Knowledge Base

Abaqus/CAE plug-in for plotting Campbell diagrams

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Information

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QUESTION

How can I create a Campbell diagram for my rotor dynamics model?

ANSWER

(The following applies to Abaqus Version 6.12 and later)

In rotor dynamics, Campbell diagrams are used to plot whirling frequency versus spin speed. An Abaqus/CAE plug-in application for this purpose is attached below.

The application requires an output database (.odb) file that contains displaced shape field output from one or more complex frequency analyses (i.e., mode shapes). Each complex extraction step should compute the frequencies and mode shapes for a single spin speed, and each step should request the same number of modes.

The general approach of the application is to successively sort the modes at each spin speed by ***shape***, using the mode shapes of the first frequency extraction as the baseline. Specifically, the modes of the second step (spin speed) are sorted by shape to best match the order of those in the first step. The modes of the third step are then ordered to best match the already sorted second step modes, and so on through all the steps. The corresponding frequencies of the shape-sorted modes are then X-Y plotted against spin speed.

The shape sorting is done by using the modal assurance criteria. The function of the MAC is to provide a measure of consistency, or similarity, between estimates of a modal vector. The MAC varies between 0 and 1, with 0 representing no consistency and 1 representing perfect consistency. Additionally, the MAC is independent of the type of eigenvector normalization (displacement or mass), and eigenvectors with mixed normalization types can still be considered. For additional information, please refer to Plug-in utility for computing Modal Assurance Criteria.

For example, it may be the case that the third mode of spin speed two is closest in shape to the second mode of spin speed one; and the fourth mode of spin speed three is closest in shape to the third mode of spin speed two. The three (frequency, spin speed) pairs would lie on the same Campbell diagram line. Subsequently there will be as many lines on the diagram as modes requested.

Installation

In order to run the Campbell plug-in, the MAC plug-in (MAC.zip) must also be installed inside the same abaqus_plugins directory.

To install the plug-in, save the attached archive file to one of the following directories:

abaqus_dir\abaqus_plugins where *abaqus_dir* is the Abaqus parent directory

home_dir\abaqus_plugins where *home_dir* is your home directory

current_dir\abaqus_plugins where *current_dir* is the current directory

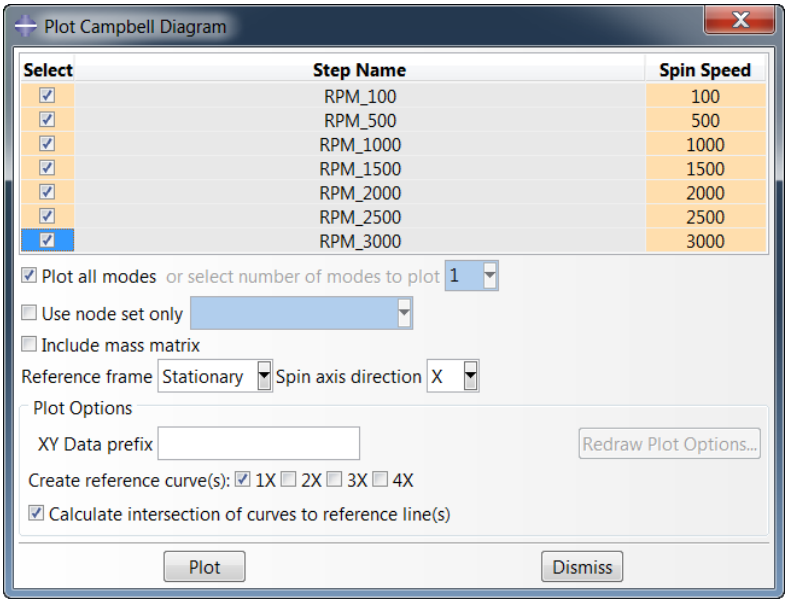
Note that if the abaqus_plugins directory does not exist in the desired path, it must be created. The *plugin_dir* directory can also be used, where *plugin_dir* is a directory specified in the abaqus_v6.env file by the environment variable **plugin_central_dir**. You can store plug-ins in a central location that can be accessed by all users at your site if the directory to which **plugin_central_dir** refers is mounted on a file system that all users can access. For example,

plugin_central_dir = r'\\fileServer\sharedDirectory'

On Windows platforms, right click on the archive file and select **WinZip** → **Extract to here**. On Linux platforms, type **unzip campbellDiagram.zip** at the command prompt. A folder named campbellDiagram, sub-folders and a file named campbellDiagram_plugin.py will be extracted. Note that the plug-in will not function properly if this procedure is not followed.

Usage

When activated, the plug-in lists all complex frequency extraction steps found in the active viewport output database (.odb) file. Select **Plug-ins→Tools→Plot Campbell Diagram...** to invoke the following dialog:



Use the check buttons in the table (**Select** column) to deselect specific steps not needed for evaluation. The step names found in the current odb will be listed under the **Step Name** column. Enter the spin speed in the third column.

