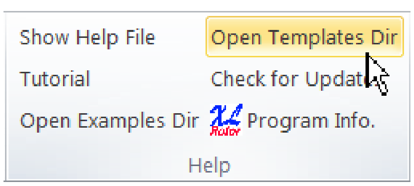


Open a Shaft Model Template File

The way to start up XLRotor is to open an Excel workbook file which has been structured for creating XLRotor models. Open the rotor model template file XLROTOR (in-lbf-lbm).xls (any rotor model file will do). If you want to work in SI units, open the file XLROTOR (m-N-kg).xls. These files are located at C:\ProgramData\XLRotor\Templates (if C:\ProgramData is hidden, enter this in the Windows search box).

You can also open either of these two files from the Windows Start button by way of the XLRotor program group. **Start⇨All Programs⇨XLRotor⇨Shaft Model Templates**. Look for items named **Shaft Model Template, English Units** or **Shaft Model Template, SI Units**. If Excel is not already open, it should start automatically when you select the item from Start menu.

If XLRotor is already open in Excel, then the XLRotor ribbon should be visible and you can click the button named **Open Templates Dir**.

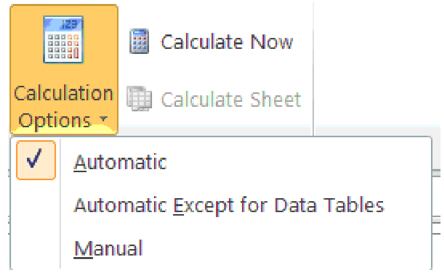


Excel's Calculation Mode

Although not absolutely necessary, let's make sure Excel's calculation mode is set to Automatic.

- On the Excel ribbon go to the **Formulas** tab.
- In the **Calculation** button group click **Calculation Options.**

- Select **Automatic.**

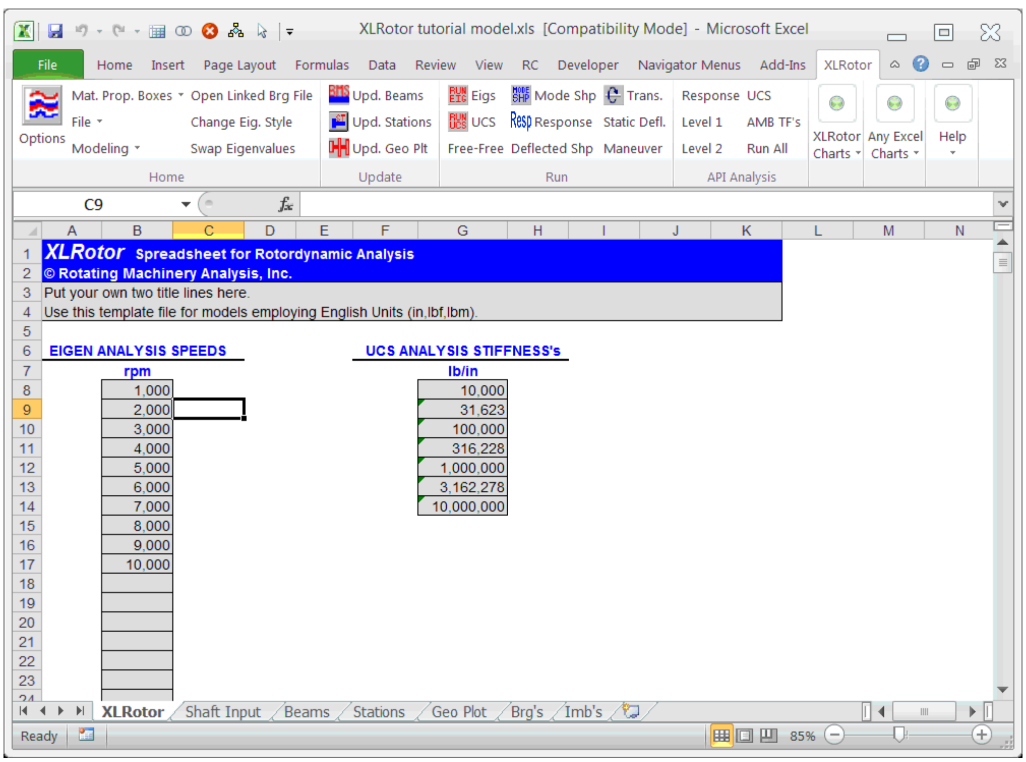


The calculation mode is saved with your file, but if you have multiple files open, the same calculation mode is used for all open files. Excel uses the mode saved with the first file that is opened, or else uses the mode you specifically select from the ribbon.

Now is a good time to save the file with a name of your choosing. From the Excel menu do a **File⇨SaveAs** command, and name the file "**XLRotor tutorial model.xls**". The Automatic calculation setting will have been saved with the file.

Excel offers several different file formats for saving workbook files. Use either the old **.xls** format or the newer **.xlsb** format. Do <u>not</u> use the **.xlsx** or **.xlsm** formats.

At this point, the file should look like the following. When Excel opens an XLRotor file you should see a splash screen for XLRotor displaying version information, and the XLRotor ribbon tab should appear. If you don't see the XLRotor ribbon tab, then XLRotor is not installed correctly. Either re-install the software, or go to the XLRotor program directory and run the file named **SETUP TOOLBAR.XLS**.



Contents of an XLRotor File

Before getting started on creating a rotor model, here's a quick overview of the contents of an XLRotor file. First is a list of **worksheets that must be in every XLRotor lateral rotor model file**:

XLRotor Project titles, speed and stiffness ranges.

	(this sheet is named **Xltorsion** in a torsional model file)
Shaft Input	Shaft geometry and material properties.
Beams	Output sheet of calculated beam properties.
Stations	Output sheet of calculated station properties.
Geo Plot	Plot of model geometry.
Brg's	Bearing locations and some of their properties.
	(this sheet is named **Cplg's** in a torsional model file)
Imb's	Imbalance response inputs.
	(this sheet is named **Orders** in a torsional model file)
GeoPltData	***Hidden*** sheet containing data for the geometry plot.
lists	***Hidden*** sheet containing all XLRotor option settings saved with this file.

Optional sheets that are added by you and/or XLRotor as needed:

Transient	Transient analysis input sheet. If needed, XLRotor will create this sheet the first time you perform an **XLRotor/Run/Transient** command.
Bearing sheets	Worksheets that contain stiffness and damping properties for individual bearings. These sheets are copied from bearing template files for different kinds of bearings.

Worksheets that are added by XLRotor for displaying **calculation results**:

Roots Damped	Damped eigenvalues versus shaft speed.
	(this sheet is named **Roots Tors** in a torsional model file)
Roots UCS	Undamped synchronous critical speeds versus support stiffness.
Roots FF	Free-free eigenvalue results versus shaft speed.
Shapes	Mode shapes.
Resp	All linear response results (rotating imbalance, asynchronous excitations, static deflection, operating deflected shapes).
Transient Resp	Response results for transient analyses.

The XLRotor Worksheet

The first worksheet in the file (shown on the previous page) is named **XLRotor**. Every XLRotor file used for lateral analysis will contain a sheet with this exact name. For torsional analysis you start with a different template file that contains a similar sheet named **Xltorsion**.

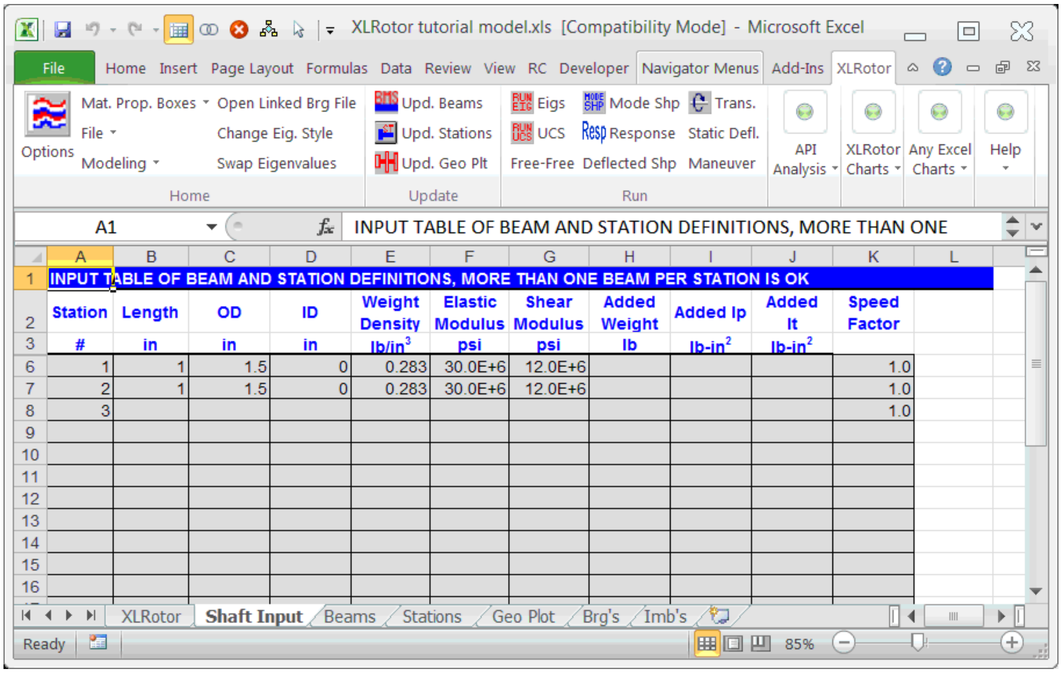
On the XLRotor sheet enter project titles in cells **A3** and **A4**. Later, when you perform an analysis (critical speed, imbalance response, etc.), these titles will be copied to charts which are created automatically.

- Enter **Tutorial 5 station model** in cell **A3.**
- Enter **Critical speed and imbalance response analysis** in cell **A4.**

This sheet is also where you enter rotor speed and bearing stiffness ranges that will be used for doing critical speed analyses. You can come back and change these at any time.

Entering a Shaft Model

Shaft Input Worksheet



- Move to the sheet named **Shaft Input** shown above.
- Do this by clicking on the sheet tab with the mouse.
- Or by pressing **Control-PageDown**.

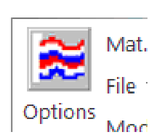
Every XLRotor rotor model file, both lateral and torsional, must contain a sheet named **Shaft Input**. The table on this sheet is where you define the geometry of the model. Shafts, bearing supports, and machine housings are all defined here. The template file has a couple of stations already entered which we'll overwrite with new data.

The demo version of XLRotor is limited to 5 stations. So we'll create a shaft model with this many stations.

- Enter a **1** in cell **A6** for the station number of the first station
- In cell **A7** enter a formula by pressing the equal sign, **=**, then the **Up Arrow** key one time which highlights cell **A6**, then type a plus sign, **+**, then type a one, **1**
- Finish by pressing **Enter**

This puts a cell formula **=A6+1** in cell **A7**, and so a 2 is displayed in cell **A7**.

- Click on cell **A8** and press **control-D** on the keyboard to copy cell **A7** to cell **A8** (Control-D is a regular Excel feature that copies cells downward).
- In cell **B6** enter **4** for the length of the first station.
- In cell **B7** enter **12** for the length of the second station.
- In cells **C6** and **C7** enter **0.6** and **0.75** for the outer diameters of the beam elements.
- We'll have the shaft be solid with inner diameters of zero, so leave the cells in column D empty. You could also enter zeros for inner diameter if you prefer.
- XLRotor also allows input of radius instead of diameter
  Click **Options** on the XLRotor ribbon, then **General/Use Radius** but leave it set to diameter for this tutorial.



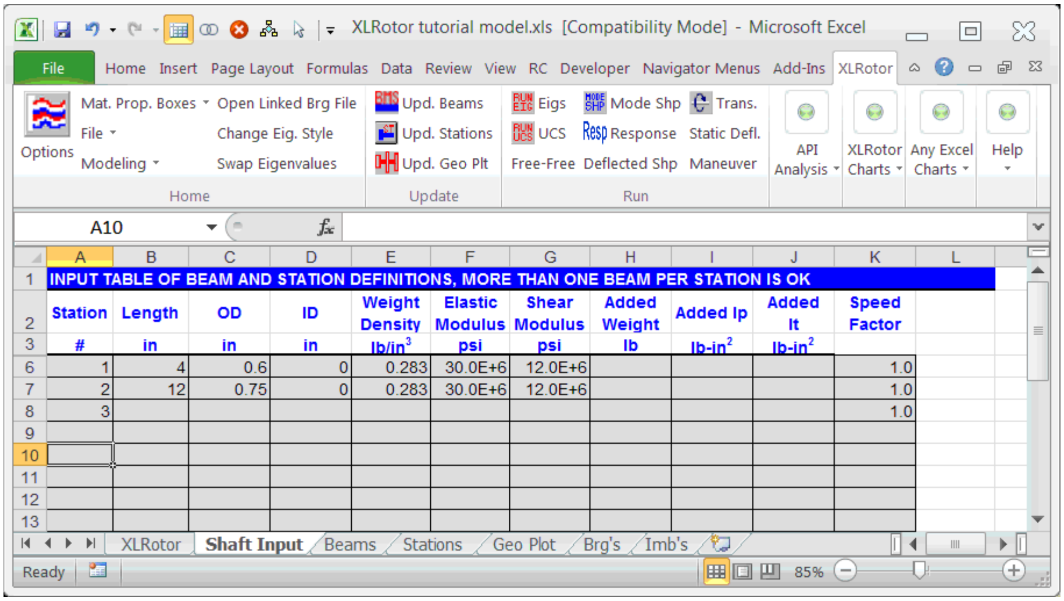
So far we have a 3 station model. Station number 3 is the last station in this model. The “length” of the last station must always be zero, and so the last station does not need, and should not have, any diameters or material properties defined for it.

The last column in the table is named Speed Factor.

- Enter a **1** in all cells from **K6** to **K8** for the Speed Factor.

This tells XLRotor that all the stations are rotating. The Speed Factor for stations that don’t rotate, like bearing supports and housings, would be 0.

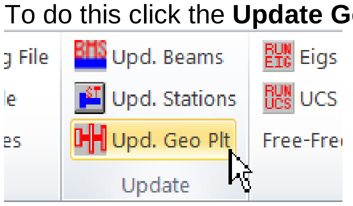
Here is what the **Shaft Input** sheet should look like so far.

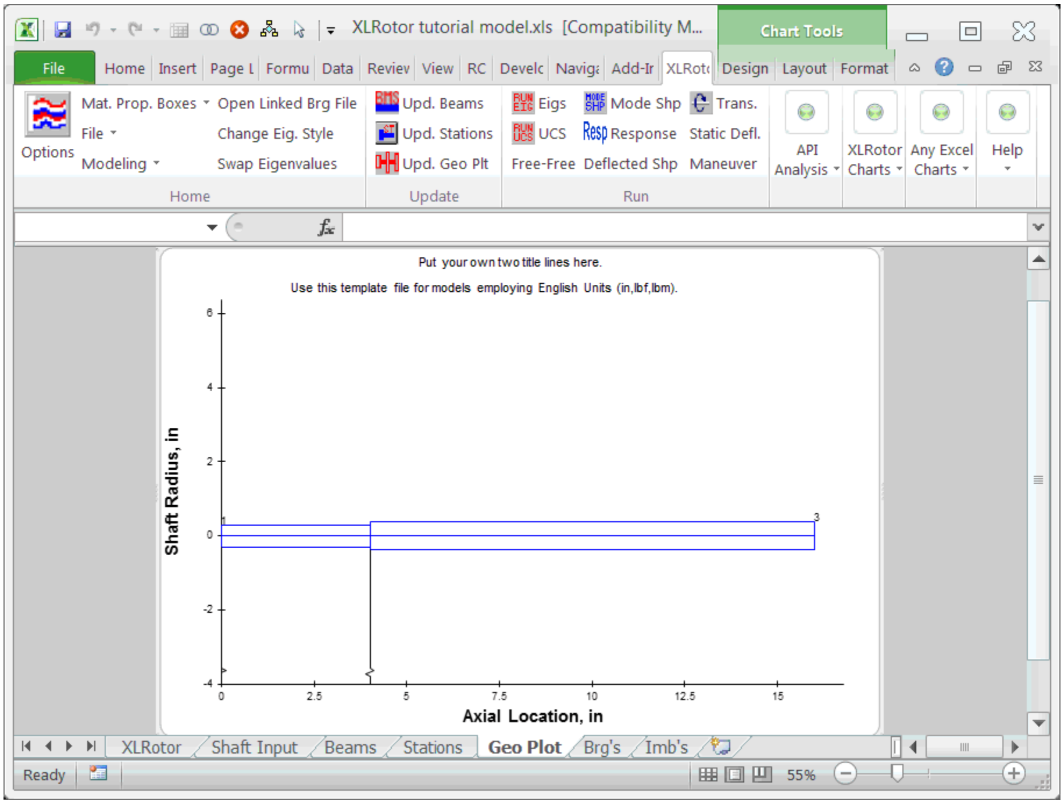


Geo Plot Sheet

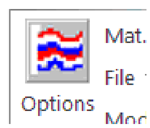
The template file already has material properties entered for two stations, but even without any material properties entered, we can see a picture of what the model looks like.

- To do this click the **Update Geo Plt** button.

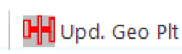


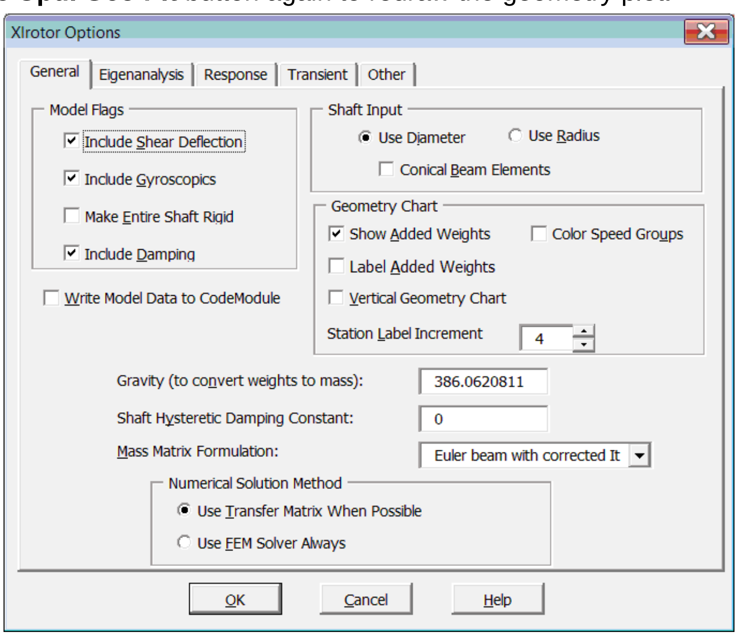


This command should take you to the sheet named **Geo Plot**. The plot for our model shows bearings at stations 1 and 2 because these have been entered elsewhere in the file. We'll fix these after finishing the shaft model.

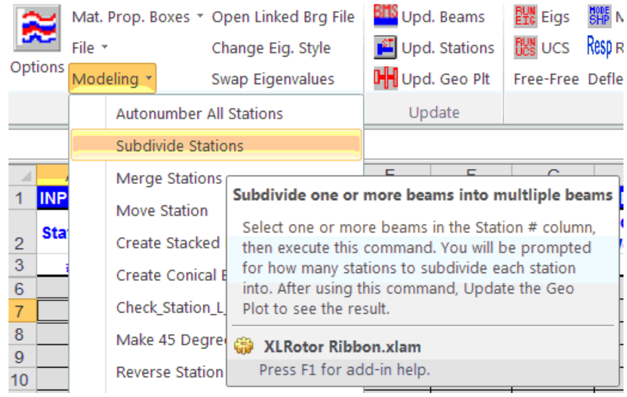


- Click on the **Options** button in the XLRotor ribbon.
- The station label increment is presently **4**. Change this to **1.**
- Select **OK** to close the dialog.
- Click the **Upd. Geo Plt** button again to redraw the geometry plot.

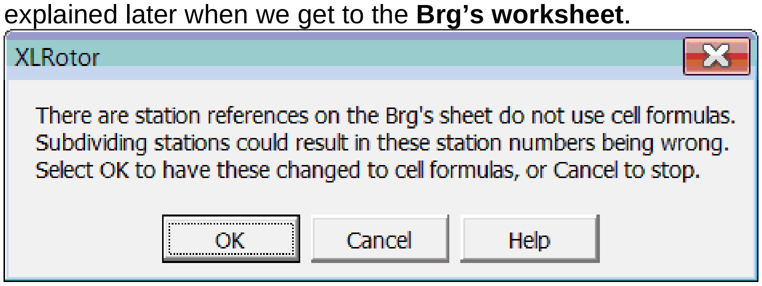




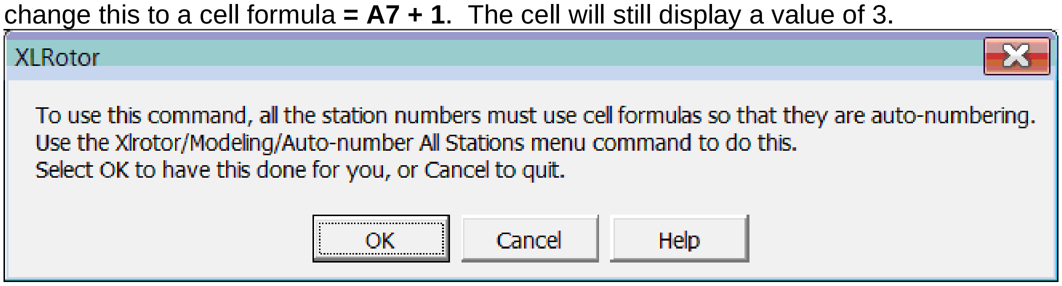
- Go back to the **Shaft Input** worksheet.
- Click on cell **A7** for station number 2.
- In the XLRotor ribbon click **Modeling** and then **Subdivide Stations**.



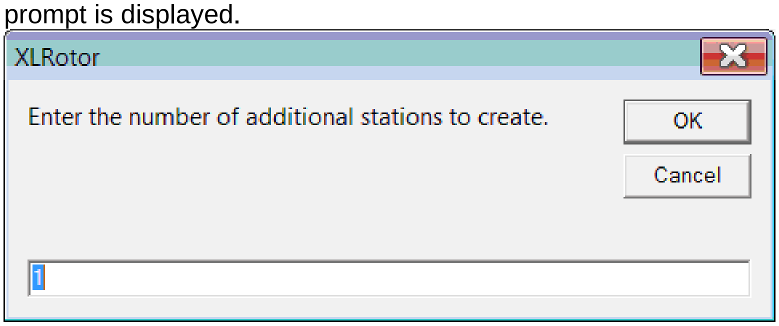
- Click **Ok** if the following message is displayed. The reason this message is displayed will be explained later when we get to the **Brg's worksheet**.



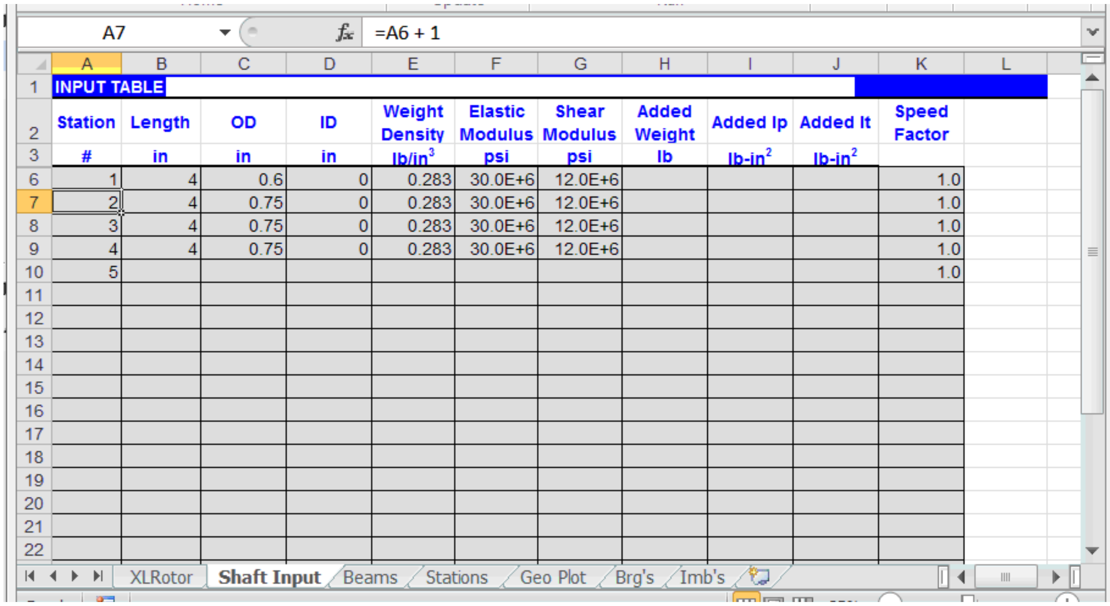
- After the above message closes, the message shown below will be displayed. Click **Ok** for this one, too. The reason this message is displayed is because cell **A8** on the Shaft Input sheet contains a simple numerical value of 3 for the third station. When Ok is clicked, the program will change this to a cell formula **= A7 + 1**. The cell will still display a value of 3.



- After the above two messages, we finally get to subdividing station number 2, and the following prompt is displayed.



