Knowledge Base

Plug-in utility for computing Modal Assurance Criteria

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QUESTION

How can I obtain the Modal Assurance Criterion (MAC) matrix to correlate the modal results of my model?

ANSWER

(The following applies to Abaqus Version 6.6 and later)

An Abaqus/CAE plug-in application for this purpose is attached below. Given two output database (.odb) files that contain displaced shape field output from frequency extractions (mode shapes), the MAC results are computed and displayed in bar graph or contour plot form.

Background

The function of the modal assurance criterion (MAC) is to provide a measure of consistency, or similarity, between estimates of a modal vector[1]. The modal vectors under consideration may be analytically or experimentally determined. The MAC is often used in conjunction with orthogonality checks to validate analytical results or experimental data.

Consider the eigenvectors for two systems: φ_A refers to analysis results and φ_B refers to measurement data or additional analysis results. For mode *i* of and mode *k* of the MAC may be written as:

$$\frac{\left(\varphi_{iA}^{T}\,\varphi_{kB}\right)^{2}}{\left(\varphi_{iA}^{T}\,\varphi_{iA}\right)\times\left(\varphi_{kB}^{T}\,\varphi_{kB}\right)} \quad (1)$$

The MAC varies between 1 and 0, with 1 representing perfect consistency and 0 representing no 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.

Installation

To install the plug-in, download and save the attached archive (MAC_1_4-2.zip) 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 MAC_1_4-2.zip** at the command prompt. A folder named abq_Mac and a file named mac_plugin.py will be extracted. Note that the plug-in will not function properly if this procedure is not followed.

The next time Abaqus/CAE is started, the plug-in will be available from the **Visualization** module. Select **Plug-ins → NVH → Modal Assurance Criteria...**.

Usage

The plug-in reads two (.odb) files. The files must contain displacement field output from a frequency extraction procedure; the plug-in will issue an error otherwise. Launching the plug-in invokes the following dialog:

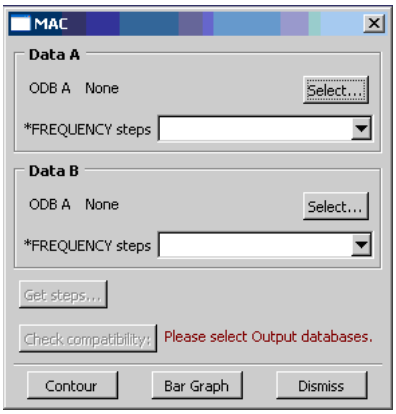

Figure 1: **MAC** *dialog box*

It is irrelevant which output database is selected first. After selecting both output databases, the **Get steps...** button is enabled. Click on this button in order for the plug-in to retrieve any frequency extraction steps that have displaced shape field output. The steps will be listed in the ***FREQUENCY steps** pulldown menu.

After retrieving the steps, the **Check compatibility:** button is enabled. It is **not** necessary to perform this check. If performed, this check returns the compatibility between the first mode of each database.

If **Contour** is selected a plot similar to the one below will be created:

MY FAVORITE CONTENT

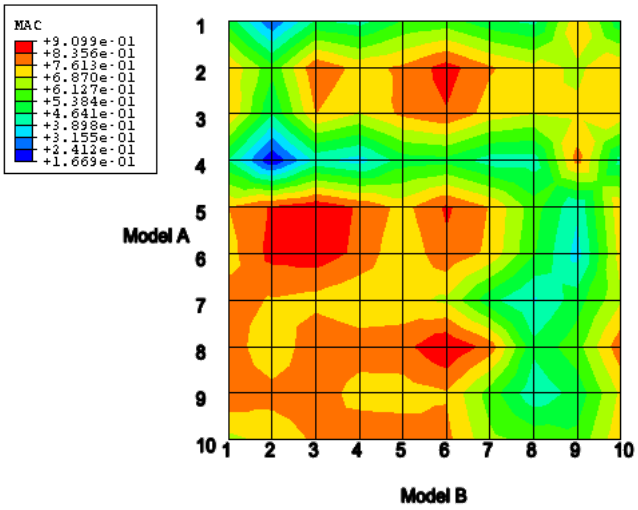

Figure 2: MAC matrix contour plot

Each (x,y) point on the contour grid displays the MAC value for the corresponding mode numbers. For example, the MAC value for mode 5 of Model A and mode 8 of Model B is given at point (8,5) on the plot. For each contour plot that is created, an output database named contourMAC*n*.odb will be written in the Abaqus/CAE working directory, where *n* refers to the n^{th} contour plot.