Deselect **Use all modes** and select a value from the drop-down menu in order to plot a selected number of modes. Note that all modes are used in every calculation, regardless of the number of modes plotted.

The evaluation can be reduced to a certain region by selecting a node set under **Use node set only** – to either reduce calculation time or to concentrate on a specific region. By default the mass matrix is not taken into account and the evaluation is only based on the displacement vectors. If the element volume is written to the output database, selecting **Include mass matrix** will add the mass into the formula for the MAC value. Calculation time might be increased in this case.

The **Reference frame** combo box allows the selection of stationary and moving reference frames. The stationary frame should be selected for SST analysis ODB or complex frequency analysis ODB with ROTDYNF load (*DLOAD option). The moving reference frame should be selected for complex frequency analysis ODB with CORIO + CENTRIF load (*DLOAD option). Using the **Spin axis direction** combo box, only one of the following global directions can be selected: X, Y, Z, -X, -Y and -Z. The plug-in uses the spin direction in order to calculate the whirl direction.

The menus available under **Plot Options** are relevant to plotting only and do not change the calculations. Thus, any option under **Plot Options** may be changed and the plot updated without running the calculations again.

If desired, enter a string in **XY Data prefix**. All XY Data created by this tool will contain the string entered.

By default a forced frequency curve (reference curve) is created representing a whirl speed equal to the spin speed (**1x**). Alternatively, curves with **2x**, **3x** or **4x** (times) the spin speed can be created. The corresponding name for these reference curves is Ref_x, where x represents 1, 2, 3 or 4. If reference curves are created, the intersection between these curves and the modes can be calculated and displayed in the diagram. The name of the **XY Data** containing the intersection of the reference curve and the calculated values is **CrossPoint at Ref_x**. Please interrogate the relevant **XY Data** in order to obtain the exact values calculated.

Please note that the Campbell Diagram tool will create a reference curve through all the modes (XY Data) calculated. You are advised to use Abaqus/Viewer plotting options (**Options→XY Options→Axis)** to adjust maximum and minimum plot values.

Notes

A hard-coded MAC cutoff value of 0.6 is used. In the event a correlation does not meet the 0.6 criteria, the spin speed (RPM) and frequency values from the previous step are entered. Thus, you may see duplicate values for a particular set of XY Data. Any value skipped will be reported in the Command Line Interface (CLI).

The plug-in only supports the input files without the part and assembly format(flat input files).

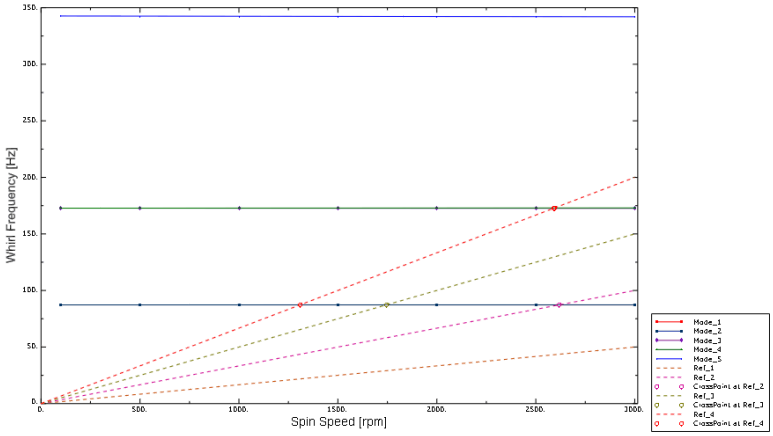
The mass matrix requires that the element volume is written as output variable EVOL for the first step selected. If the mass matrix could not be calculated the mass is assumed to be equal at each node.

No special calculations are performed for models with varying materials.

The mode number on the Campbell Diagram plot might be different from the one in the ODB, since the plug-in can change the mode number after tracking the mode.

The plug-in might not properly track the whirl mode if the zero spin speed results are included. Instead of the zero spin speed results, include the results generated from a small value of spin speed.

Please use the attached Abaqus input files (RotorBearing2D_Campbell.inp and RotorBearing3DSST_Campbell.inp) as example models. The following Campbell Diagram plot shows the 1st 5 whirl frequencies from the example model.



Revision History

14 Mar 11	Release 1.1-1
18 Jul 11	Release 1.2-1
31 Mar 13	Release 1.3-1

Disclaimer

The attachments to this article are subject to certain usage conditions. Please click here for details.

KEYWORDS **campbell, whirl, shaft, whirling, rotor, rotordynamic, forward, backward, synchronous, unbalance, wi**

ATTACHMENT campbellDiagram.zip | answer_4721_fig3.png | RotorBearing2D_Campbell.inp | RotorBearing3DSMGSST_Campbell.inp | 4721_campbell_diagram_1st_5_whirl_freq_demo.png | MAC.zip

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