- Input **2** and press **Enter.** This will subdivide station number 2, which is 12 inches long, into 3 stations of equal length, which are each 4 inches long. The two new stations that get created are stations 3 and 4. These are given the same diameters and material properties as station 2.

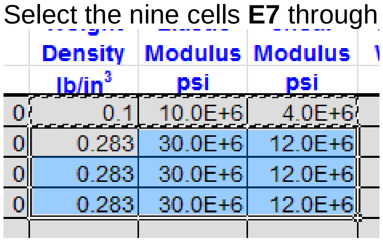


A7 =A6 + 1

	A	B	C	D	E	F	G	H	I	J	K	L
1	INPUT TABLE											
2	Station	Length	OD	ID	Weight Density	Elastic Modulus	Shear Modulus	Added Weight	Added Ip	Added It	Speed Factor	
3	#	in	in	in	lb/in³	psi	psi	lb	lb-in²	lb-in²		
6	1	4	0.6	0	0.283	30.0E+6	12.0E+6				1.0	
7	2	4	0.75	0	0.283	30.0E+6	12.0E+6				1.0	
8	3	4	0.75	0	0.283	30.0E+6	12.0E+6				1.0	
9	4	4	0.75	0	0.283	30.0E+6	12.0E+6				1.0	
10	5										1.0	
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												

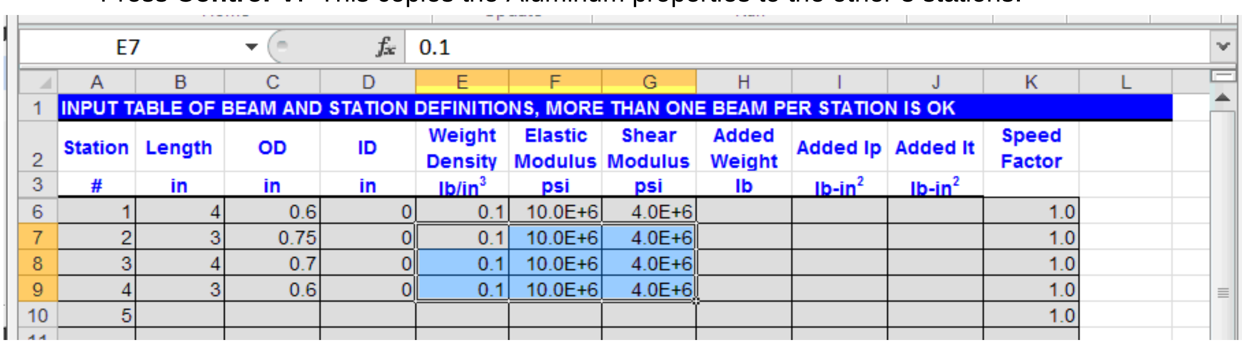
XLRotor | Shaft Input | Beams | Stations | Geo Plot | Brg's | Imb's

- In cell **B7**, change axial length of station 2 to **3** inches.
- In cell **B9**, change axial length of station 4 to **3** inches.
- In cell **C8**, change diameter of station 3 to **0.7** inches.
- In cell **C9**, change diameter of station 4 to **0.6** inches.
- Change station number 1 from steel to Aluminum by entering **0.1, 10e6 and 4e6** into cells **E6, F6 and G6**.
- Using the mouse or keyboard, select the three cells **E6, F6 and G6**.and press **Control-C.**
- Select the nine cells **E7** through **G9.**



	Density	Modulus	Modulus
	lb/in³	psi	psi
0	0.1	10.0E+6	4.0E+6
0	0.283	30.0E+6	12.0E+6
0	0.283	30.0E+6	12.0E+6
0	0.283	30.0E+6	12.0E+6

- Press **Control-V**. This copies the Aluminum properties to the other 3 stations.

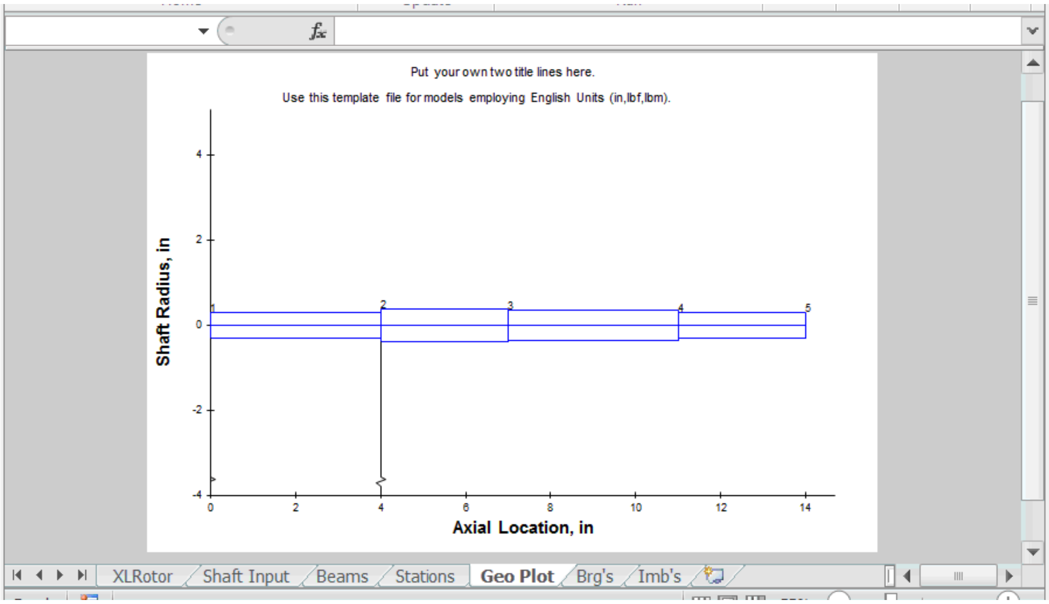


E7 0.1

	A	B	C	D	E	F	G	H	I	J	K	L
1	INPUT TABLE OF BEAM AND STATION DEFINITIONS, MORE THAN ONE BEAM PER STATION IS OK											
2	Station	Length	OD	ID	Weight Density	Elastic Modulus	Shear Modulus	Added Weight	Added Ip	Added It	Speed Factor	
3	#	in	in	in	lb/in³	psi	psi	lb	lb-in²	lb-in²		
6	1	4	0.6	0	0.1	10.0E+6	4.0E+6				1.0	
7	2	3	0.75	0	0.1	10.0E+6	4.0E+6				1.0	
8	3	4	0.7	0	0.1	10.0E+6	4.0E+6				1.0	
9	4	3	0.6	0	0.1	10.0E+6	4.0E+6				1.0	
10	5										1.0	

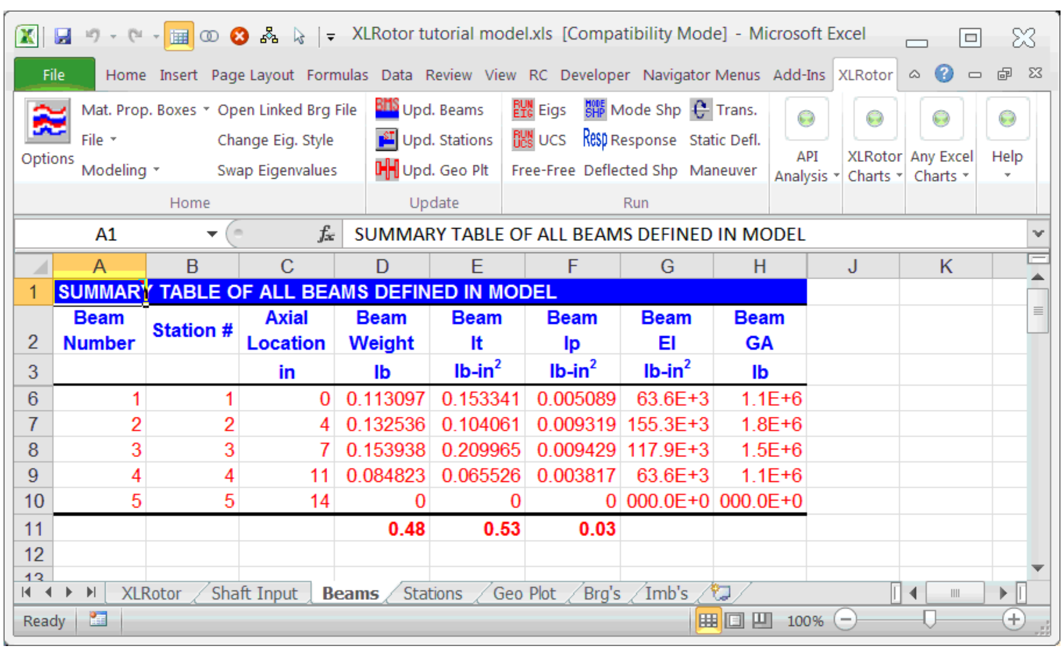
If desired, cell formulas could be used in cells E7:G9 which refer to the properties of station 1. Then later, the material for the entire shaft could be changed just changing the properties of station 1.

- Click the button to update the Geometry Plot. The two new stations will be added to the plot.



Two other worksheets in this file have the names **Beams** and **Stations**.

Beams Worksheet



Beam Number	Station #	Axial Location in	Beam Weight lb	Beam It lb-in^2	Beam Ip lb-in^2	Beam EI lb-in^2	Beam GA lb
1	1	0	0.113097	0.153341	0.005089	63.6E+3	1.1E+6
2	2	4	0.132536	0.104061	0.009319	155.3E+3	1.8E+6
3	3	7	0.153938	0.209965	0.009429	117.9E+3	1.5E+6
4	4	11	0.084823	0.065526	0.003817	63.6E+3	1.1E+6
5	5	14	0	0	0	000.0E+0	000.0E+0
			0.48	0.53	0.03		

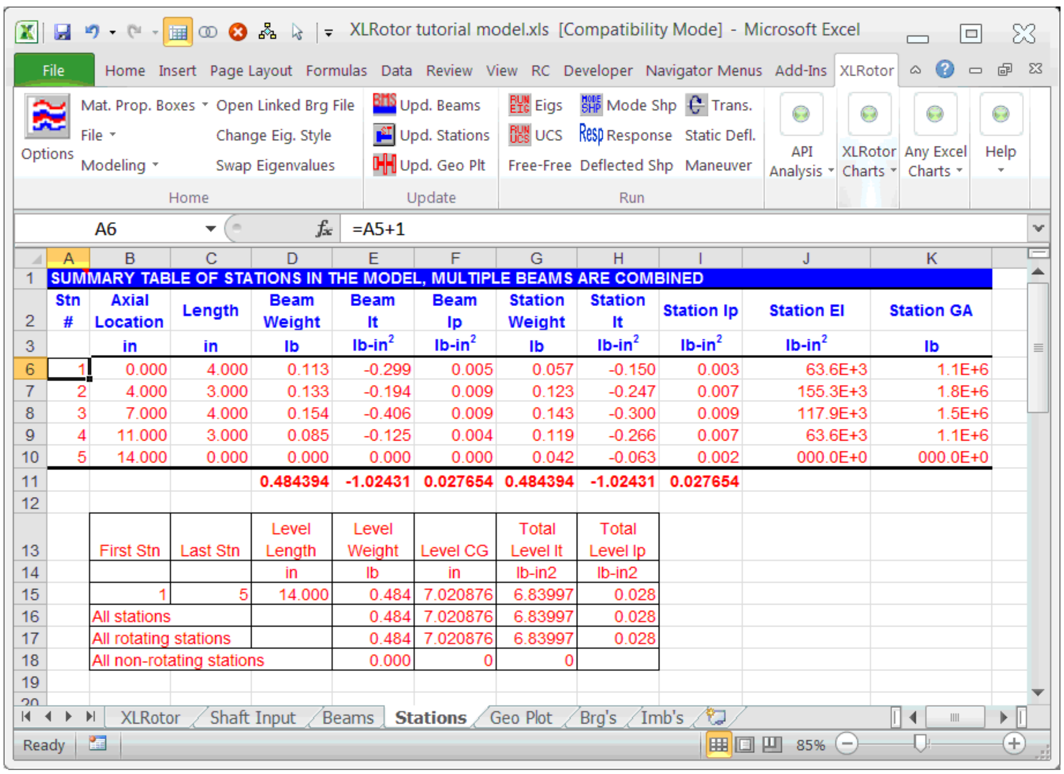
- Go to the **Beams** worksheet.

There you will see a table of inertia properties computed for each beam. The number of rows in this table should always be the same as the number of rows on the **Shaft Input** worksheet. When the Geometry Plot was updated, this table also was updated to contain all the beams now in the model. The beam element inertia properties are computed by cell formulas which refer to the geometry and material properties for each beam. You can see the formula in any cell by selecting the cell, and looking at the Excel formula bar located near the top of the Excel window. Select cell **D6** and you'll see **{=PI()/4*length*rhoa*(oda^2 - ida^2)}** in the formula bar. This formula was put there when you performed the **Update Geometry Plot** command. The **Update Geometry Plot** command will automatically execute an **Update Beams Sheet** command whenever necessary. The curly brackets that enclose the formula mean that this formula is an "array" formula. See Excel's online help or get one of the many "how to" books on Microsoft Excel, to learn what is special about array formulas.

The formula you see in cell **D6** makes use of what Excel calls Defined Names. On the **Shaft Input** sheet the cells that contain the length, diameter, and material properties have been given descriptive names, and these names are used to make the formula in cell **D6** easier to understand.

You can see all the formulas on the **Beams** sheet at one time by pressing **Control-`**. **Control-`** is a toggle between normal display and formula display. On many keyboards the ` character is at the left end of the top row of keys, to the left of the 1 key.

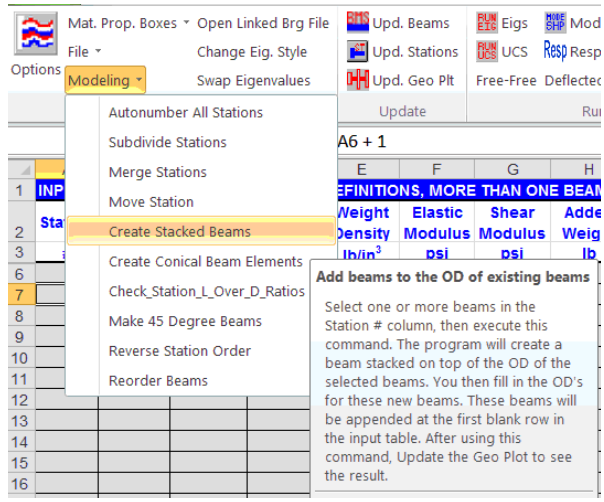
Stations Worksheet



- Go to the **Stations** worksheet shown in the above image.

The number of rows in this table should always be equal to the number of stations in the model. This can be fewer than the number of rows on the **Shaft Input** and **Beams** sheets. To see how this can happen, we'll define one more beam that will go on top of the beam already defined for station 2.

- Go back to the **Shaft Input** sheet.
- Select cell **A7** which is for station number 2 in the **Station** # column.
- In the XLRotor ribbon click **Modeling** and then **Create Stacked Beams.**



This will add another beam configured to go on top of the selected beam for station number 2. This new beam appears at the bottom of the table in worksheet row 11. The Station #, length, ID and Speed Factor are already filled in. The cells for OD and material properties are empty and need to be filled in.

Tip: the **Create Stacked Beams** command can operate on any number of beams by selecting all the beams with the mouse or keyboard.

C11

	A	B	C	D	E	F	G	H	I	J	K
1	INPUT TABLE OF BEAM AND STATION DEFINITIONS, MORE THAN ONE BEAM PER STATION IS OK										
2	Station	Length	OD	ID	Weight Density	Elastic Modulus	Shear Modulus	Added Weight	Added Ip	Added It	Speed Factor
3	#	in	in	in	lb/in^3	psi	psi	lb	$lb\text{-}in^2$	$lb\text{-}in^2$	
6	1	4	0.6	0	0.1	10.0E+6	4.0E+6				1.0
7	2	3	0.75	0	0.1	10.0E+6	4.0E+6				1.0
8	3	4	0.7	0	0.1	10.0E+6	4.0E+6				1.0
9	4	3	0.6	0	0.1	10.0E+6	4.0E+6				1.0
10	5										1.0
11	2	3		0.75							1.0
12											
13											

XLRotor | Shaft Input | Beams | Stations | Geo Plot | Brg's | Imb's

- In the columns for **OD** and **material properties**, enter the values shown in following image. This new beam will have the properties of steel.

G11 12000000

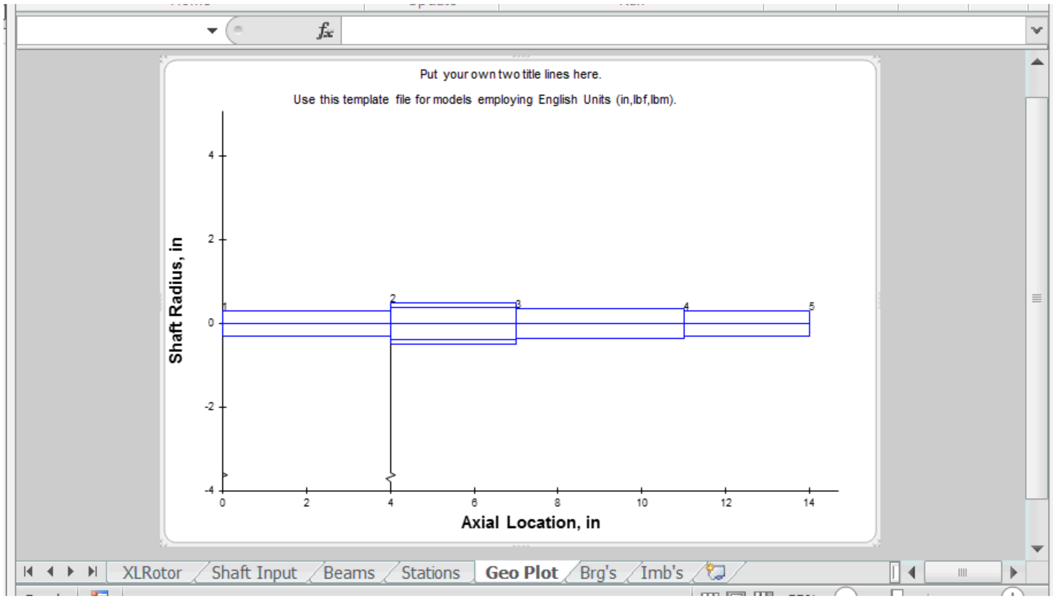
	A	B	C	D	E	F	G	H	I	J	K
1	INPUT TABLE OF BEAM AND STATION DEFINITIONS, MORE THAN ONE BEAM PER STATION IS OK										
2	Station	Length	OD	ID	Weight Density	Elastic Modulus	Shear Modulus	Added Weight	Added Ip	Added It	Speed Factor
3	#	in	in	in	lb/in^3	psi	psi	lb	$lb\text{-}in^2$	$lb\text{-}in^2$	
6	1	4	0.6		0.1	10.0E+6	4.0E+6				1.0
7	2	3	0.75		0.1	1E+07	4000000				1.0
8	3	4	0.7		0.1	1E+07	4000000				1.0
9	4	3	0.6		0.1	1E+07	4000000				1.0
10	5							10	20.0	10.0	1.0
11	2	3	1	0.75	0.28	29.0E+6	12.0E+6				1.0
12											
13											

XLRotor | Shaft Input | Beams | Stations | Geo Plot | Brg's | Imb's

What we've done is added another beam to the model, but we have <u>not</u> added another station. Every beam has to be assigned to a station, and one station can have any number of beams. The program will check to make sure that none of the beams in the model overlap. Gaps between the OD of an inner beam and ID of an outer beam are allowed, but interferences are not and are treated as a modeling error.

- Click the **Update Geometry Plot** button.

This action will cause the tables on the **Beams** and **Stations** sheets to get updated along with the Geometry Plot itself. The geometry plot now shows the extra beam added to the model.



- Go to the **Beams** worksheet.

You'll see that another row of formulas has been added to the table on that sheet.

D6 | {=PI()/4*length*rhoa*(oda^2 - ida^2)}

	A	B	C	D	E	F	G	H
1	SUMMARY TABLE OF ALL BEAMS DEFINED IN MODEL							
2	Beam Number	Station #	Axial Location	Beam Weight	Beam It	Beam Ip	Beam EI	Beam GA
3			in	lb	lb-in^2	lb-in^2	lb-in^2	lb
6	1	1	0	0.113097	0.153341	0.005089	63.6E+3	1.1E+6
7	2	2	4	0.132536	0.104061	0.009319	155.3E+3	1.8E+6
8	3	3	7	0.153938	0.209965	0.009429	117.9E+3	1.5E+6
9	4	4	11	0.084823	0.065526	0.003817	63.6E+3	1.1E+6
10	5	5	14	0	0	0	000.0E+0	000.0E+0
11	6	2	4	0.291726	0.247284	0.056978	973.1E+3	4.1E+6
12				**0.78**	**0.78**	**0.08**		
13								

XLRotor / Shaft Input / **Beams** / Stations / Geo Plot / Brg's / Imb's

- Go to the **Stations** sheet.

1	SUMMARY TABLE OF STATIONS IN THE MODEL, MULTIPLE BEAMS ARE COMBINED										
2	Stn #	Axial Location	Length	Beam Weight	Beam It	Beam Ip	Station Weight	Station It	Station Ip	Station EI	Station GA
3		in	in	lb	lb-in^2	lb-in^2	lb	lb-in^2	lb-in^2	lb-in^2	lb
6	1	0.000	4.000	0.113	-0.299	0.005	0.057	-0.150	0.003	63.6E+3	1.1E+6
7	2	4.000	3.000	0.424	-0.603	0.066	0.269	-0.451	0.036	1.1E+6	5.9E+6
8	3	7.000	4.000	0.154	-0.406	0.009	0.289	-0.505	0.038	117.9E+3	1.5E+6
9	4	11.000	3.000	0.085	-0.125	0.004	0.119	-0.266	0.007	63.6E+3	1.1E+6
10	5	14.000	0.000	0.000	0.000	0.000	0.042	-0.063	0.002	000.0E+0	000.0E+0
11				**0.776121**	**-1.43341**	**0.084632**	**0.776121**	**-1.43341**	**0.084632**		
12											
13		First Stn	Last Stn	Level Length	Level Weight	Level CG	Total Level It	Total Level Ip			
14				in	lb	in	lb-in2	lb-in2			
15		1	5	14.000	0.776	6.449213	7.508399	0.085			
16		All stations			0.776	6.449213	7.508399	0.085			
17		All rotating stations			0.776	6.449213	7.508399	0.085			
18		All non-rotating stations			0.000	0	0				

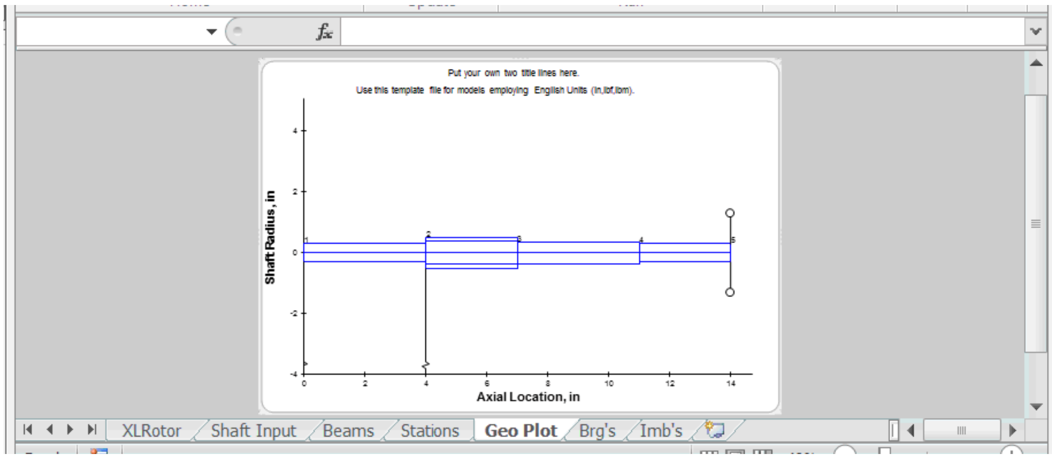
The number of rows in this table is 5, the number of stations in the model. The main purpose of the **Stations** sheet is to add together the properties of beams that are at the same station. The formulas that appear in the cells on this sheet use defined names that refer to the columns of the table on the **Beams** sheet. The formulas in the row for station 2 cause the properties of the Aluminum and Steel beams to be added together.

Some of the formulas on this sheet also refer to columns on the **Shaft Input** sheet called Added Weight, Added It and Added Ip. In the formulas on the **Stations** sheet these cell ranges are referred to using their Defined Names *awt*, *ait* and *aip*.

- Go to the **Shaft Input** sheet and type **10** in cell **H10** for an added weight at station 5
- Type **20** in cell **I10** for added polar inertia
- Type **10** in cell **J10** for added transverse inertia
- Click the button to update the Geometry Plot

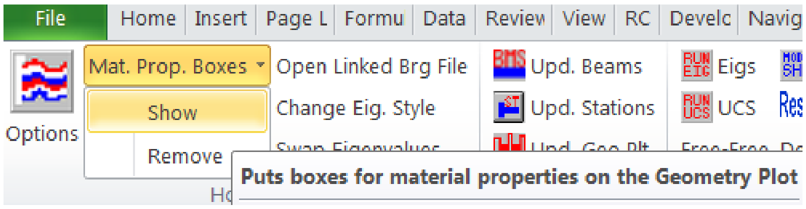
hear odulus psi	Added Weight lb	Added Ip $lb\text{-}in^2$	Added It $lb\text{-}in^2$	Speed Factor
4.0E+6				1.
4.0E+6				1.
4.0E+6				1.
4.0E+6				1.
	10.0	20.0	10.0	1.
2.0E+6				1.

The geometry plot should now show the presence of the added weight.

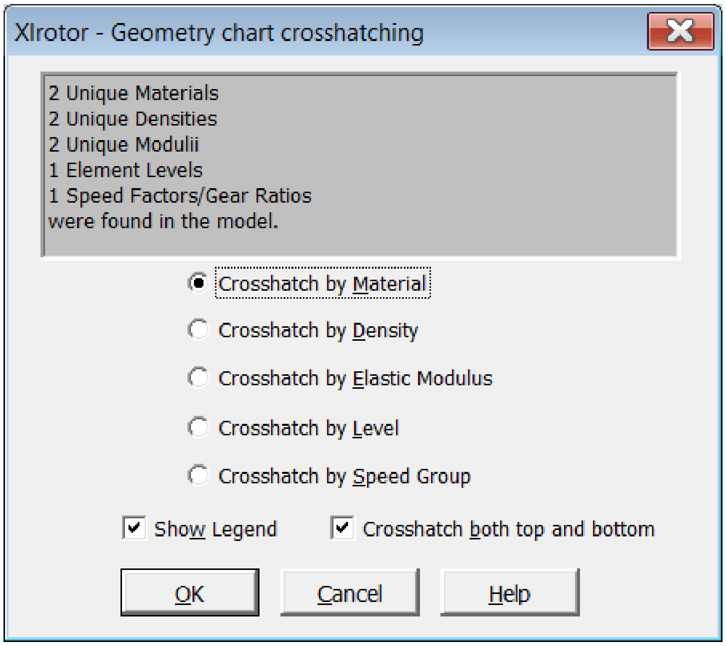


The formulas on the **Stations** sheet also now show that the extra weight has been lumped at station 5 along with half the weight of the beam connecting stations 4 and 5.

- While you are on the **Geo Plot** sheet, in the XLRotor ribbon click **Mat. Prop. Boxes** and then **Show**

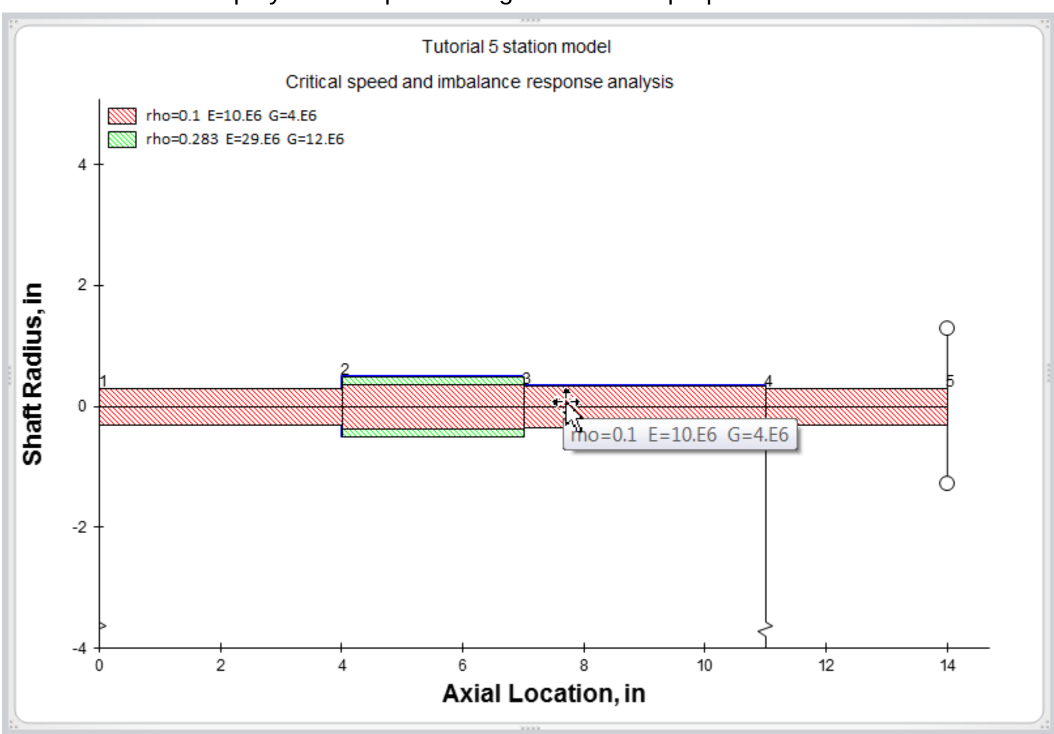


This will display the following dialog box summarizing the materials in the model, and offering options for adding cross hatching to the geometry plot.



- Select **Crosshatch by Material**, and put checks in the boxes for **Show Legend** and **Crosshatch both top and bottom.**
- Click **Ok.**

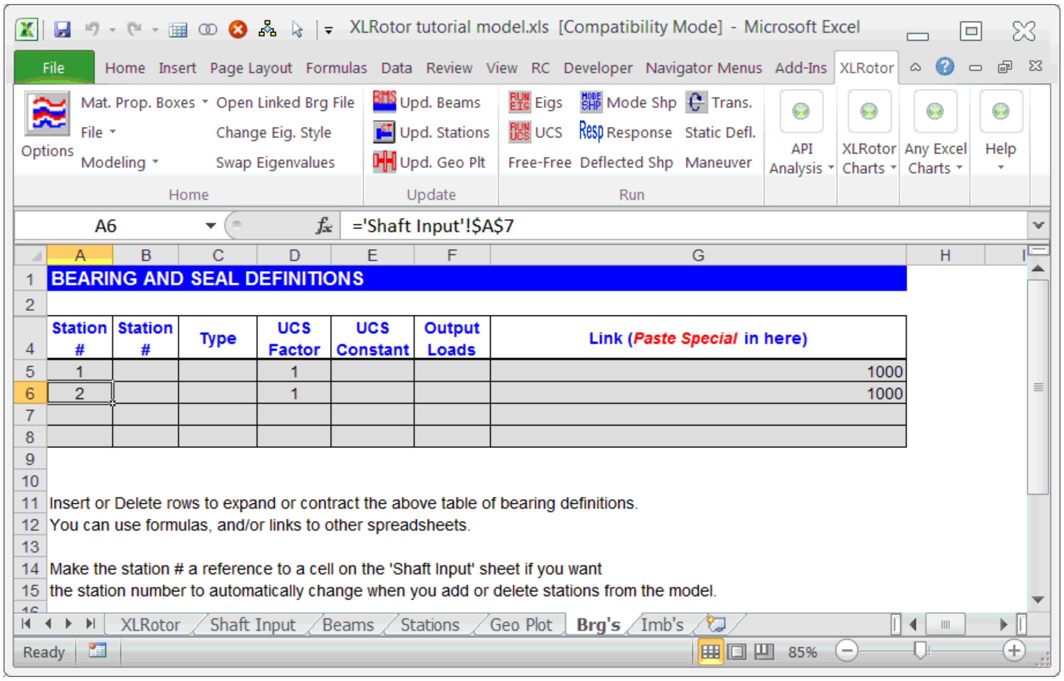
This draws a colored box over each beam element in the model. The boxes are intended to make it easy to see what parts of the shaft model share the same material properties. Hovering your mouse over any of the boxes will display a "tool tip" showing the material properties for that beam element.



- In the XLRotor ribbon click **Mat. Prop. Boxes** and then **Remove** to remove the boxes.

This completes creation of the shaft model. The next step is to setup the bearings.

Defining Bearings



To setup bearings you need to specify where the bearings are located on the shaft, and what their stiffness and damping properties are.

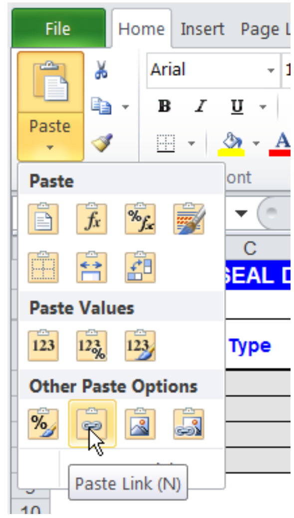
- Go to the worksheet named **Brg's** (in a torsional model file this sheet is named **Cplg's**).

In the first column of the table on this sheet enter the station numbers where you want to have bearings. For our example model we'll have two bearings, one at station 1 and another at station 4. You could simply enter a 1 and a 4 in cells **A5** and **A6**, but there is a better way.

- Go to the **Shaft Input** worksheet .
- Click on cell **A6.**
- Hold down the control key and click on cell **A9**. These are the station numbers where we want the bearings.
- Press **Control-C** to copy these two cells to the clipboard.

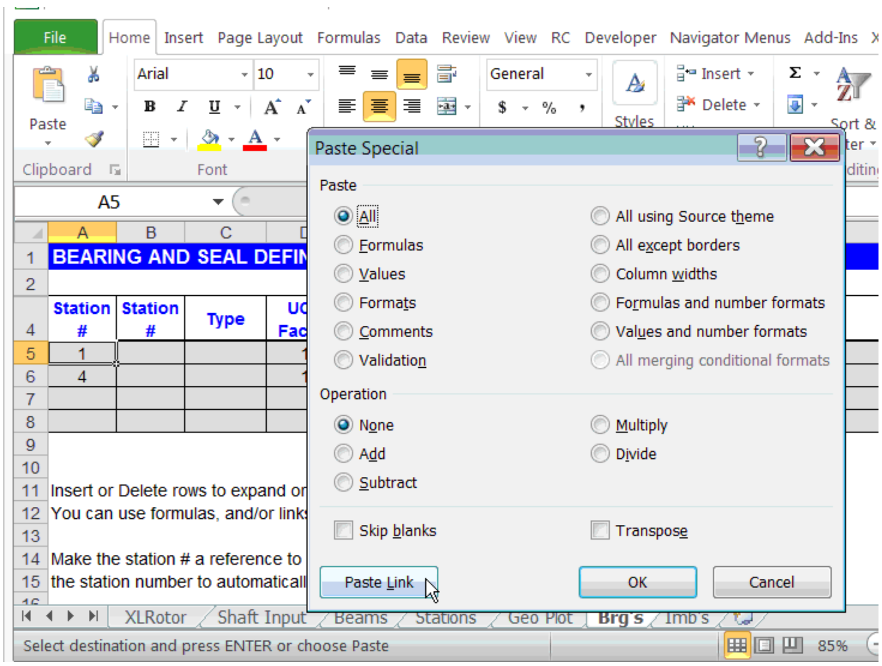
	A	B	C	D	E	F	G
1	INPUT TABLE OF BEAM AND STATION DEFINITIONS, MORE THAN (						
2	Station	Length	OD	ID	Weight Density	Elastic Modulus	Shear Modulu
3	#	in	in	in	lb/in^3	psi	psi
6	1	4	0.6	0	0.1	10.0E+6	4.0E-
7	2	3	0.75	0	0.1	10.0E+6	4.0E-
8	3	4	0.7	0	0.1	10.0E+6	4.0E-
9	4	3	0.6	0	0.1	10.0E+6	4.0E-
10	5						
11	2	3	1	0.75	0.283	29.0E+6	12.0E-

- Return to the **Brg's** sheet.
- Click on cell **A5**.



- In the Excel ribbon go to the **Home** tab.
- Click the word **Paste**, and then the button for **Paste Link**.

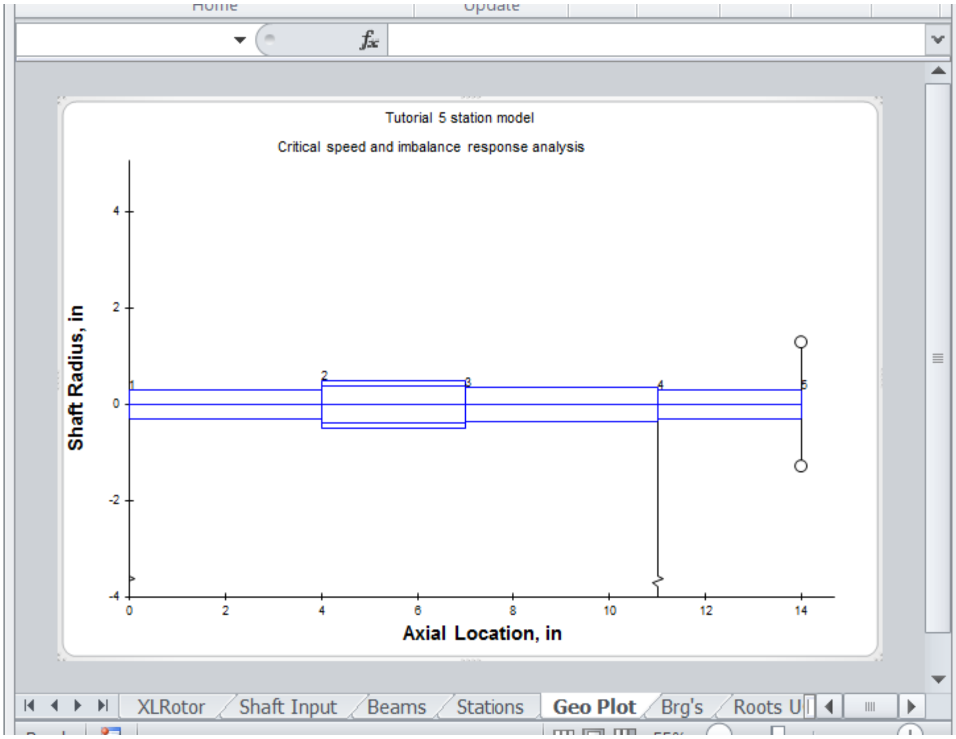
- Alternatively, this can be done with the keyboard by holding down the **Alternate** key, and by pressing **E** then **S** which causes the Paste Special Dialog to be displayed.
- Press either **L** or **Alt-L** to perform the Paste Link, or else click the **Paste Link** button in the dialog.



Whichever way you do it, this will paste formulas into cells **A5** and **A6** on the **Brg's** sheet which refer to the two cells that were selected on the **Shaft Input** sheet. You can see these formulas by looking at the formula bar (or pressing **Control-`**). Using formulas to refer to the station numbers on the **Shaft Input** sheet is recommended because it means that if these station numbers change because of inserting or deleting stations in the model, the station numbers appearing here on the **Brg's** sheet will update automatically.

The second column on the **Brg's** sheet is used for specifying bearings that connect two stations together. When the cell in the second column is empty, the bearing connects the station in the first column to ground. Leave the second column empty for this model.

- Click the  button, and the bearings will now be shown at stations 1 and 4.



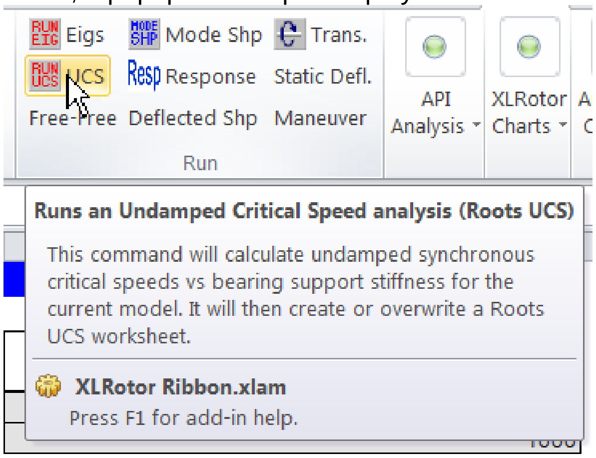
Undamped Critical Speed Analysis

We're almost ready to perform our first rotordynamic analysis.

- On the **Brg's** sheet in cells **D5** and **D6** enter the value **1**.
  This is the column named UCS Factor.

	A	B	C	D	E	F
1	BEARING AND SEAL DEFINITIONS					
2						
4	Station #	Station #	Type	UCS Factor	UCS Constant	Output Loads
5	1			1		
6	4			1		
7						
8						

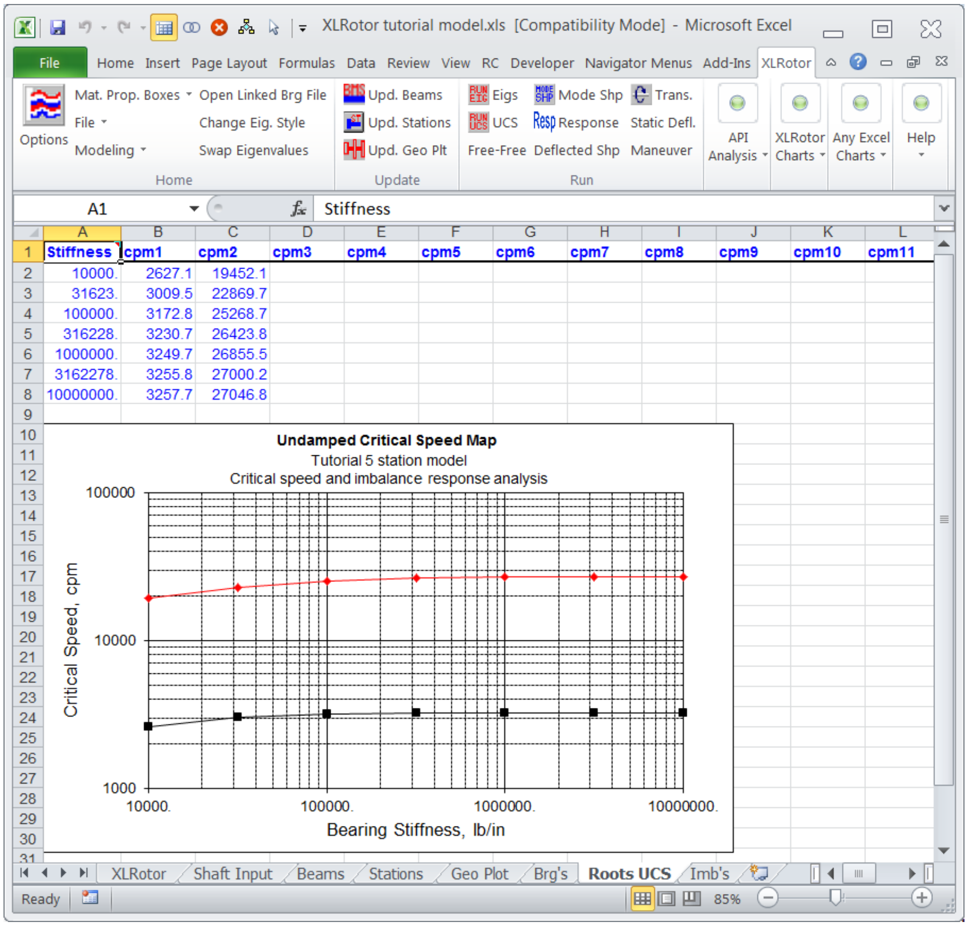
- On the XLRotor ribbon in the **Run** group, click the **UCS** button. When the mouse is over the button, a popup screentip is displayed with a description of what this button does.



UCS stands for Undamped Critical Speeds. The program will run an analysis where the stiffness of each of the two bearings takes on the values listed in column G on the **XLRotor** worksheet. A worksheet named **Roots UCS** will be created automatically to display the results of the analysis.

An undamped critical speed analysis is a special type of eigenvalue calculation. All bearings are reduced to simple undamped axisymmetric springs such that Kxx=Kyy and Kxy=Kyx=0. Also, the rotor transverse inertia, `It`, is replaced with the transverse minus the polar inertia `(It-Ip)`. This last modification, in effect, constrains the rotor rotational speed to equal the eigenvalue frequency. This means that computed eigenvalues are automatically synchronous (i.e., whirl frequency = rotor speed). Eigenvalue frequencies normally vary with rotor speed because of gyroscopics. At particular values of rotor speed where the frequency of a forward whirling eigenvalue matches exactly the speed, the eigenvalue is termed a synchronous critical speed. The **Run⇨UCS** command computes such eigenvalues directly, without the need to iterate the rotor speed.

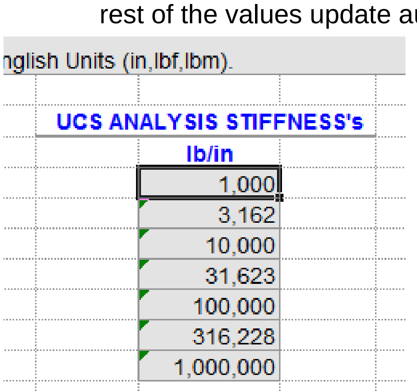
The UCS analysis provides a quick look at what to expect the critical speeds to be for a wide range of support stiffness values. However, this analysis tells nothing about damping and stability. That requires a damped eigenvalue calculation which we will get to a little later in this tutorial.



Stiffness	cpm1	cpm2	cpm3	cpm4	cpm5	cpm6	cpm7	cpm8	cpm9	cpm10	cpm11
10000.	2627.1	19452.1									
31623.	3009.5	22869.7									
100000.	3172.8	25268.7									
316228.	3230.7	26423.8									
1000000.	3249.7	26855.5									
3162278.	3255.8	27000.2									
10000000.	3257.7	27046.8									

From the look of this plot, the stiffness range needs to be changed. Normally we would want the stiffness range to span the entire transition from soft enough to be "free-free" to stiff enough to be "rigidly supported".

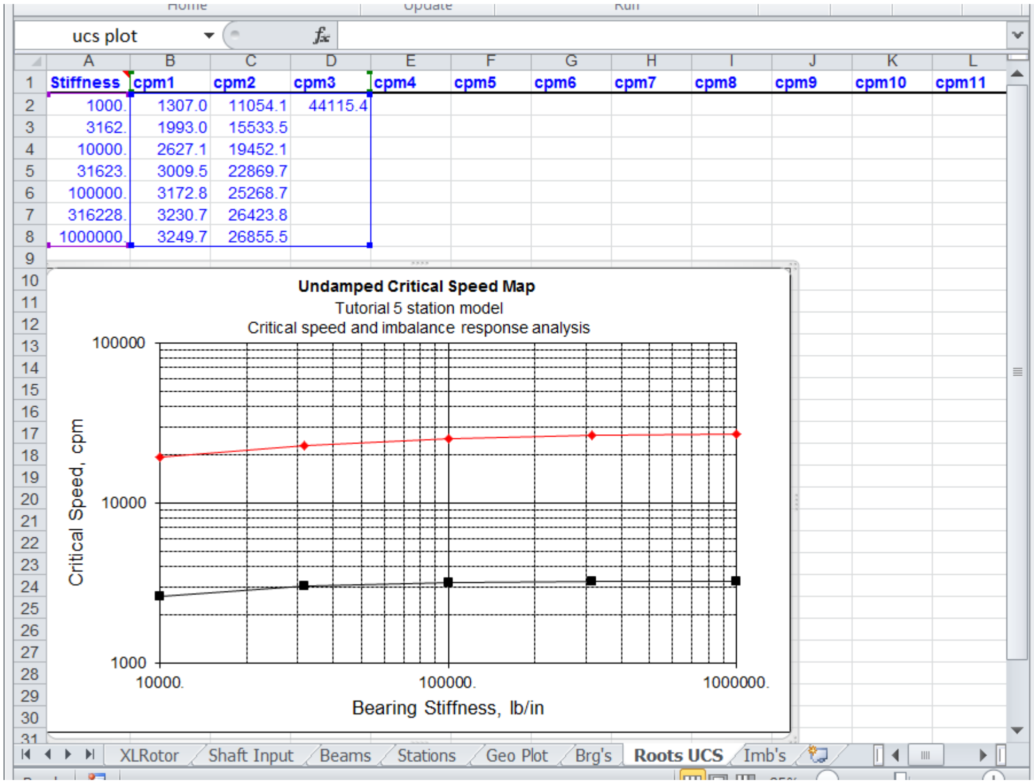
- Go to the **XLRotor** worksheet.
- Change the value in cell **G8** from **10000** to **1000**. Cell formulas should be in the other cells so the rest of the values update automatically.



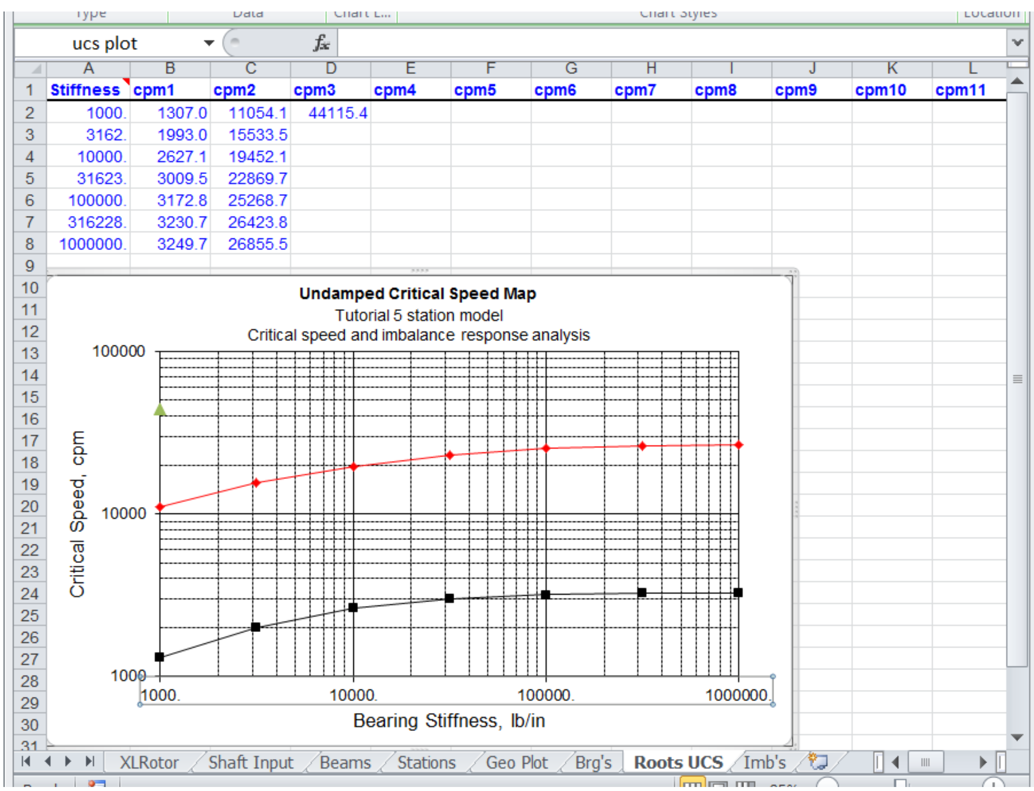
nglish Units (in,lbf,lbm).

UCS ANALYSIS STIFFNESS's
lb/in
1,000
3,162
10,000
31,623
100,000
316,228
1,000,000

- Click the  button again to re-compute the critical speeds with the new range of stiffness values.
- Answer "YES" when prompted for permission to overwrite the previous critical speed results.

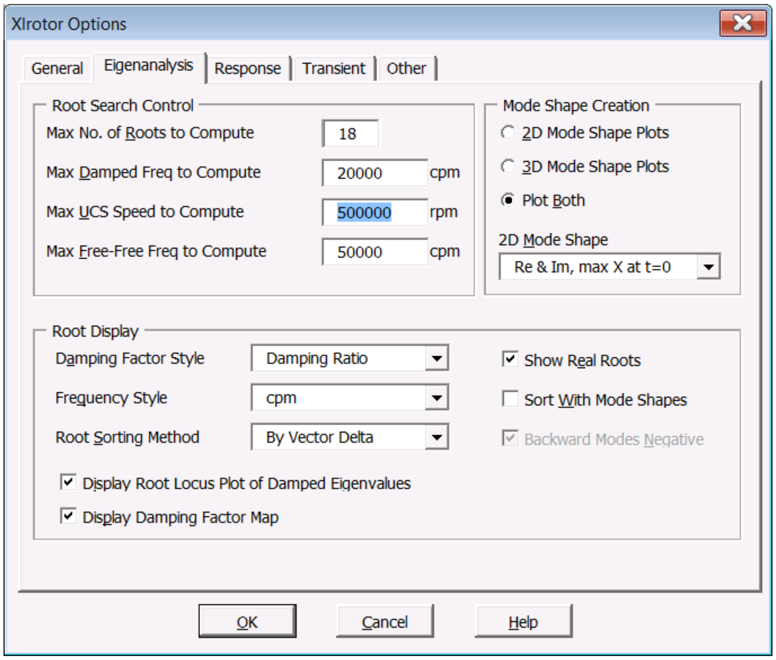


The lower limit on the x axis of the UCS plot is still 10,000. Because of a quirk in Excel with limits of log axes, XLRotor set the lower limit to 10000 when originally creating the chart, but will not change it on subsequent runs. We could manually change it to 1000, or delete the chart and rerun the UCS analysis, during which XLRotor will make a new chart. The new chart will have 1000 as the lower limit.



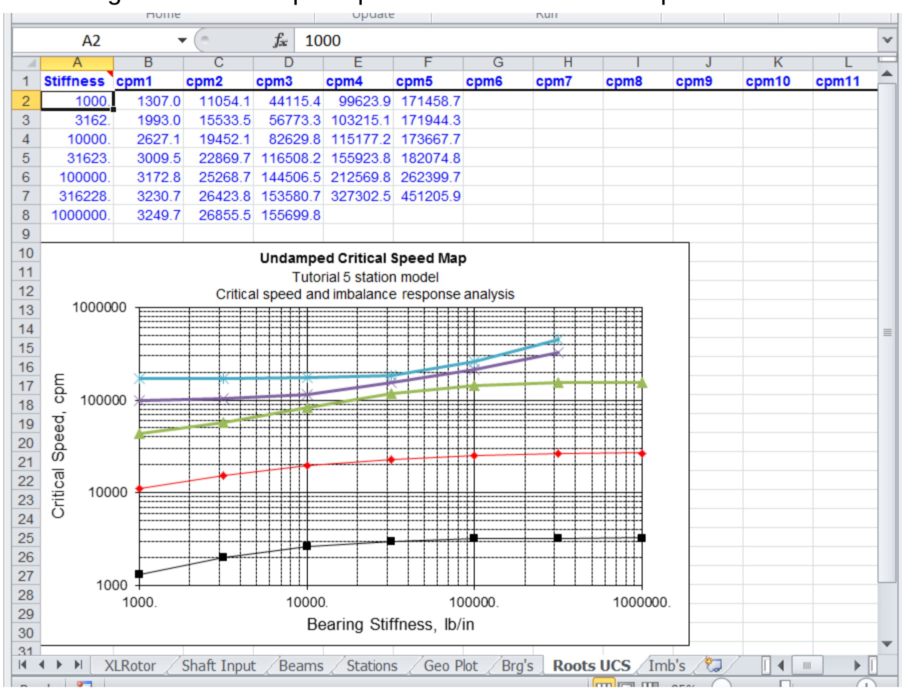
Based on the resulting plot, the stiffness range now looks adequate. It would be better, however, to see a little more of the third mode displayed on the plot, and perhaps the 4th mode as well. So we'll tell the program to put more critical speeds on the plot.

- Click the button to bring up the **Options** dialog box.
- Go to the **Eigenanalysis** tab.
- Change the value for **Max UCS Speed to Compute** from 50000 to **500000.**



- Click the RUN UCS button again to re-compute the critical speeds.

We now get a more complete plot of the rotor's critical speeds as a function of support stiffness.



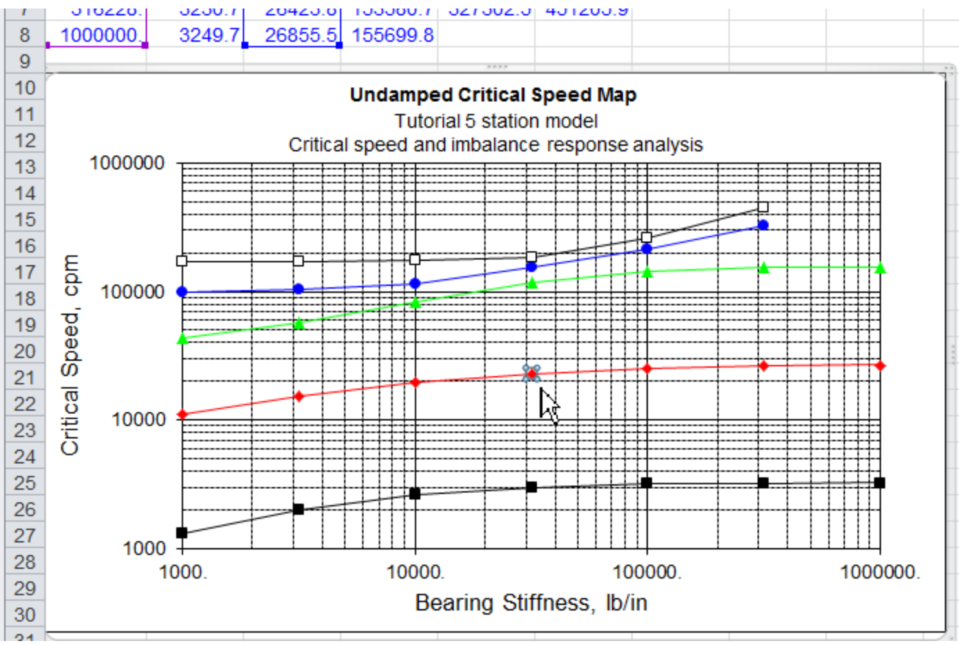
Stiffness	cpm1	cpm2	cpm3	cpm4	cpm5	cpm6	cpm7	cpm8	cpm9	cpm10	cpm11
1000.	1307.0	11054.1	44115.4	99623.9	171458.7						
3162.	1993.0	15533.5	56773.3	103215.1	171944.3						
10000.	2627.1	19452.1	82629.8	115177.2	173667.7						
31623.	3009.5	22869.7	116508.2	155923.8	182074.8						
100000.	3172.8	25268.7	144506.5	212569.8	262399.7						
316228.	3230.7	26423.8	153580.7	327302.5	451205.9						
1000000.	3249.7	26855.5	155699.8								

Mode Shapes

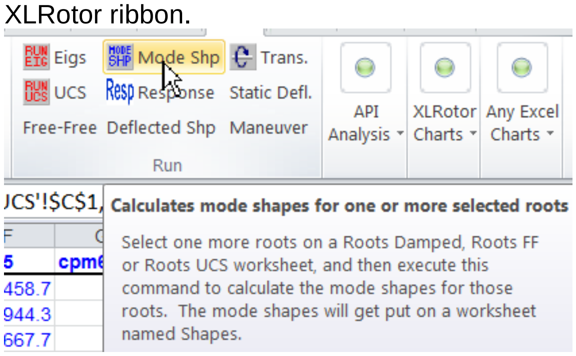
In XLRotor mode shapes are *not* generated automatically at the same time eigenvalues are calculated. Mode shapes are generated as a separate step after computing eigenvalues.

Mode Shapes from a Single Chart Point

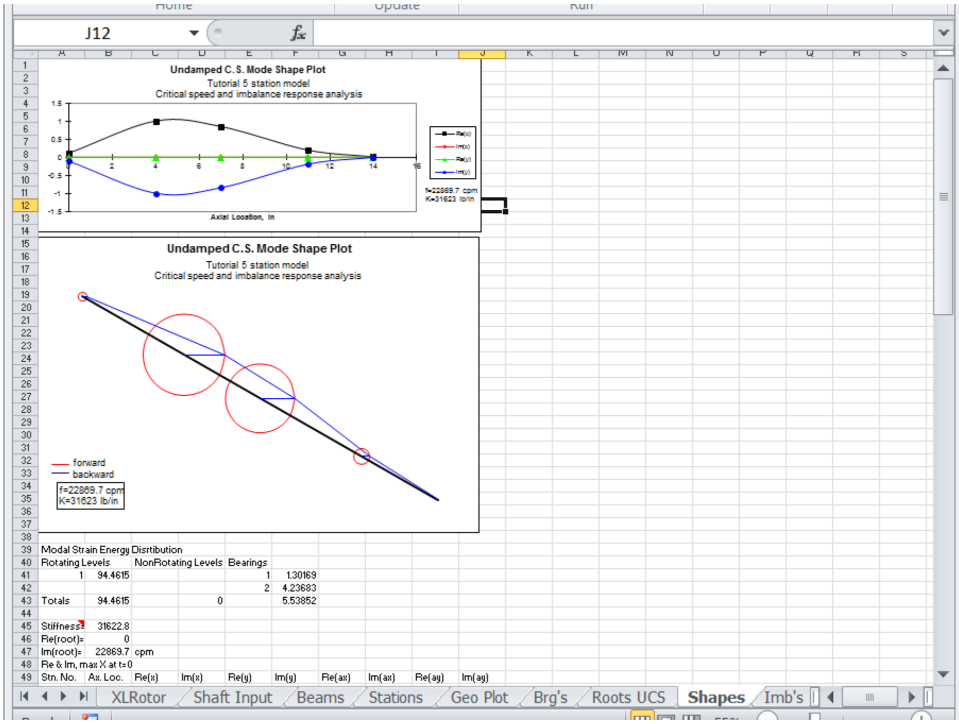
- Go to the **Roots UCS** worksheet.
- In the chart use your mouse to click on the data series of the second mode (the red one). This selects the entire data series.
- Click one time on the 4th data point in this series. If you click once and don't move the mouse, this will select the single point, and your display should look like the one shown here.



- Now that you have a single data point selected, click the **Calc. Mode Shapes** button on the XLRotor ribbon.



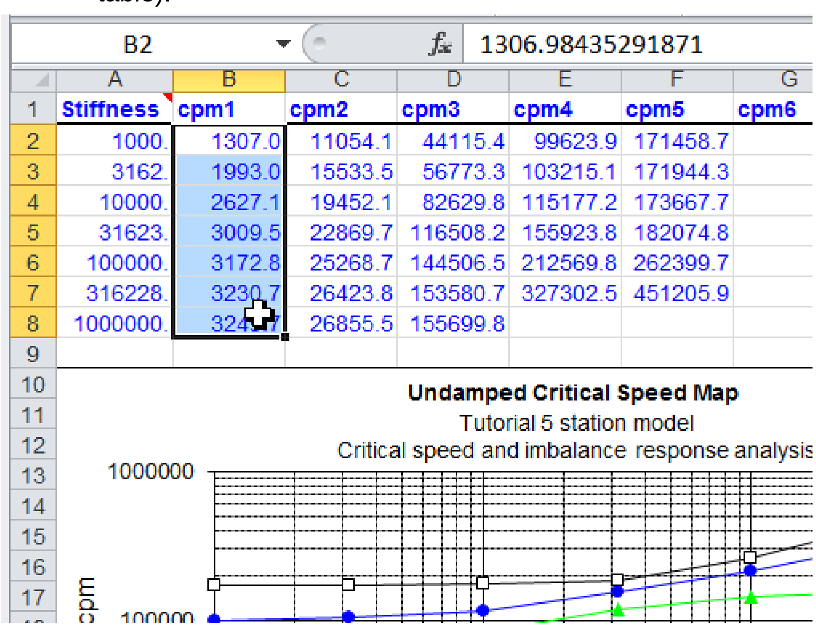
The program will compute the mode shape for the selected point, and create a new worksheet named **Shapes** on which to place plots for the mode shape.



XLRotor generates 2D and 3D plots of the mode shape. The XLRotor **Options/Eigenanalysis** dialog box has settings that control how mode shapes are generated. Below the plots are tables of values displayed in the plots. There is also a table that shows the strain energy in the bearings and shaft.

Mode Shapes for a Group of Roots

- Go back to the **Roots UCS** worksheet.
- Use your mouse to select cells **B2 through B8**. These are the critical speeds of the first mode for the entire range of stiffnesses (XLRotor lets you select any number of roots anywhere in the table).

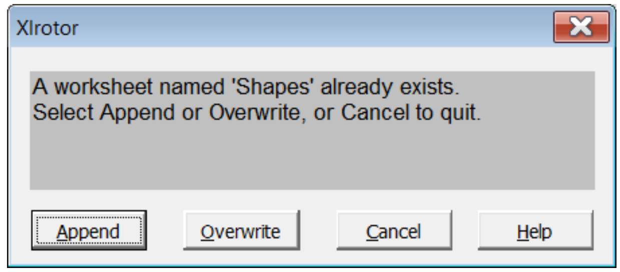


Stiffness	cpm1	cpm2	cpm3	cpm4	cpm5	cpm6
1000.	1307.0	11054.1	44115.4	99623.9	171458.7	
3162.	1993.0	15533.5	56773.3	103215.1	171944.3	
10000.	2627.1	19452.1	82629.8	115177.2	173667.7	
31623.	3009.5	22869.7	116508.2	155923.8	182074.8	
100000.	3172.8	25268.7	144506.5	212569.8	262399.7	
316228.	3230.7	26423.8	153580.7	327302.5	451205.9	
1000000.	324[illegible]7	26855.5	155699.8			

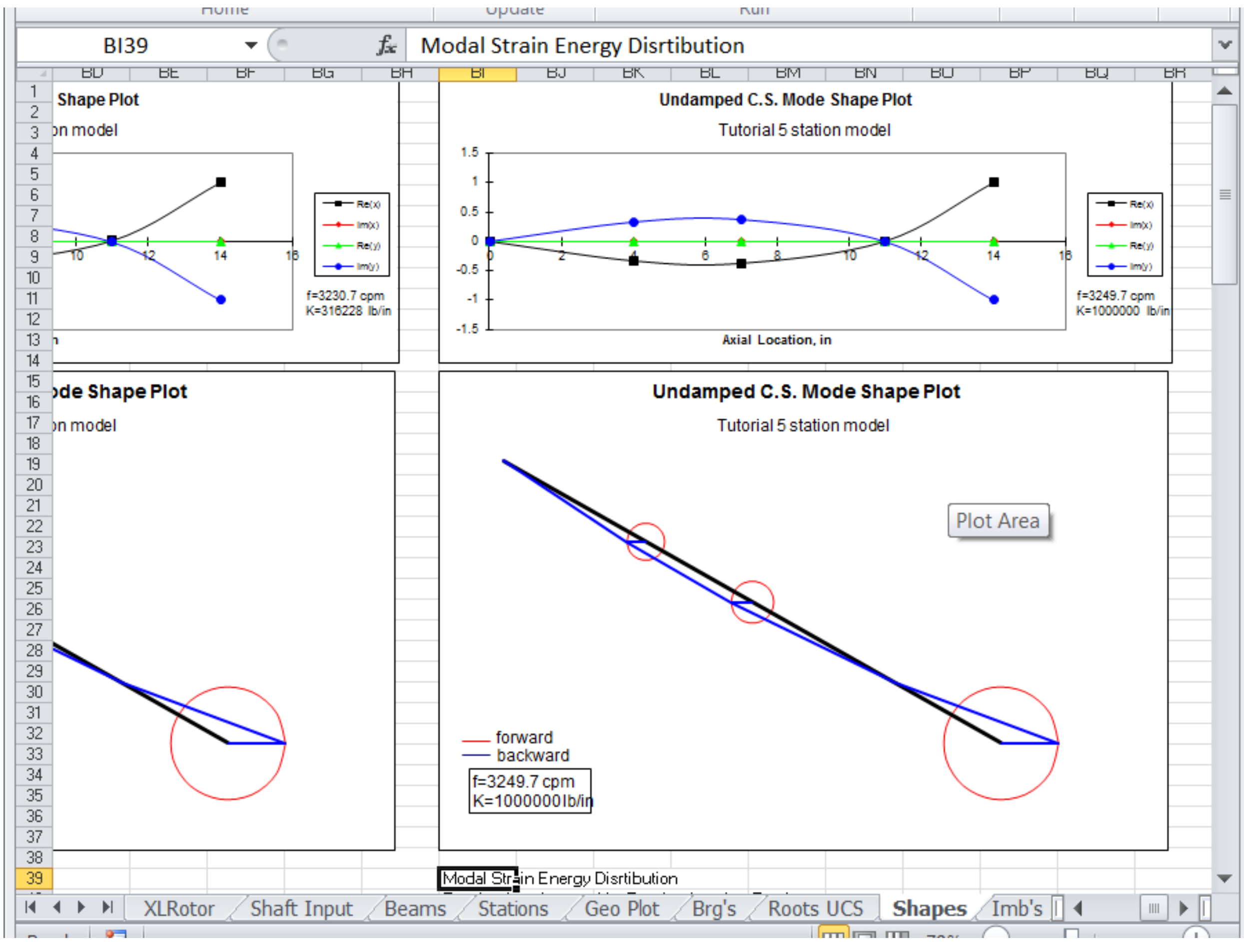
- Then click the **Calc. Mode Shapes** button  on the XLRotor ribbon.

Since there is already a **Shapes** worksheet present, the program will display this prompt.

- Click the **Overwrite** button, or press the letter **o**.



The program will clear the **Shapes** worksheet of all its contents, compute the mode shapes for the selected critical speeds, and place them on the **Shapes** worksheet. We had selected eight critical speed values, so eight modes shapes will be generated. You should see the mode shapes appear one at a time while this happens.

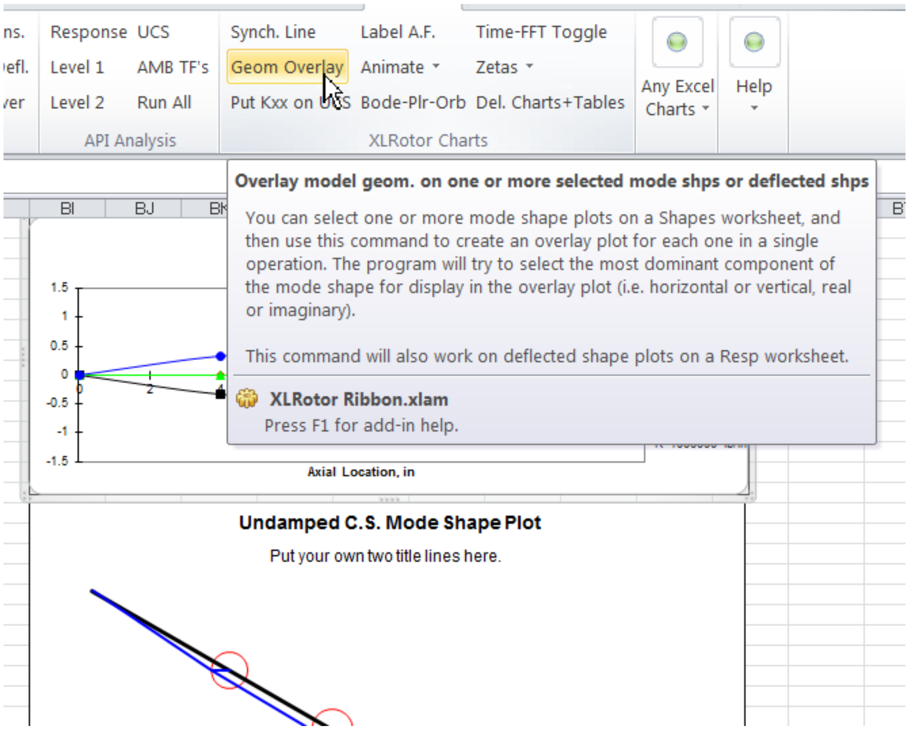


The mode shape you see on the screen was the last one computed, and is for the maximum stiffness value of 1,000,000 lb/in. Plots of the other mode shapes are to the left on this worksheet.

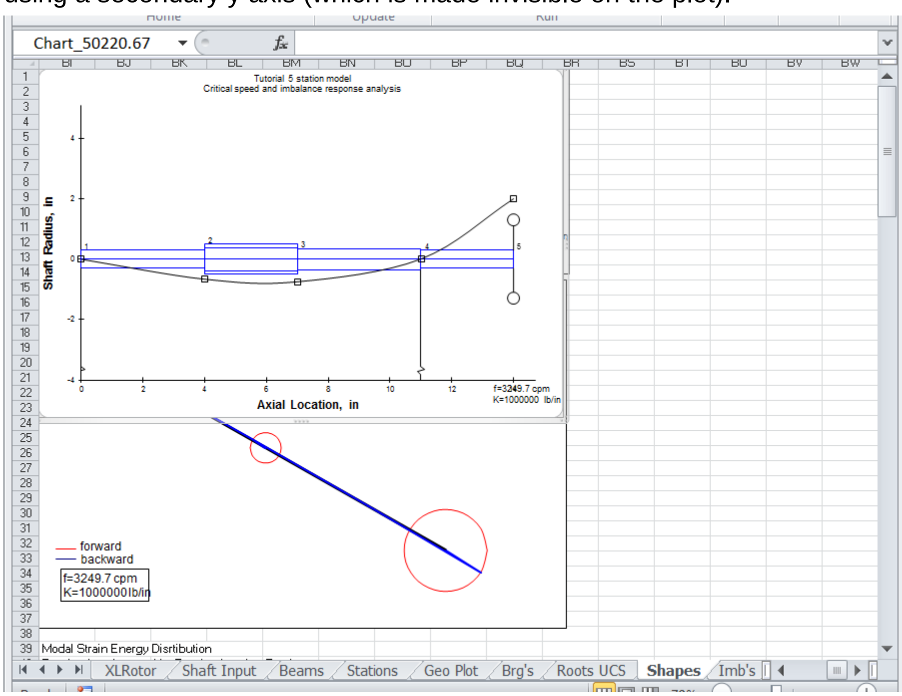
Overlay Model Geometry on a Mode Shape

There is a 2D plot and a 3D plot.

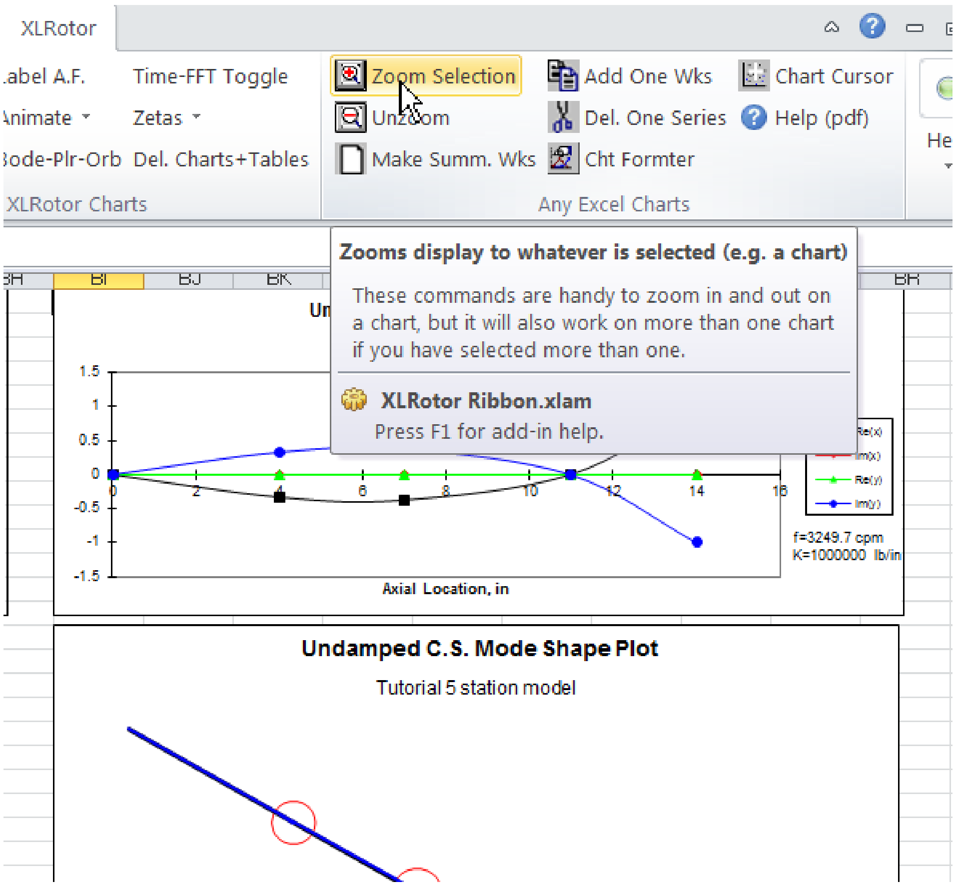
- **Click** on the 2D plot to select it (you'll see halo around the edge of the plot).
- In the XLRotor ribbon click the **Geom Overlay** button.



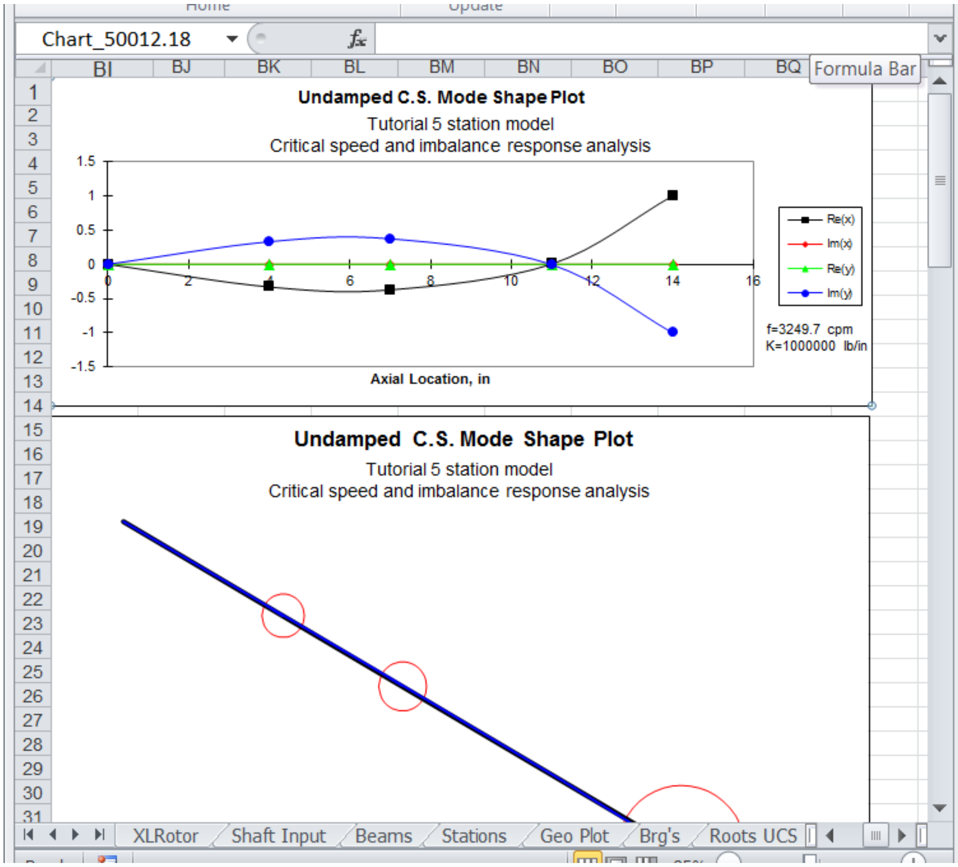
This will put an additional plot on the sheet showing the model geometry along with the mode shape. This was done by pasting a copy of the model geometry here, and the mode shape was added to the plot using a secondary y axis (which is made invisible on the plot).



- Select the overlay plot by clicking on the border of the plot.
- Press the **Delete** key on the keyboard to delete the plot.
- Click again on the 2D plot to select it.
- Click the **Zoom Selection** button  on the XLRotor ribbon which will fill the Excel screen as much as possible with the 2D plot.



After clicking the button you should see the following:

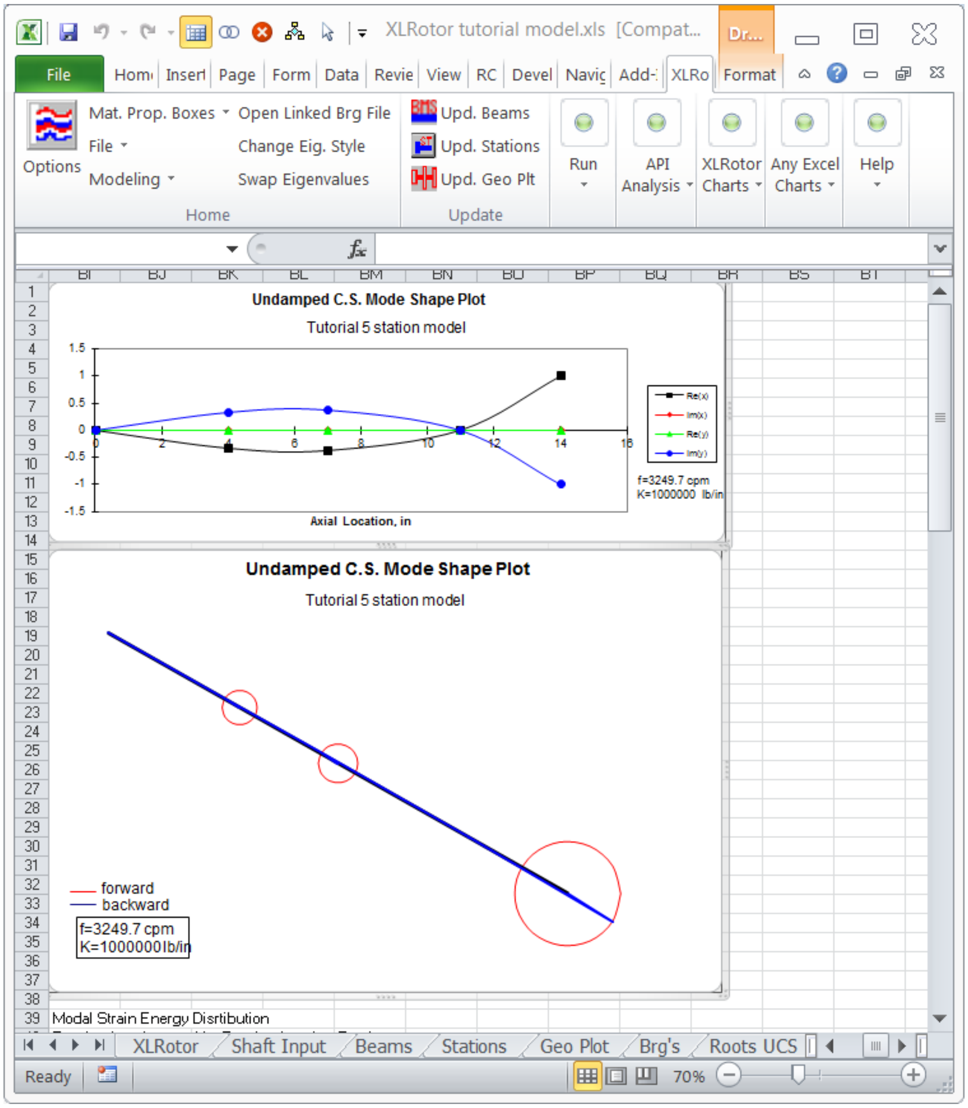


- On the keyboard, hold down the **Alternate** key and press the **Page Up** key.
- This will scroll the Excel window one screen to the left, which should bring into view the mode shape for a stiffness value of 316,228 lb/in.
- Quickly pressing **Alt-PgUp** and **Alt-PgDn** makes for a revealing display of how the mode shape of the first critical speed evolves as the bearings get stiffer or softer.

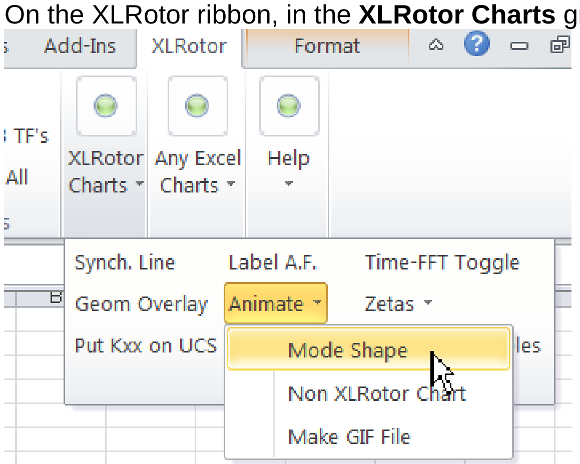
Animating a 3D Mode Shape

- Return to the last mode shape on the Shapes worksheet.
- Click on the 2D mode shape chart to select it
- Hold down the **Shift key** and click on the 3D mode shape chart. Both charts will be enclosed by halos.
- With both charts selected, click the  **Zoom Selection** button on the XLRotor ribbon.

Your Excel window should now look like the following:



- Deselect the charts by either pressing the **Escape** key or by clicking on a worksheet cell.
- Click on the 3D chart to select it or any item inside it.
- On the XLRotor ribbon, in the **XLRotor Charts** group, click the **Animate,** then click **Mode Shape.**



After a few seconds the 3D mode shape will begin to animate in the Excel window.

- Move your mouse left or right to control the animation.

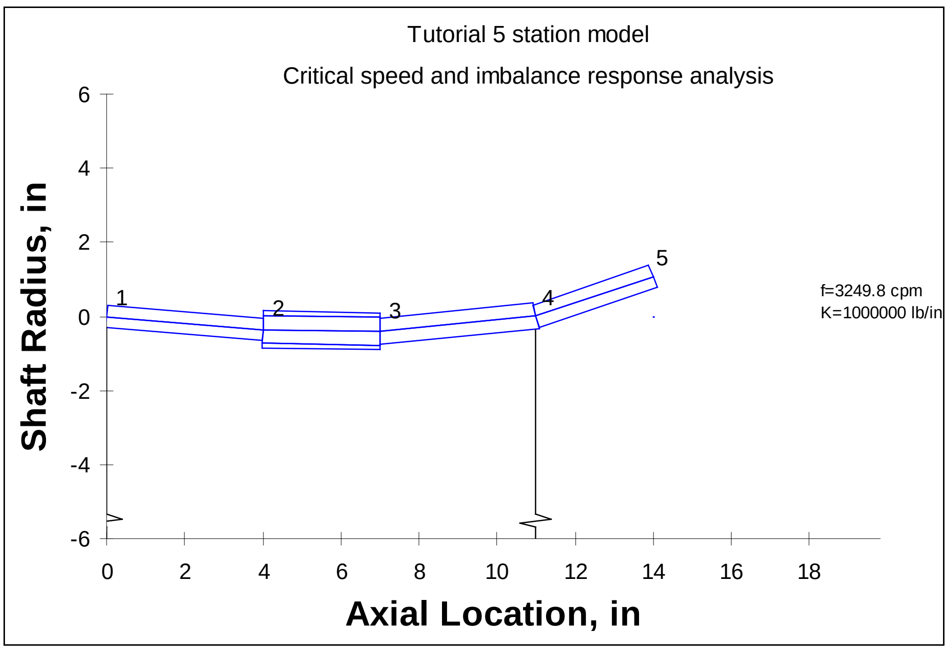
Mouse motion to the right animates the mode shape forward in time. Left motion animates backward in time. This does ***not*** refer to the direction of whirl. In XLRotor "forward" whirl is counter clockwise.

- Pressing the **Left Arrow** and **Right Arrow** keys will play play the animation one frame at a time.
- Pressing the **Escape** key stops the animation.

Using the same procedure the 2D mode shape chart can also be animated. In this case the X axis and Y axis mode shape components are animated simultaneously. During the animation you can press the "x" and/or "y" keys on the keyboard to toggle the display of these two components.

Using the animate command on a mode shape plot which has been overlaid with the model geometry will produce a live animation of the entire model geometry.

- Click on the 2D mode shape chart.
- Click **Geom Overlay** button.
- Click **Animate / Mode Shape.**

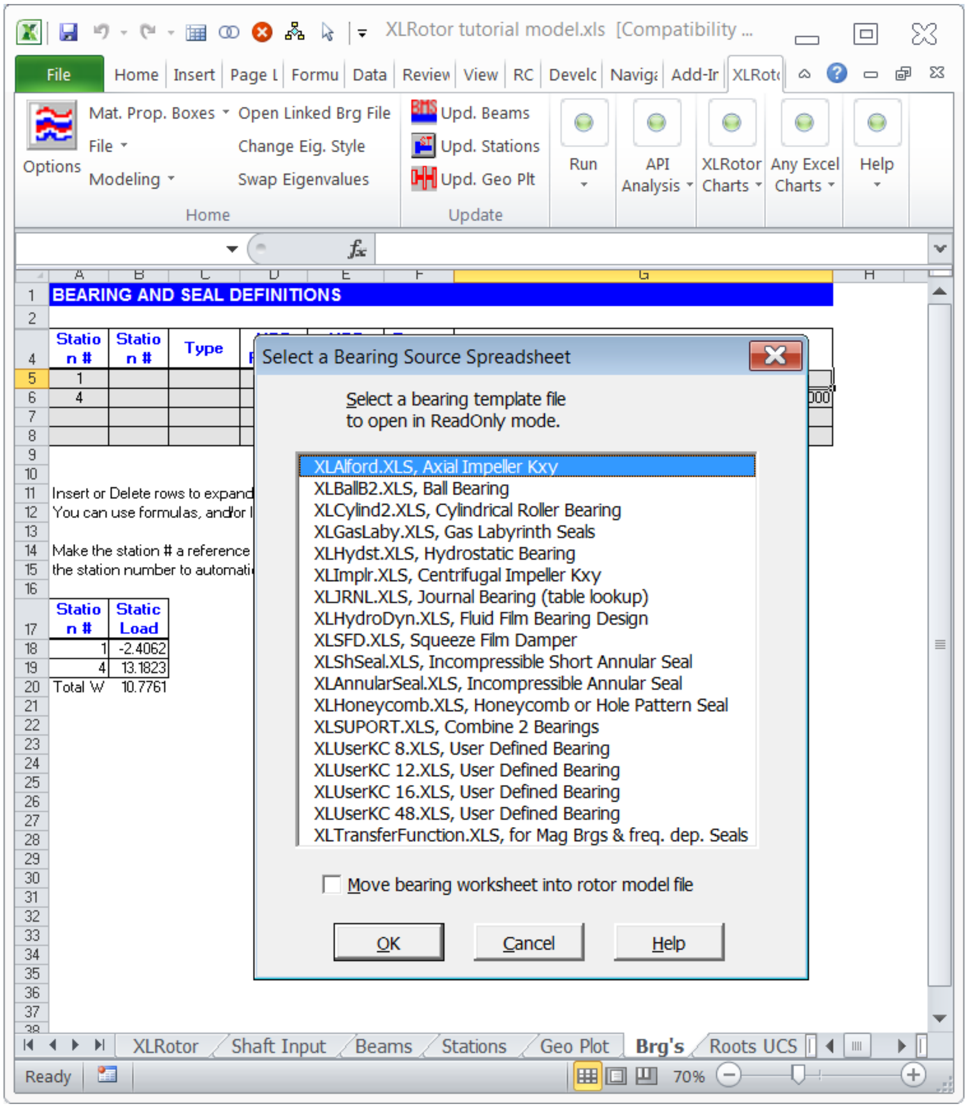


Back to the Bearings

The next step is to fully define the bearing for each of the two bearings in this model. This is where we'll define the complete stiffness and damping properties for each bearing.

Creating a User Defined Bearing

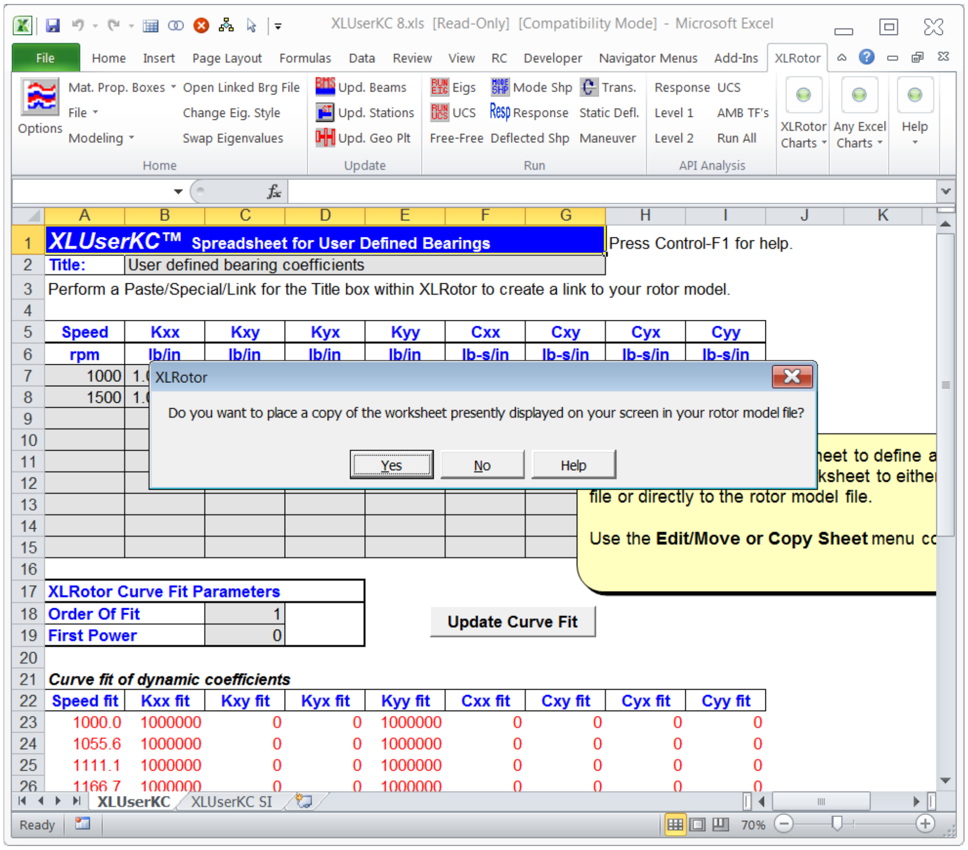
- Go to the **Brg's** worksheet, and click on cell **G5** which should be empty. If it is not empty, press the **Delete** key.
- In the XLRotor ribbon, in the **Home** group, click **Open Linked Brg File**. Since cell **G5** is empty, this will cause the Select a Bearing Source Spreadsheet dialog box to be displayed.



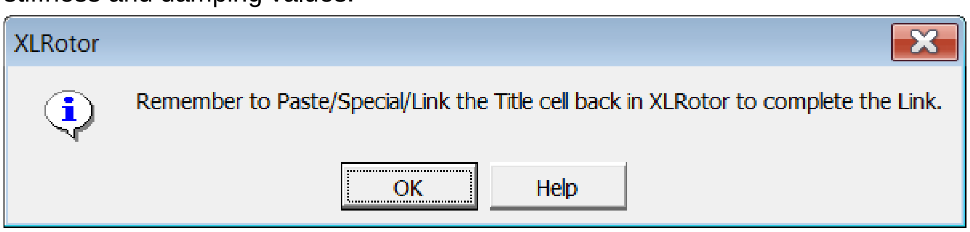
- In the dialog select the **XLUserKC 8.xls, User Defined Bearing** from the list of bearing template files. This template will have 8 input columns; 4 for stiffness, and 4 for damping.
- Put a check in the box for **Move bearing worksheet into rotor model file**
- Click **OK.**

This will open the selected bearing file. The file contains worksheets in both English and SI units, the English unit sheet will have been selected, and you will be prompted for permission to place a copy of this worksheet into your rotor model file.

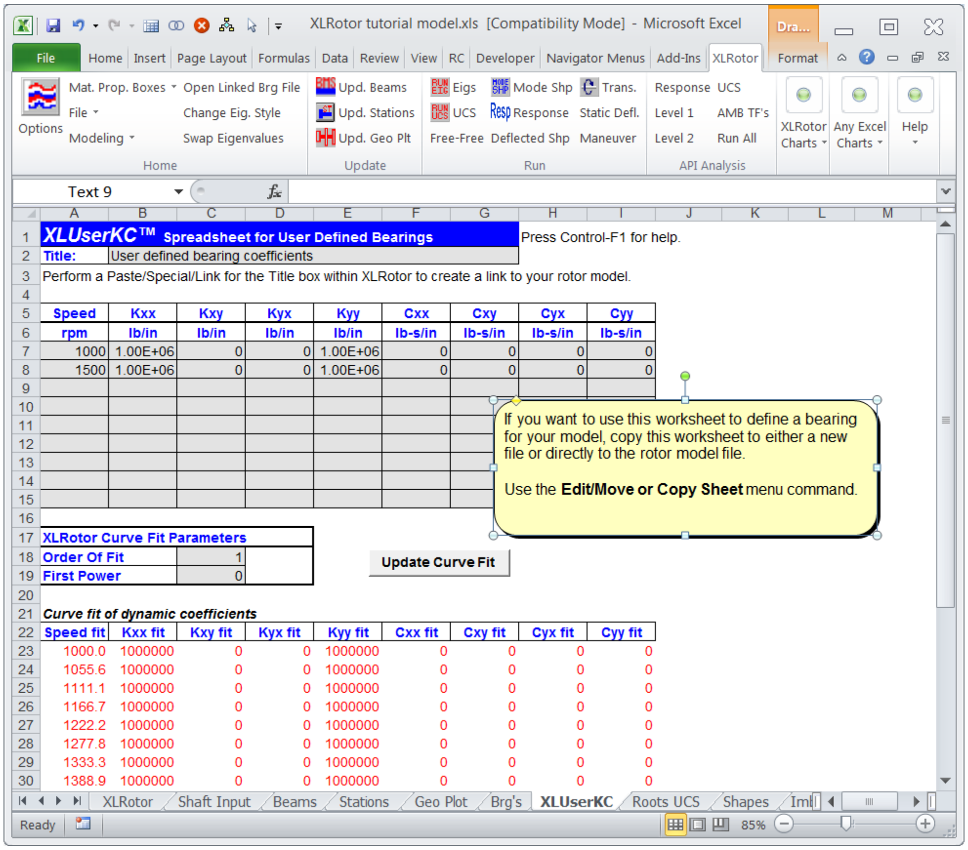
- Select **YES**.



The program will display the following reminder message. We will perform this step after we type in some stiffness and damping values.



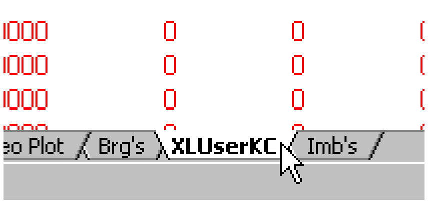
- **Click** on the edge of the yellow text box to select it.
- Press the **Delete** key to remove it



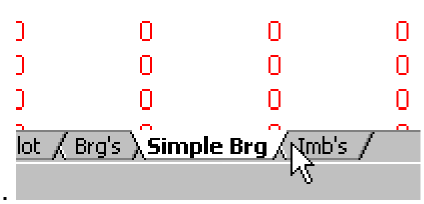
- Click on cell **B7** and enter the value **10000** for **Kxx.**
- Click on cell **E7** and enter **10000** for **Kyy.**
- In cell **F7** enter **10** for a damping constant **Cxx.**
- Also enter **10** in cell **I7** for **Cyy.**
- Select all the cells in row 8 and press the **Delete** key. We'll enter just one set of stiffness and damping values for one speed.
- Click on cell **C18** for **Order Of Fit,** and enter **0.**
- Click the **Update Curve Fit** button on the worksheet (if Excel displays a run time error when you click this button, save your file and restart Excel).

The curve fitting part of this worksheet does not mean very much with just one input speed for the bearing. It is more applicable to other kinds of bearings.

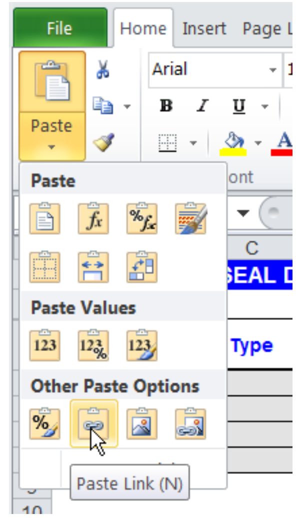
- Rename the worksheet by double clicking it's sheet tab.
- And type "**Simple Brg**" without the quotes.



Double click and type **Simple Brg**.



Linking the Bearing to the Rotor Model



Now that we've created a simple bearing, we'll use this bearing at station number 1 on the rotor.

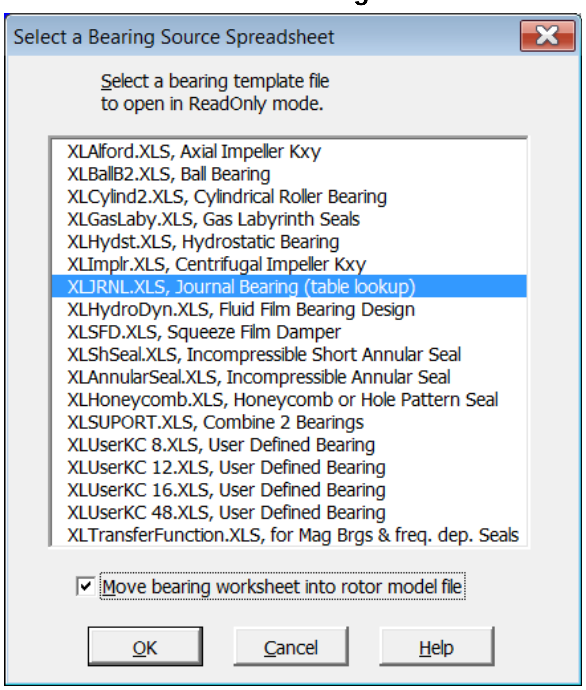
- Click on cell **B2** (you should still be on the XLUserKC worksheet).
- Press **Control-C** (or **Edit/Copy**).
- Go to the **Brg's** worksheet and click on cell **G5**.
- In the Excel ribbon on the **Home** tab, click on the word **Paste**.
- Click the **Paste Link** button.

This creates a cell formula in cell **G5** that refers to the title cell on the **Simple Brg** worksheet, and the text in that cell is displayed in cell **G5**.

- While cell **G5** is still selected, press **Control-[** to go back to cell **B2** on the **Simple Brg** worksheet (control-[is a handy Excel shortcut).
- In cell **B2** enter this cell formula **="Simple bearing, constant K="&B7.**
- Go back to the **Brg's** worksheet, and you'll see the result of this formula displayed there as well.

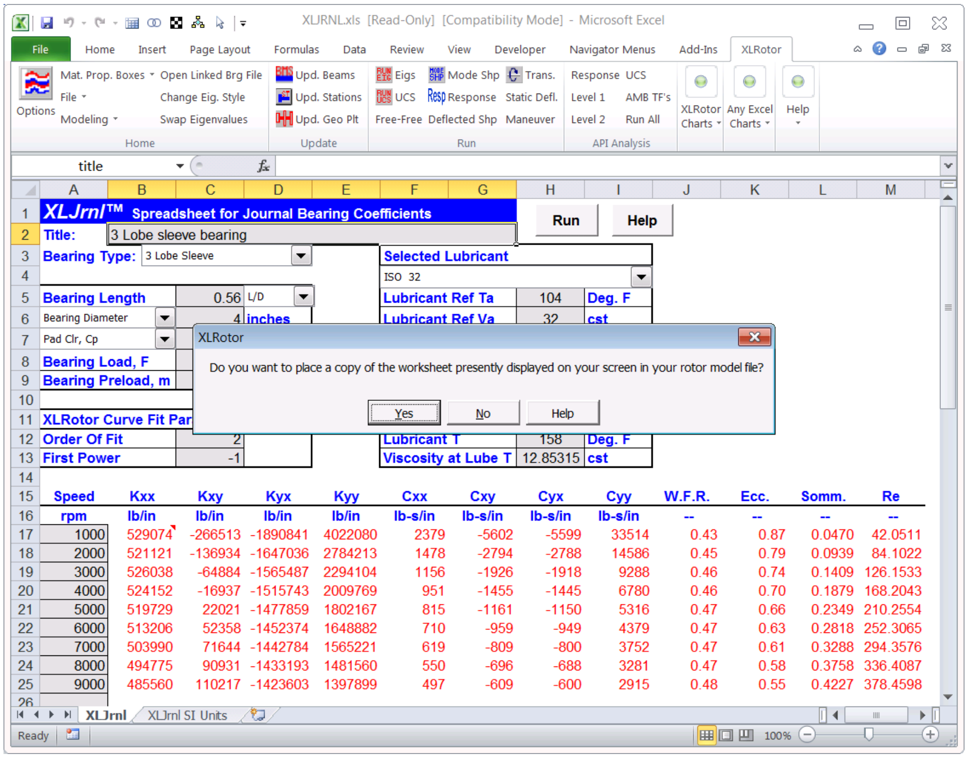
Creating a Journal Bearing

- Click on cell **G6**, which should be empty (press **Delete** if it's not empty).
- In the XLRotor ribbon click the button for **Open Linked Bearing File.**
- In the dialog box that appears select **XLJRNL.XLS, Journal Bearing (table lookup)** in the list bearing templates.
- And again put a check in the box for **Move bearing worksheet into rotor model file.**



- Click the **OK** button.

This will open the XLJRNL template file, and you should be presented with the English units worksheet in this file.



In the same way as with the first bearing worksheet…

- Select **YES** to have a copy of this sheet placed within the rotor model file.
- In cell **B2** type **Tilting pad bearing, 4 pad, load between pad** (copy and paste from here).
- Then in the drop down list of bearing types select the first item in the list which is **4 Pad Tilting, LBP.**
- For the bearing length, enter **0.4** in cell **C5.**
- Select **L/D** in the drop down list to the right of cell **C5.**
- Select **Bearing Diameter** in the drop down list to the left of cell **C6.**
- and in cell **C6** type an **=** sign, then press **Control-PgUp** until you come to the **Shaft Input** worksheet.
- Click on cell **C9**.
- Press **Enter.**

This will cause the diameter input for this bearing to be taken directly from the shaft diameter of the rotor model at station 4.

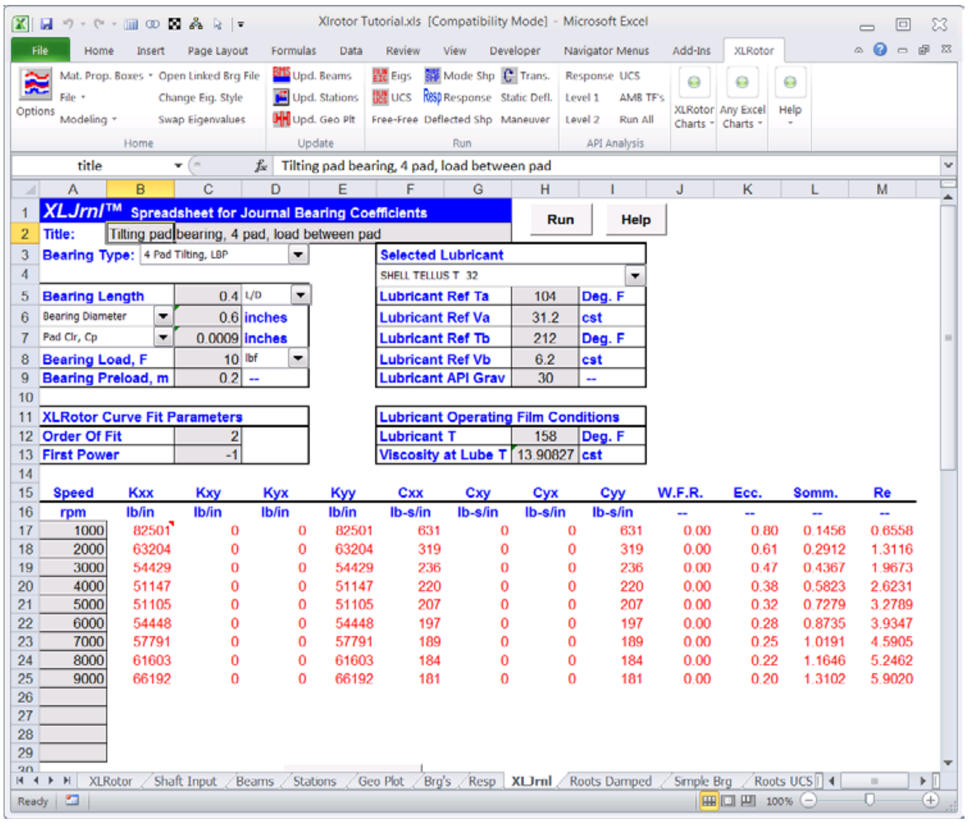
- For the clearance select **Pad Clr, Cp** in the drop down list. This means the clearance that is entered will be the *pad bore clearance* as opposed to *assembled bearing clearance*.
- In cell **C7** enter the cell formula **=0.0015*C6** which will result in a clearance of 0.0009 inches to be displayed in cell **C7.**
- For the bearing load enter a value of **10** in cell **C8**.
- Select **lbf** in the drop down list to the right of cell C8.
- For the bearing preload enter **0.2** in cell **C9.**

The template will probably already have one of the various ISO32 weight oils selected, which fills in values in cells **H5** to **H9** with the oil's fluid properties. If you select a different oil, these 5 fluid properties will change accordingly. The only other input you need to enter is the **Lubricant Temperature** in cell **H12**.

- Select **SHELL TELLUS T 32** from the drop down list of lubricants.
- Enter **158** degrees in cell **H12.**

The operating film viscosity in cell **H13** is computed using a cell formula from the lube temperature and oil reference properties. Click on cell **H13** if you want to see this formula.

- Click on the **RUN** button near the top of the worksheet. This will cause the stiffness and damping values to be updated for the new set of bearing parameters.



This bearing is now ready to be linked to the rotor model.

- Go to the **Brg's** worksheet where cell **G6** should still be selected (if not, select it).
- Press an **=** sign.
- Use your mouse to click on the sheet tab named **XLJRNL** to jump to that worksheet.
- Click on cell **B2** and press **Enter**. This enters a cell formula in cell **G6** that refers to the title cell on the **XLJRNL** worksheet.

We could have done a **Copy** followed by **Paste Special/Paste Link** procedure like we did for the first bearing. This is another way to accomplish the same thing.

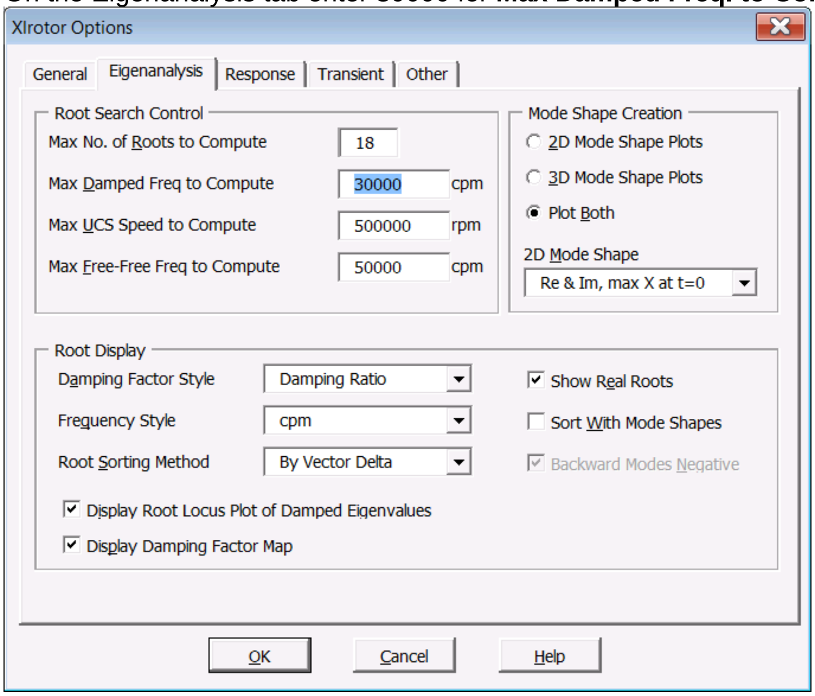
Now is a good time to save the rotor model file. Since you've already given the template file a new name, all you need to do to save the file is…

- Press **Control-S**, or go **File/Save** in the Excel ribbon.

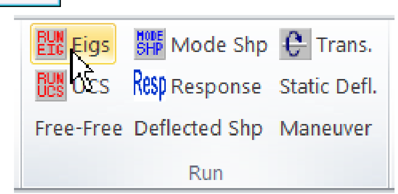
Damped Eigenvalue Analysis

With the shaft model and both bearings now completely defined, we can compute damped eigenvalues as a function of rotor speed.

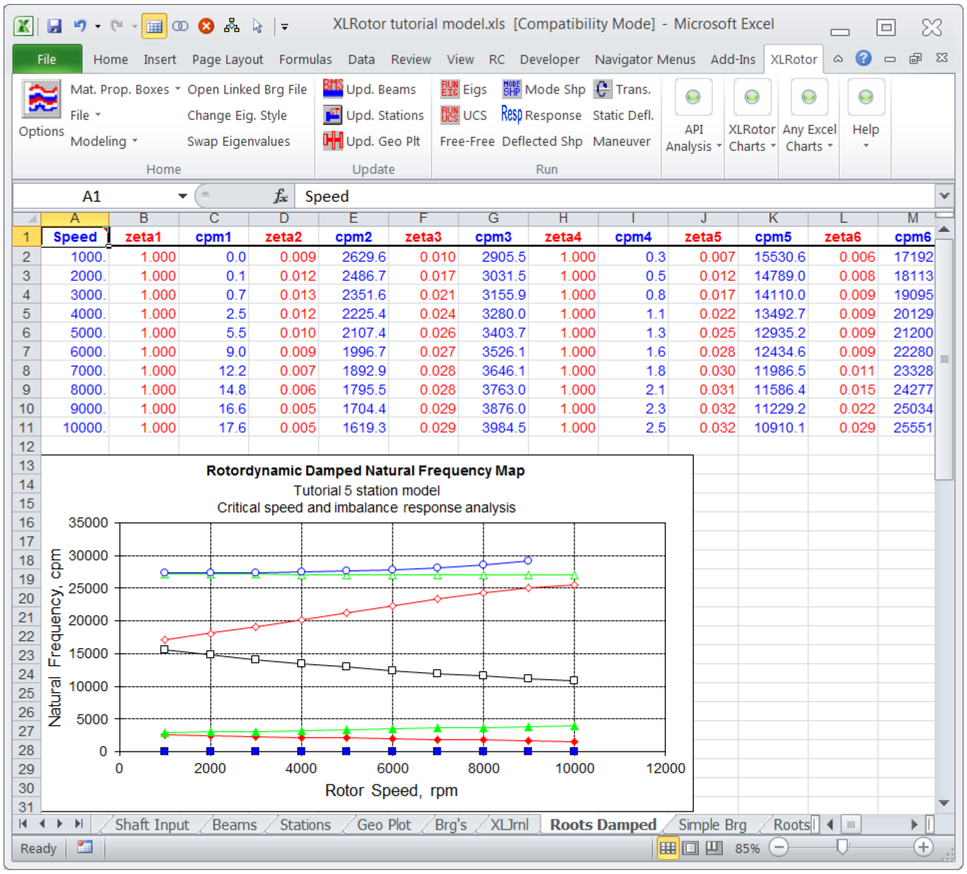
- Click the XLRotor **Options** button .
- On the Eigenanalysis tab enter **30000** for **Max Damped Freq. to Compute**.



- Click on the  button in the XLRotor ribbon.

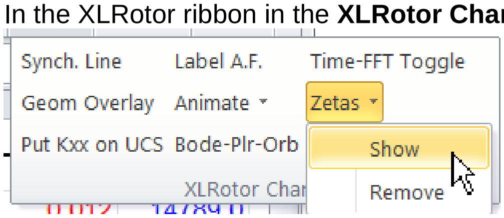


After a few moments, a sheet named **Roots Damped** will be created which contains a damped natural frequency map showing how the damped natural frequencies vary with running speed. The list of speed values used for this analysis came from the **XLRotor** worksheet.

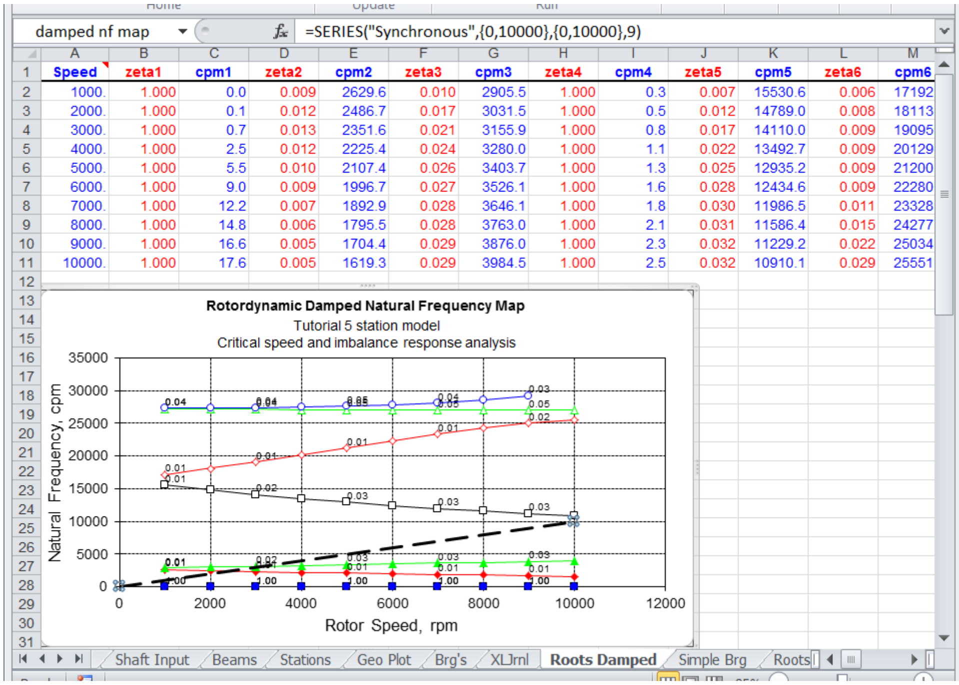


The real parts of the eigenvalues, which have been output as damping ratio, can also be displayed on the natural frequency plot as follows:

- Click on the plot to select it, so there is a halo around its edges.
- In the XLRotor ribbon in the **XLRotor Charts** group, click **Zetas** and then **Show.**

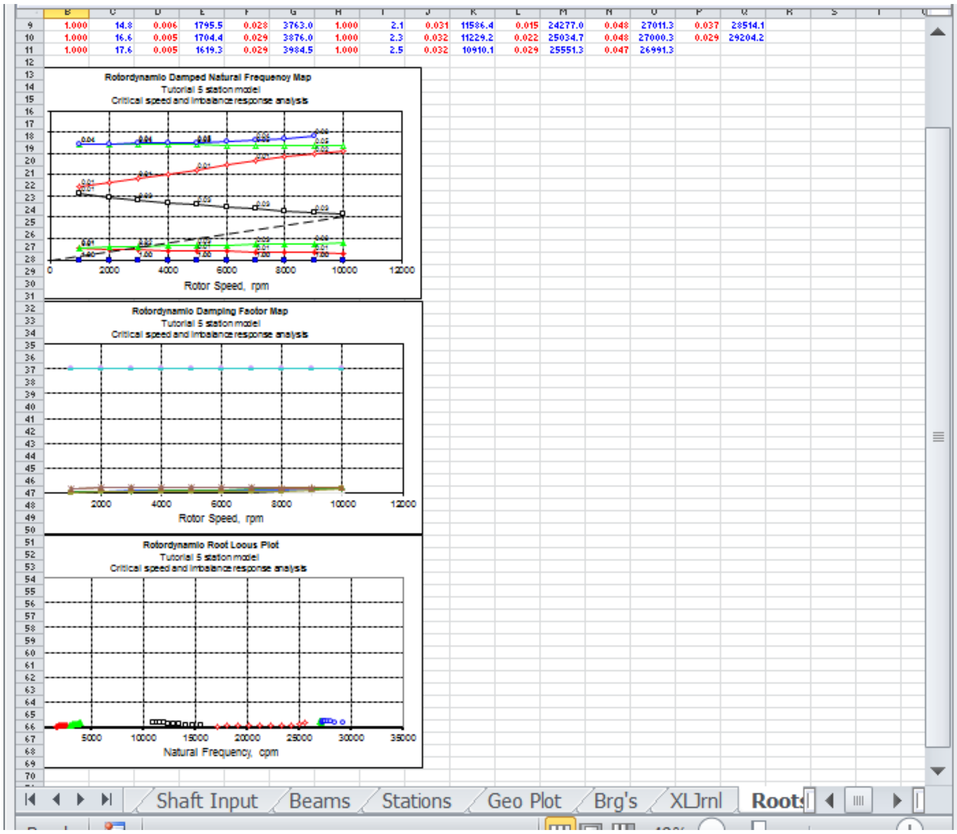


- While the chart is still selected. add a synchronous line (which has a slope of 1) to the plot by clicking the button labeled **Synch. Line.**



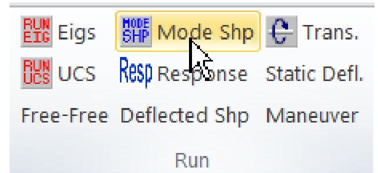
There are two other plots on the worksheet. You can zoom out or scroll down the worksheet to see plots of damping ratio versus running speed, and a root locus plot.

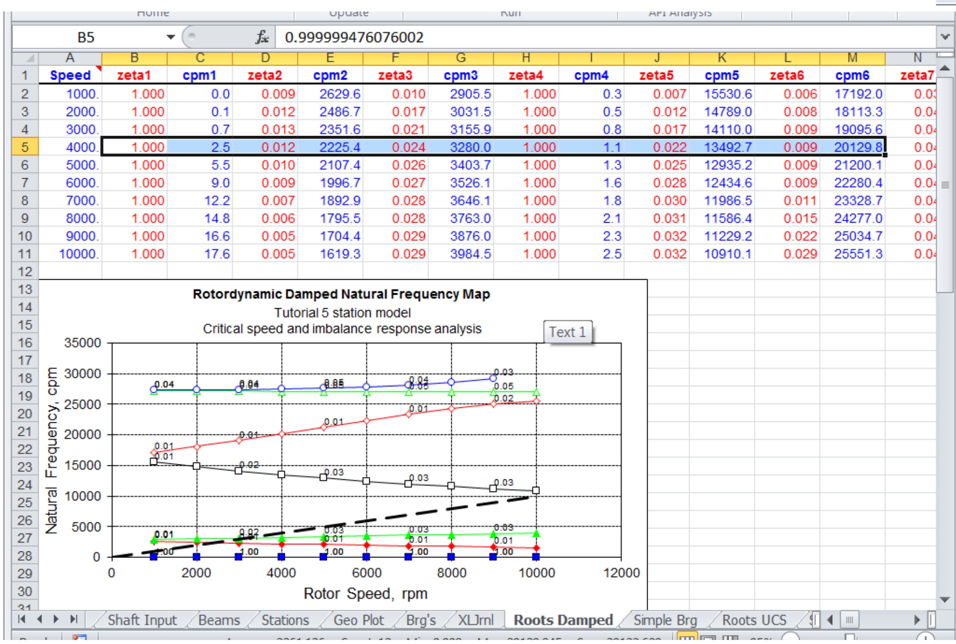
- Zoom out to see the other two plots on this sheet.



Damped Mode Shapes

- On the **Roots Damped** worksheet select cells **B5 to M5.**
- This selects both the real and imaginary parts of 6 eigenvalues that were computed for a shaft speed of 4000 rpm.
- Be sure to not select the speed in column A.
- To see mode shapes for these selected roots click the  button.

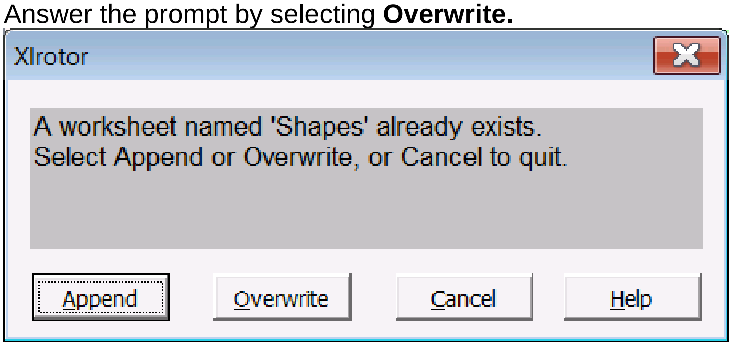




	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Speed	zeta1	cpm1	zeta2	cpm2	zeta3	cpm3	zeta4	cpm4	zeta5	cpm5	zeta6	cpm6	zeta7
2	1000.	1.000	0.0	0.009	2629.6	0.010	2905.5	1.000	0.3	0.007	15530.6	0.006	17192.0	0.03
3	2000.	1.000	0.1	0.012	2486.7	0.017	3031.5	1.000	0.5	0.012	14789.0	0.008	18113.3	0.04
4	3000.	1.000	0.7	0.013	2351.6	0.021	3155.9	1.000	0.8	0.017	14110.0	0.009	19095.6	0.04
5	4000.	1.000	2.5	0.012	2225.4	0.024	3280.0	1.000	1.1	0.022	13492.7	0.009	20129.8	0.04
6	5000.	1.000	5.5	0.010	2107.4	0.026	3403.7	1.000	1.3	0.025	12935.2	0.009	21200.1	0.04
7	6000.	1.000	9.0	0.009	1996.7	0.027	3526.1	1.000	1.6	0.028	12434.6	0.009	22280.4	0.04
8	7000.	1.000	12.2	0.007	1892.9	0.028	3646.1	1.000	1.8	0.030	11986.5	0.011	23328.7	0.04
9	8000.	1.000	14.8	0.006	1795.5	0.028	3763.0	1.000	2.1	0.031	11586.4	0.015	24277.0	0.04
10	9000.	1.000	16.6	0.005	1704.4	0.029	3876.0	1.000	2.3	0.032	11229.2	0.022	25034.7	0.04
11	10000.	1.000	17.6	0.005	1619.3	0.029	3984.5	1.000	2.5	0.032	10910.1	0.029	25551.3	0.04

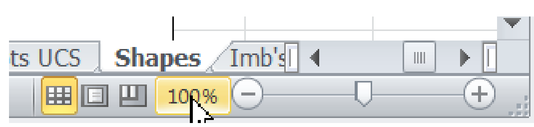
When you do this, you will be taken to the **Shapes** worksheet that was created earlier for the mode shapes of undamped critical speeds.

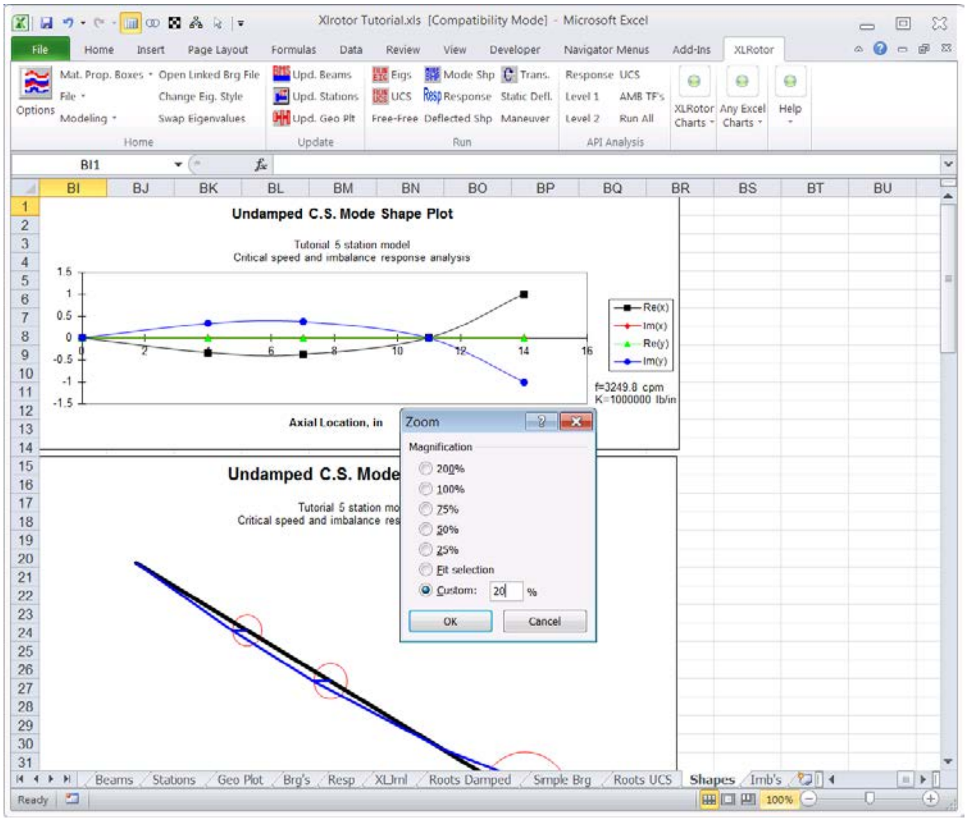
- Answer the prompt by selecting **Overwrite.**



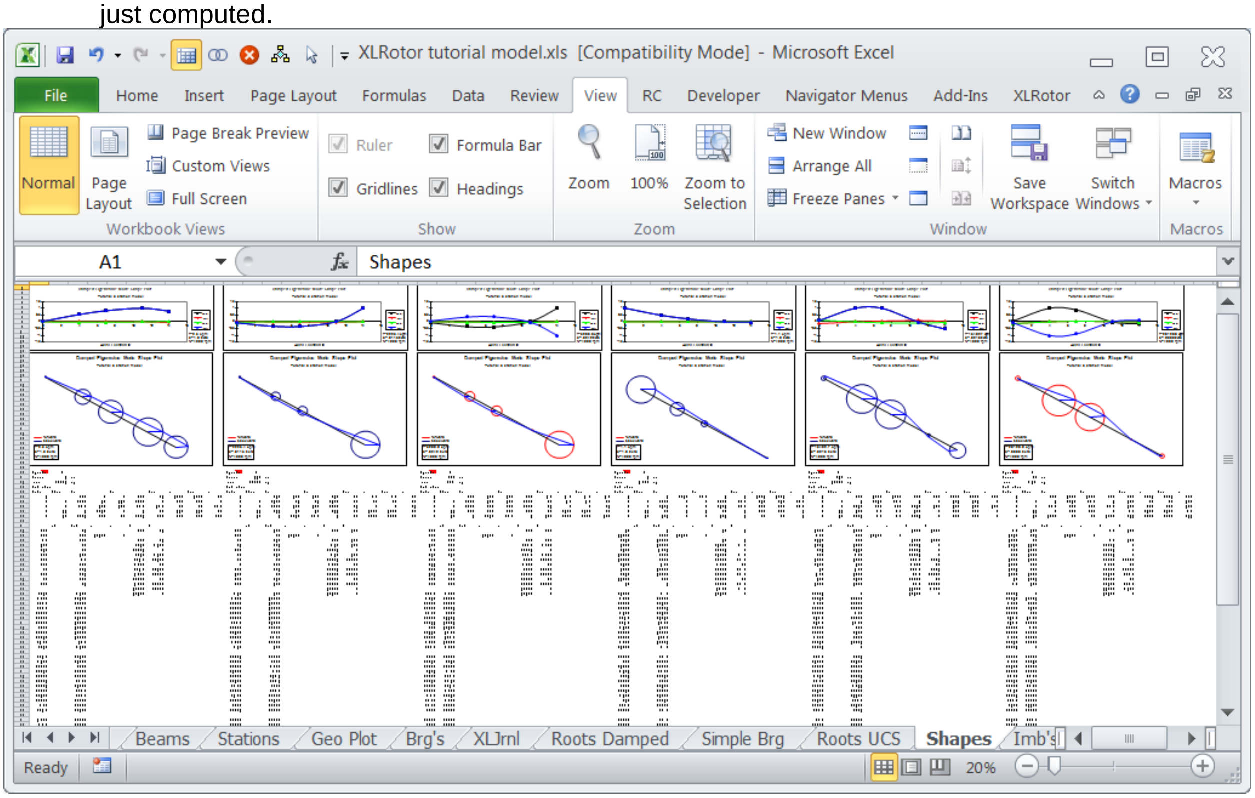
This will delete all the previously computed mode shapes from the worksheet, and replace them with new ones.

- At the bottom of the Excel window click the **Zoom** button.
- In the dialog box which appears, enter a value of **20** percent and press **Enter**.





- Press the **Escape** key a few times.
- Press **Control-Home** to move to cell **A1**. This allows you to see all or most of the mode shapes just computed.

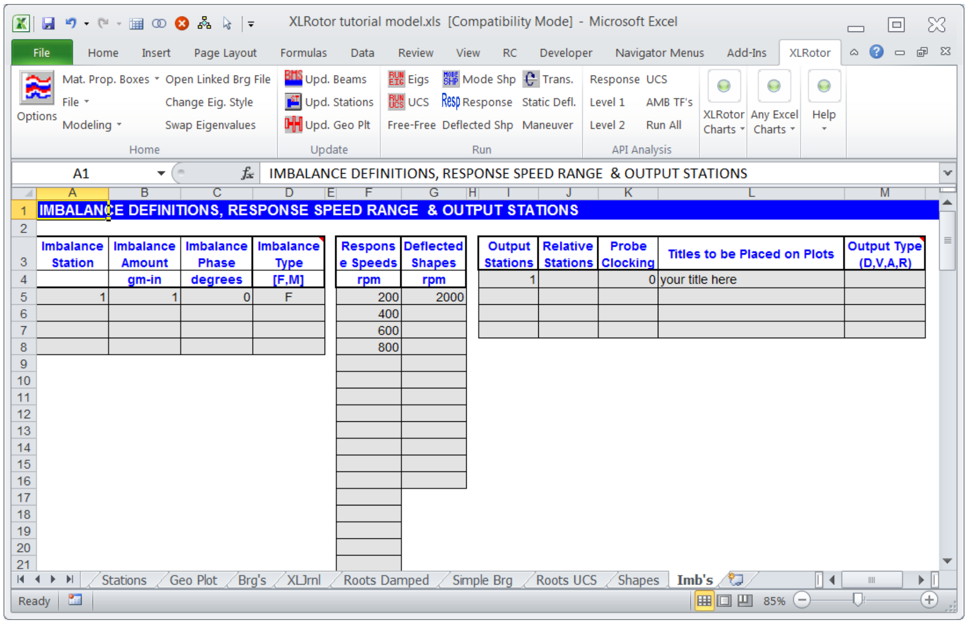


Imbalance Response Analysis

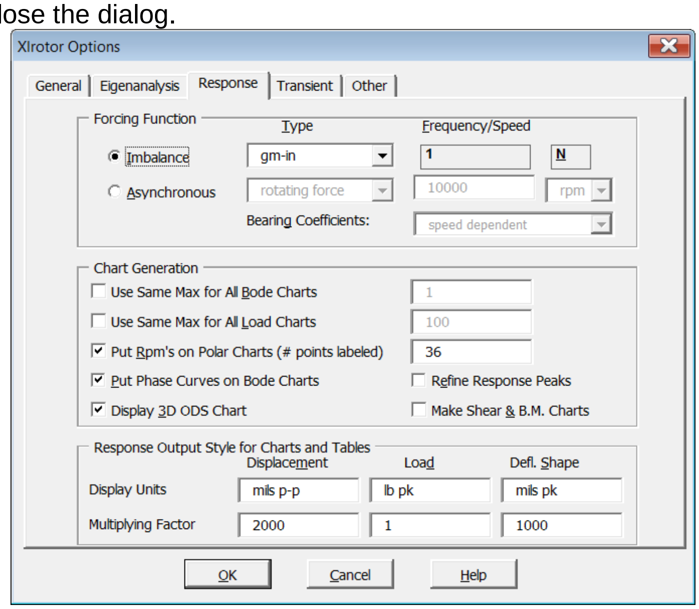
To perform a synchronous imbalance response analysis we'll need to specify three things.

- The imbalance distribution.
- The speeds at which to compute the response.
- What we want in the way of output.

This is done on a worksheet named **Imb's**. Every XLRotor file used for lateral analysis will contain a worksheet with this exact name.



- Go to the worksheet named **Imb's.**
- In the XLRotor ribbon click the **Options** button. 
- Go to the **Response** tab.
- Set the imbalance type to **gm-in.**
- Make sure the other settings match those shown below.
- Select **OK** to close the dialog.



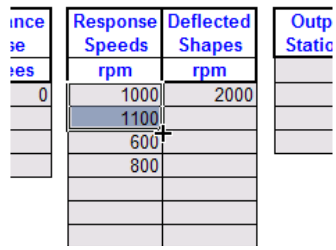
- Back on the Imb's sheet, in cell **A5** for **Imbalance Station**, enter **5** for the station where we will apply an imbalance (tip: it would actually be better to use a cell formula **='Shaft Input'!A10** to refer to station number 5 on the Shaft Input sheet).

Recall that we have placed a 10 lb disk in the rotor model at station 5.

- In cell **B5** enter **=10*.0005*454** to specify the gram inch value for half a mil of mass offset for the disk.
- Leave the value in the **Phase** column **blank** or zero.

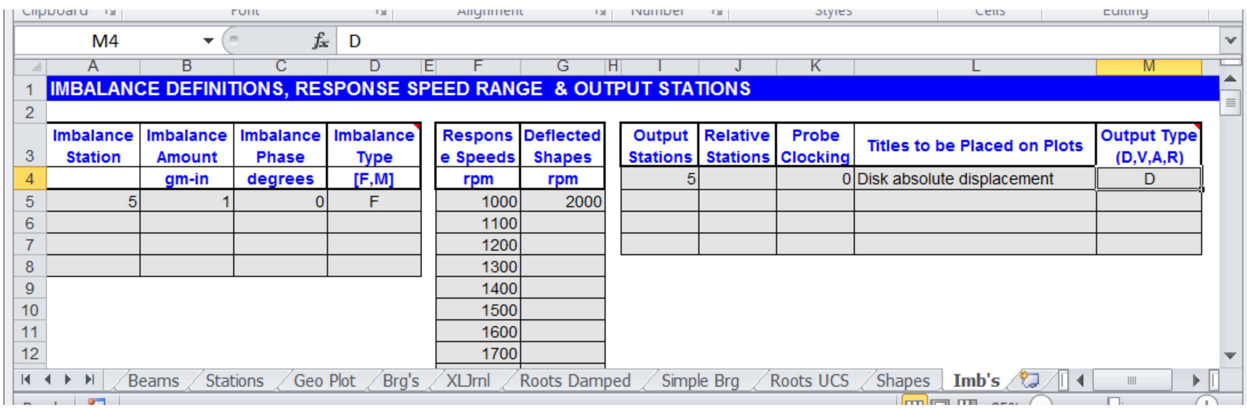
Response Versus Speed

- In the **Response Speeds** column, in cell **E5** enter **1000.**
- In cell **E6** enter **1100.**
- Use your mouse to drag/select both cells **E5 and E6.**
- Position the mouse over the lower right corner of cell **E6** so the mouse changes to a black plus sign.
- Hold down the left mouse button and drag downward to add values in 100 rpm increments until you reach 10000 rpm.



Before running the response analysis we'll specify what results to output.

- In cell **I4** enter **5** for the **Output Station** number.
- Leave the **Relative Station** and **Probe Clocking** entries zero or blank.
- In cell L**4** enter a title of **Disk absolute displacement.**
- In the **Output Type** column enter a **D** for displacement.

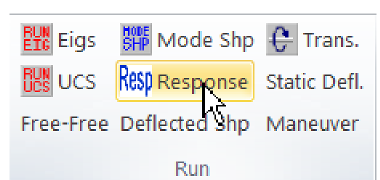


The last step above shows how to specify shaft deflections for output. Velocity or Acceleration can also be specified for output. In order to specify a bearing reaction load for output, perform the following steps:

- go to the **Brg's** worksheet.
- Drag to select both cell **F5** and cell **F6.**
- Type the word **yes** and press **Control-Enter.**
- The word **yes** should now be entered in both cells.

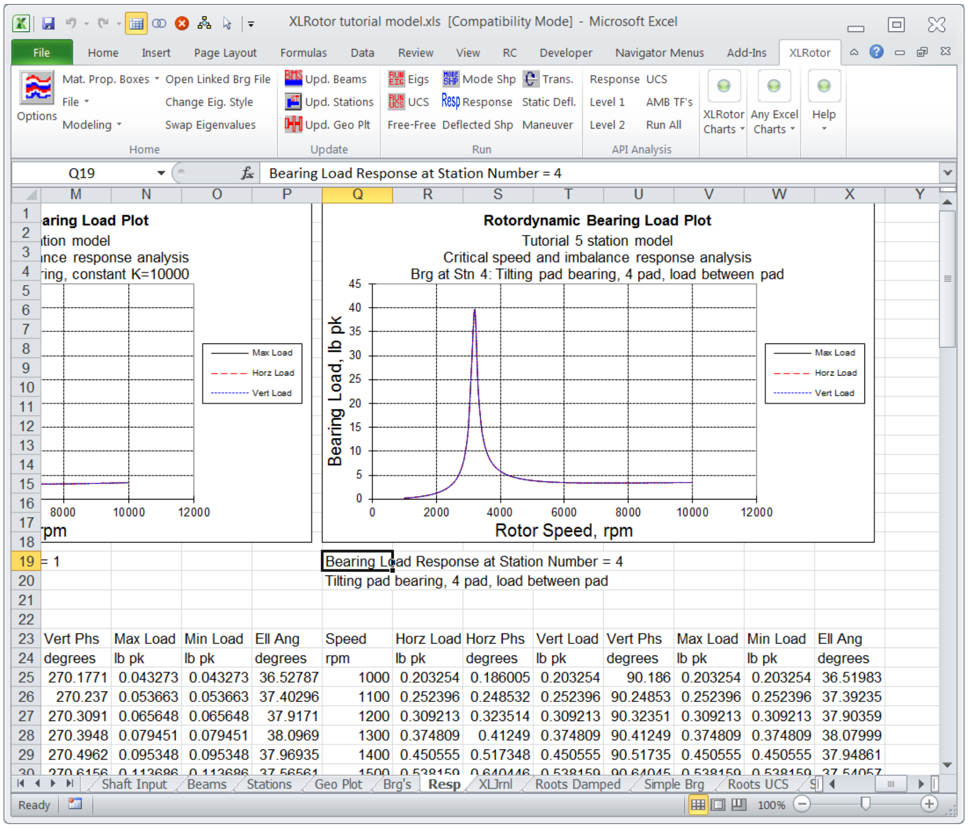
Now we're ready.

- In the XLRotor ribbon, in the **Run** group, click **Response**.



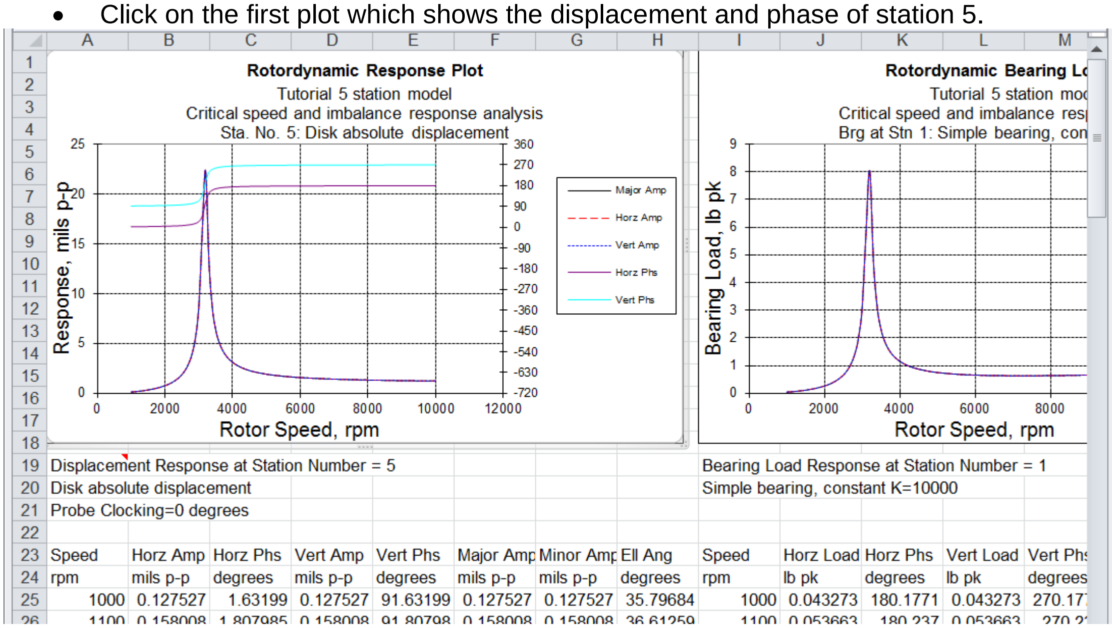
A worksheet named **Resp** will automatically be created (or prompted to be overwritten) on which to place the imbalance response outputs.

When the analysis is complete, you'll be on the **Resp** worksheet looking at the last of the plots just created.

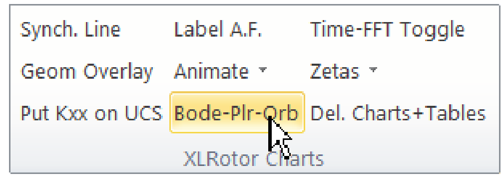


Bode Plots, Polar Plots and Orbit Plots

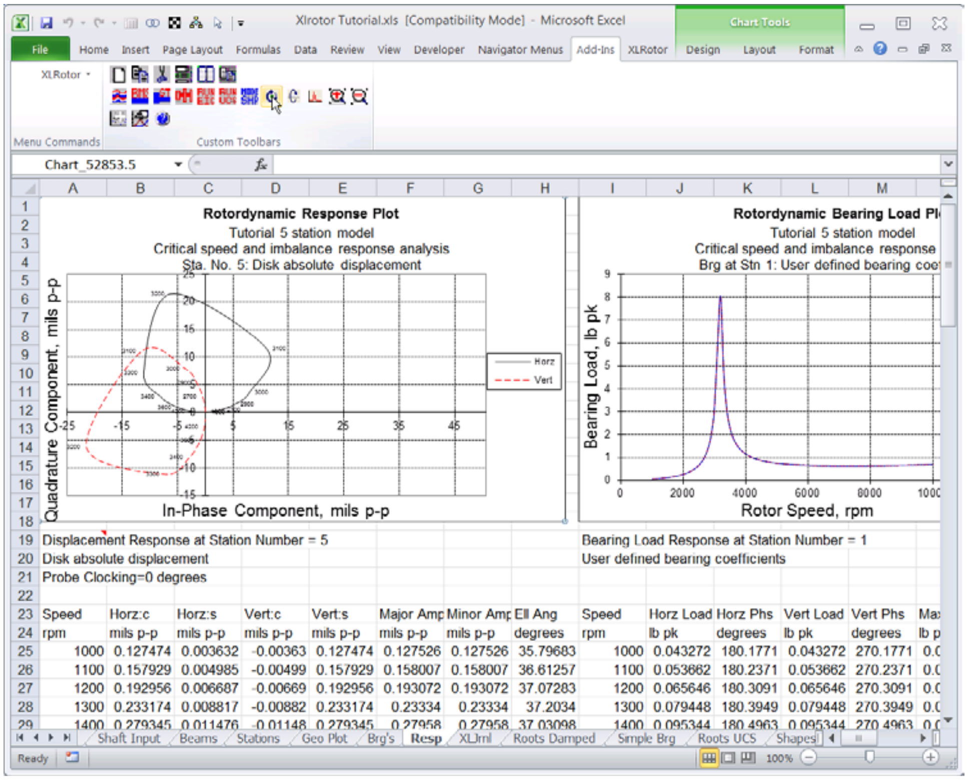
- Press and hold down the **Left Arrow** key on your keyboard to scroll the display all the way to the left to get to the first plot.
- Click on the first plot which shows the displacement and phase of station 5.



- In the XLRotor ribbon, click the **Bode-Plr-Orb** button which switches the plot format from Bode to Polar to Orbit and back to Bode.



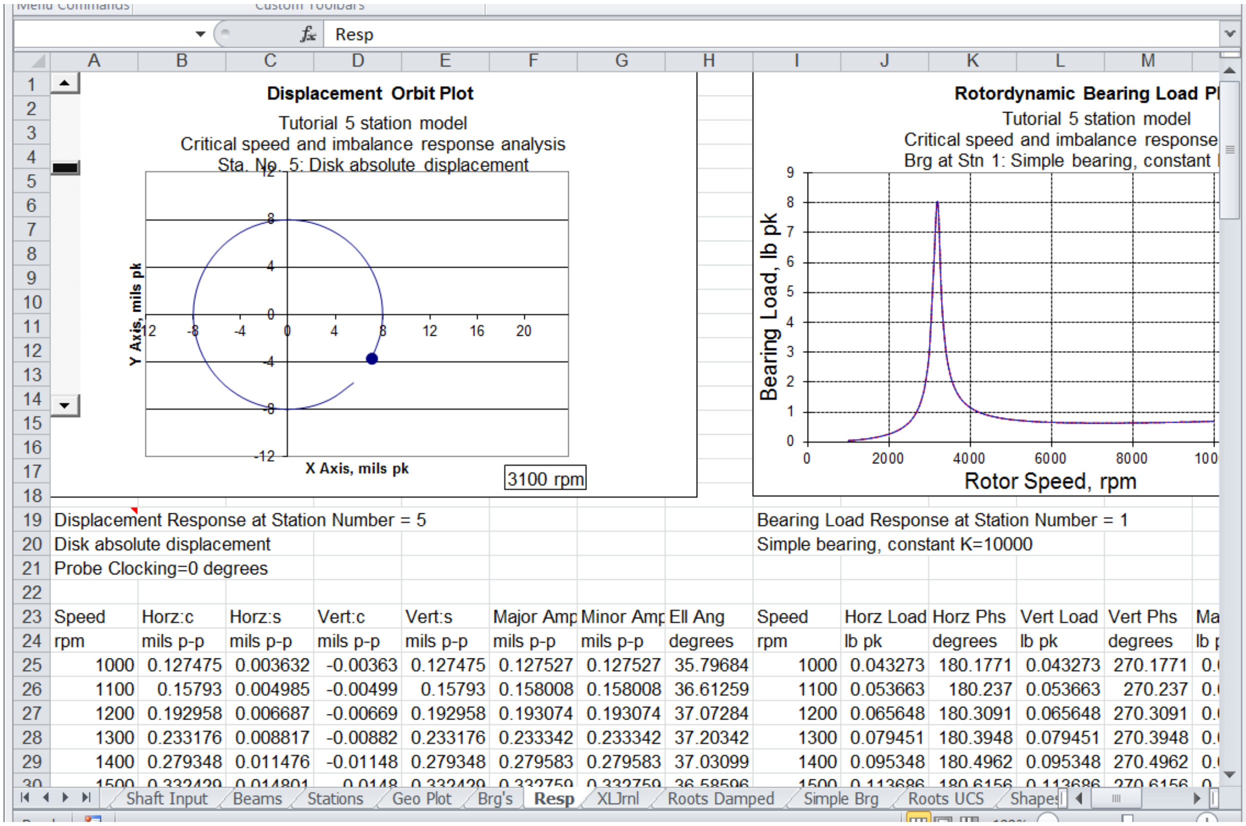
The first click of the button will change the format of the plot from amplitude and phase versus speed (Bode), to that of a polar plot.



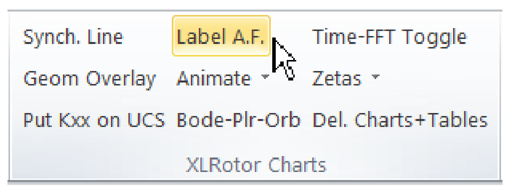
The reason the resonance loops don't look more like circles is because not enough speed points were used to do a good job of defining the critical speed peak. But before we address this…

- Click the **Bode-Plr-Orb** button a second time to change the format of the plot to an Orbit plot, which shows the orbit of the shaft at a single speed.

The scrollbar inside the plot changes the speed, and the currently displayed speed is shown in a textbox near the lower right corner of the plot. By using the scrollbar you can see the orbit grow as the speed approaches the critical speed near 3000 rpm. The orbit also shows that mass center inversion takes place as the rotor passes through the critical speed. The round dot on the orbit mimics a key phasor mark on an oscilloscope. This dot is seen to be in the +X+Y quadrant below the critical, and is in the -X-Y quadrant at speeds above the critical. This is mass center inversion.



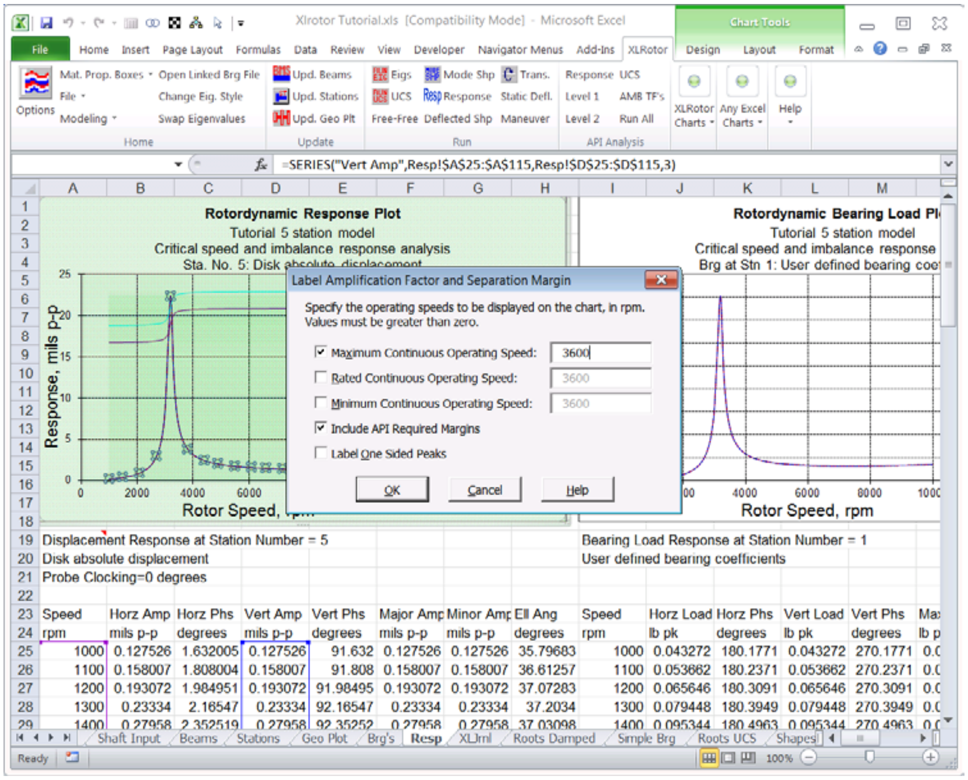
Amplification Factors and Critical Speed Margins



- Click the **Bode-Plr-Orb** button again to switch the plot back to Bode format.
- Click on the displacement curve in the plot to select it.
- In the XLRotor ribbon, in the XLRotor Charts group, click **Label A.F.**

This will display the following dialog box asking you for a maximum continuous operating speed.

- Enter **3600** and click the **OK** button (or press **Enter**).



When you do this you'll get the following warning about not having enough points to adequately define the peak in the response plot. We will fix this in just a moment. Go ahead and click the **OK** button, and the peak will be labeled with its amplification factor and separation margin to the 3600 rpm operating speed.

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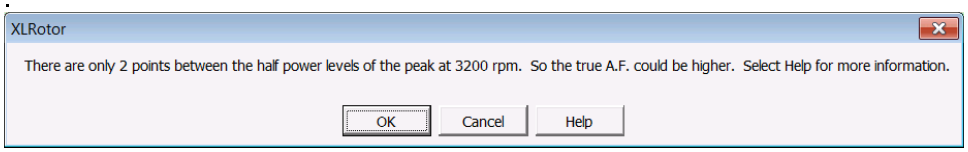
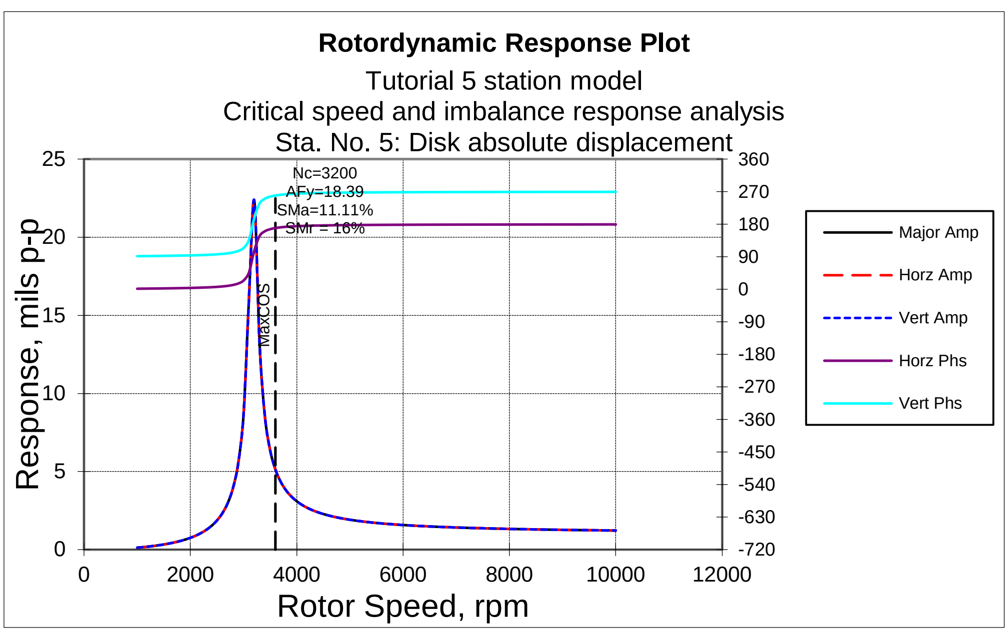
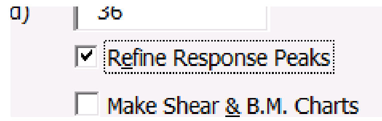




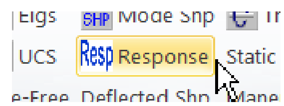
Now we'll have the program compute responses with a smaller speed increment around the critical near 3200 rpm so as to better define the resonance peak.

- Go back to the **Imb's** worksheet

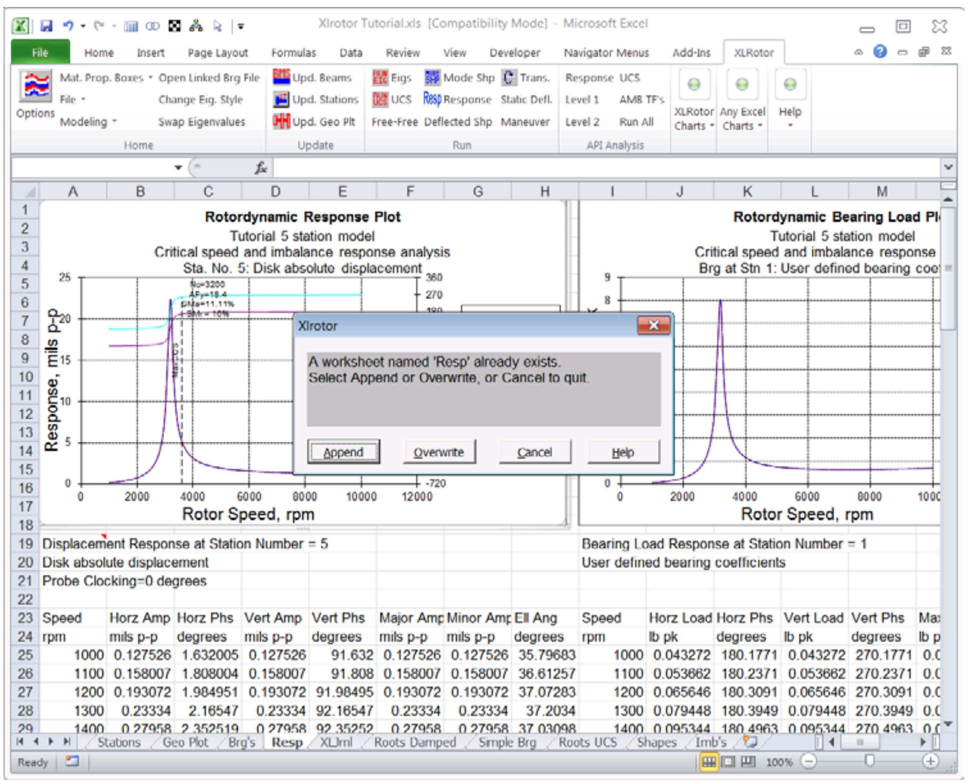
In the **Response Speeds** column, we could enter speed values with a smaller increment than 100 rpm, but there is an easier way.



- Click the XLRotor **Options** button. 
- Go to the **Response** tab of the dialog, and check the box named **Refine Response Peaks**.

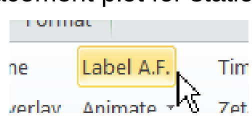


- Click the button to rerun the response analysis.
- Select the **Overwrite** option in the dialog which appears by pressing the letter **o.**

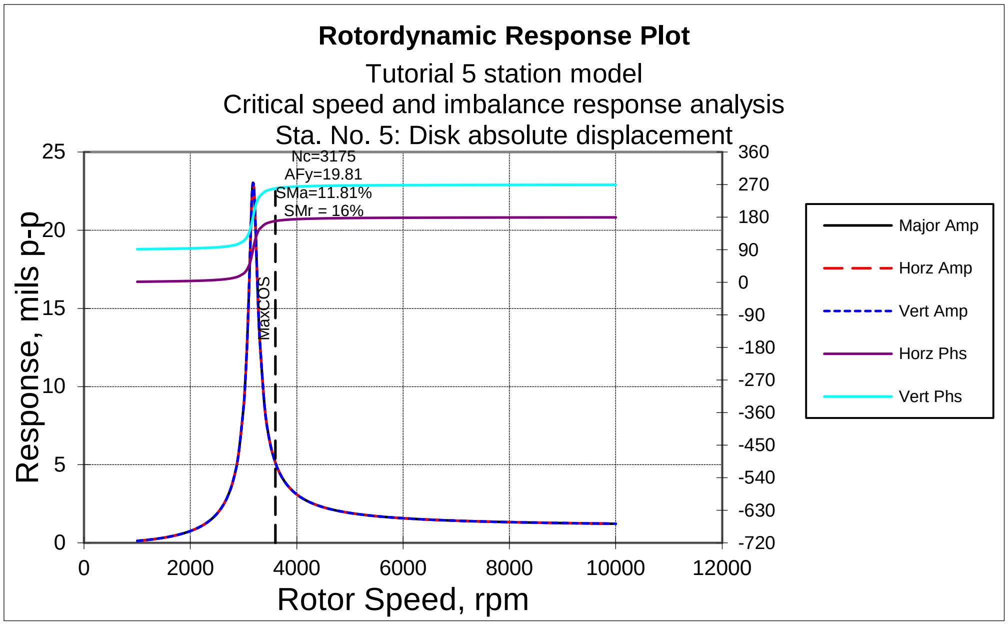


The current contents of the **Resp** sheet will be cleared, the response analysis will be run, and results placed on the **Resp** worksheet.

- Press the **Alt-PageUp** key a few times to get to the displacement plot for station 5.
- **Click** on the displacement curve in the plot to select it.
- **Click** the **Label A.F.** button.
- As before enter **3600** rpm and click the **OK** button.

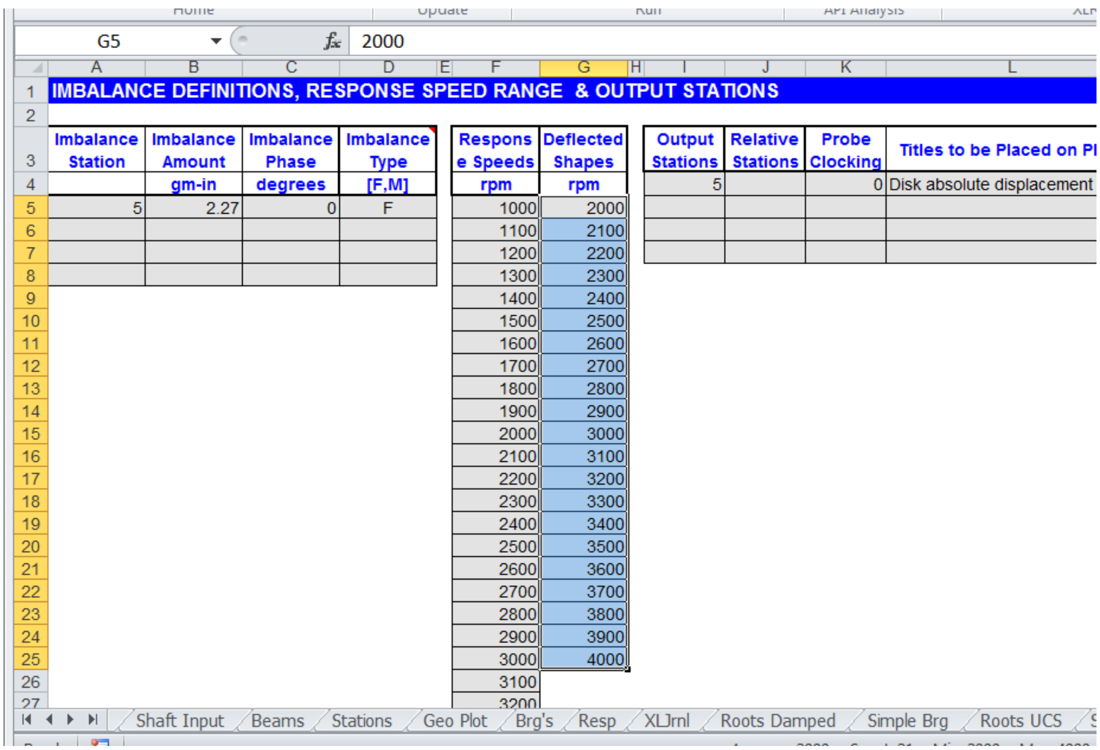


This time there won't be a warning about not having enough points between the half power levels. The amplitude of the peak increased a little bit, and occurred at 3175 rpm. As expected, the amplification factor also increased a little bit due to the refined definition of the peak. XLRotor filled in additional speeds around the peak. These can be seen by scrolling down the worksheet.



Deflected Shapes

- Once again go to the **Imbs'** worksheet.
- In cell **F5** enter **2000.**
- In cell **F6** enter **2100.**
- Use your mouse to extend the list of speeds. Continue down the column to get **4000** rpm in cell **F25.**

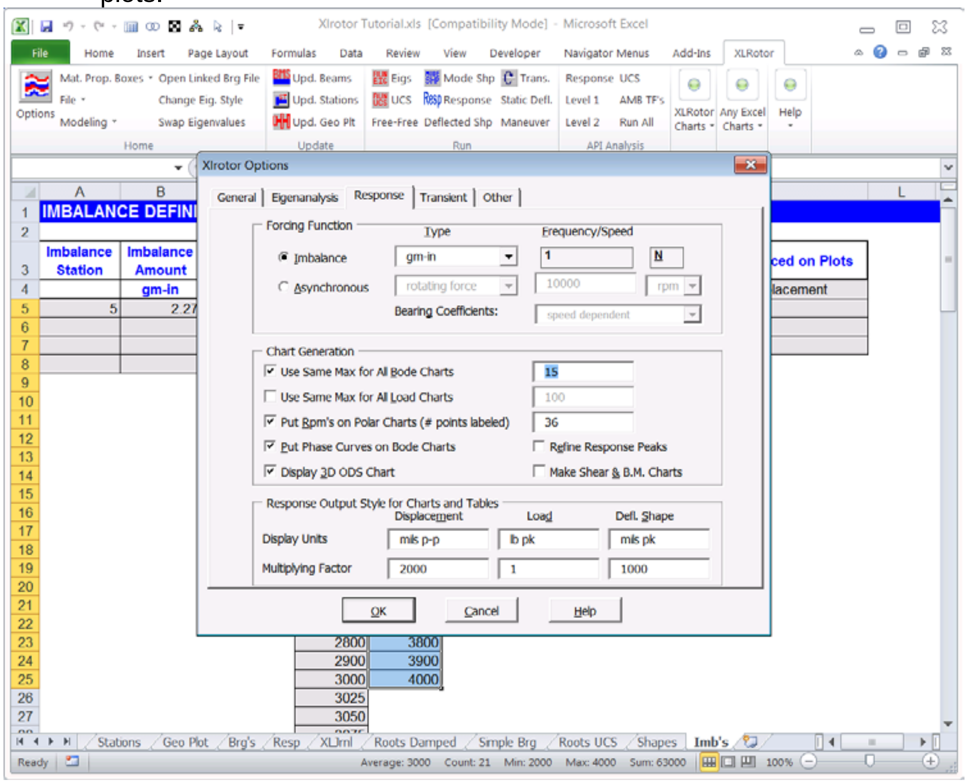


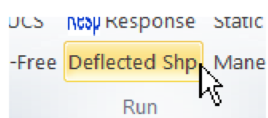
IMBALANCE DEFINITIONS, RESPONSE SPEED RANGE & OUTPUT STATIONS

Row	Imbalance Station	Imbalance Amount gm-in	Imbalance Phase degrees	Imbalance Type [F,M]	Response Speeds rpm	Deflected Shapes rpm	Output Stations	Relative Stations	Probe Clocking	Titles to be Placed on Pl
4							5		0	Disk absolute displacement
5	5	2.27	0	F	1000	2000				
6					1100	2100				
7					1200	2200				
8					1300	2300				
9					1400	2400				
10					1500	2500				
11					1600	2600				
12					1700	2700				
13					1800	2800				
14					1900	2900				
15					2000	3000				
16					2100	3100				
17					2200	3200				
18					2300	3300				
19					2400	3400				
20					2500	3500				
21					2600	3600				
22					2700	3700				
23					2800	3800				
24					2900	3900				
25					3000	4000				
26					3100					
27					3200					

The deflected shape analysis will create one plot for each speed in the list. Before running the analysis we'll do one more thing so all the plots will have the same plot scale on the y axis.

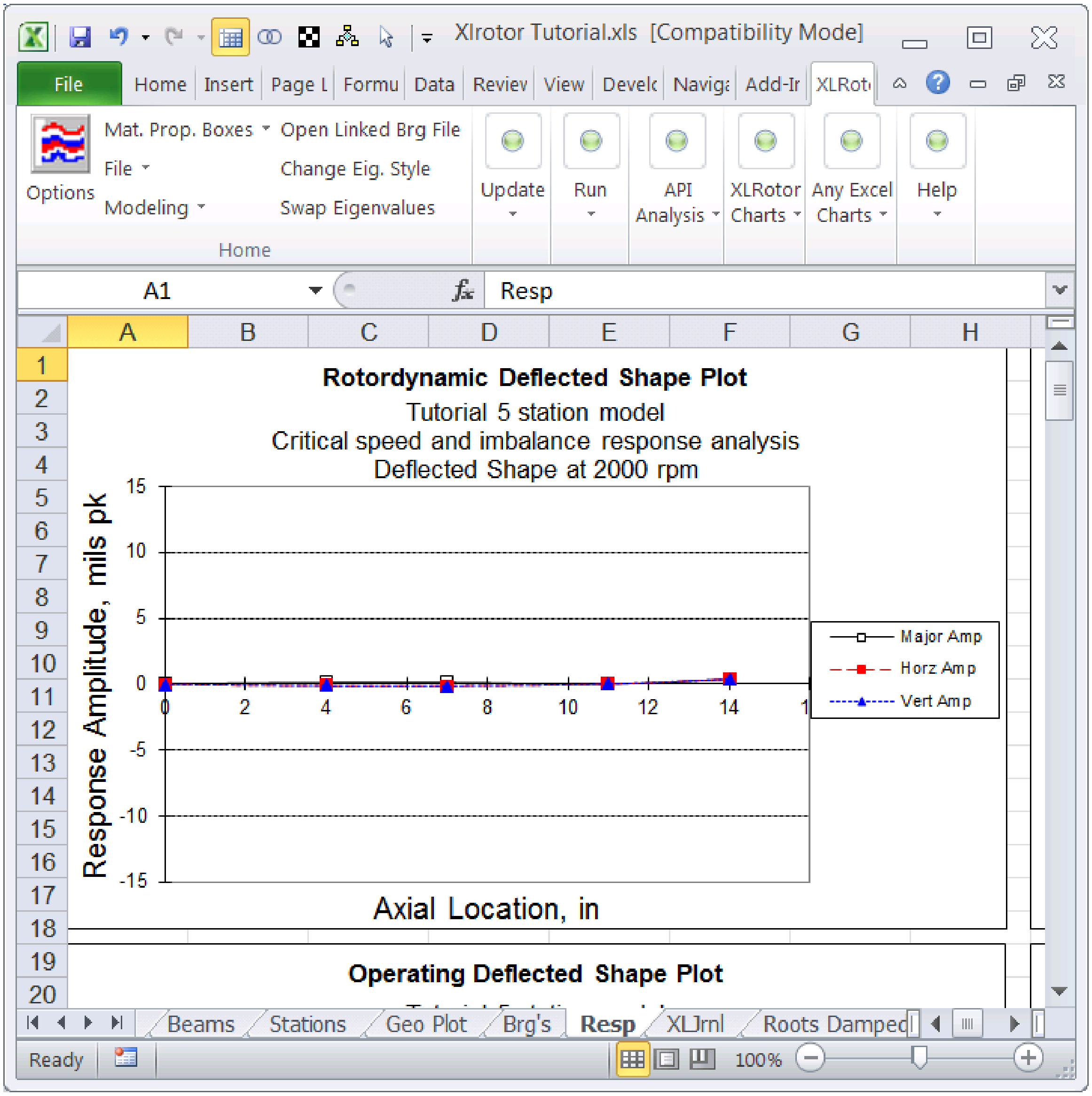
- Click the **Options** button  on the XLRotor ribbon.
- Go to the **Response** tab.
- Put a check in the box for the **Use Same Max for All Bode Charts.**
- Type the value **15** in the edit box for this option. This setting will also apply to deflected shape plots.



- In the XLRotor ribbon, click the **Deflected Shp** button. 

If prompted, select the **Overwrite** option to overwrite the present **Resp** sheet with the deflected shapes about to be computed. You'll see the plots get created one at a time as they are placed on the worksheet. When the analysis is complete, you will be looking at the last plot created.

- Press **Control-Home** to scroll the display to the upper left corner of the worksheet. Before doing this, you may need to press the **Escape** key to deselect the last chart. This should bring you to the deflected shape plot for 2000 rpm.
- Click on the plot to select it.
- Click the **Zoom Selection** button  on the XLRotor ribbon to fill the Excel screen as much as possible with the plot.
- Resize the Excel application window to be just a little wider than the 8 columns the chart is in (see image below).
- On the keyboard hold down the **Alternate** key and press the **Page Down** key.
- This will scroll the Excel window one screen to the right, which should bring into view the deflected shape for 2100 rpm.
- If you hold down or rapidly press **Alt-PageDown**, you should see an animation of the rotor passing through its critical speed near 3200 rpm.



This completes the first part of the XLRotor tutorial.

To continue with the next part, click this link: XLRotor Tutorial Part 2.pdf