If **Bar Graph** is selected, a plot similar to the one below will be created.

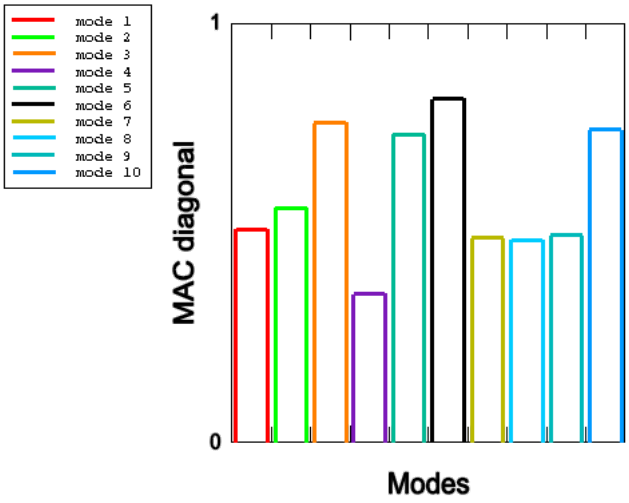

Figure 3: MAC matrix diagonal entries bar graph

The contour plot shows the value of each entry in the MAC matrix in color, whereas the bar graph shows the values of all the diagonal entries in the MAC matrix. It is generally accepted that two modes are consistent if their MAC value is greater than 0.9 and inconsistent if their MAC value is less than 0.05.

Usage Notes

1. The plug-in accomodates .odb files that have different numbers of eigenvectors, as well as eigenvectors of different lengths. No attempt is made to ensure that the range of the extracted frequencies in the two.odb files is consistent.
2. The computed MAC matrix is always square. If the two .odb files do not contain the same number of eigenvectors, the lower number of available eigenvectors determines the dimension of the MAC matrix. Additionally, the modes from the .odb files are compared in ascending order.

   For example, if .odb A has 20 modes, and .odb B has 15 modes, the plug-in will compute a 15 x 15 MAC matrix which compares the first 15 modes of .odb A with all the modes of .odb B.
3. Before computing the MAC value for a given pair of eigenvectors, the plug-in modifies the vectors to make sure they are the same length. This is done by considering the node labels of each eigenvector component and discarding those components that are not common to the two vectors.

   Consider a MAC calculation for two .odb files. Output database A corresponds to a model with 10 nodes, labeled 1-10. Output database B corresponds to a model with 5 nodes, labeled 2-6. When the MAC matrix is computed, the plug-in will extract the entries for nodes 2-6 from the eigenvectors of .odb A and use these in the comparison with the eigenvectors of .odb B.

   Caution must therefore be used when comparing .odb files that are *not* generated from the same model; if the node labeling or mesh topology in the two models is not consistent, then the MAC results will have no meaning, or the computation may fail.

   If the plug-in is used to compare the eigenvectors of a substructure to those of the full model used to generate the substructure, the labels of the substructure nodes at the usage level must be the same as the labels of the nodes that are retained when the substructure is generated.
4. The plug-in uses only translational displacements (U1,U2,U3) for the eigenvectors. Rotational displacements (UR) are not considered in the calculation of the MAC.
5. The ability to compare analytical results with test results is not yet implemented.
6. The plug-in can use results from any of the available eigensolvers.

7. The plug-in creates annotations in the viewport. If consecutive runs of the plug-in are done, these annotations are overwritten rather than deleted; this may sometimes clutter the viewport if MAC matrices of different dimensions are created consecutively. To clear the viewport of the annotations simply close the .odb that is created when the plug-in is executed.
8. This version (1.4-2) of the MAC plug-in attached to the answer calculates real modes only.

References

1. Allemang, R.J., "The Modal Assurance Criterion – Twenty Years of Use and Abuse," *Sound and Vibration*, August 2003, pp. 14-21.
2. Ewins, D.J. *Modal Testing: Theory and Practice*, Research Studies Press, 1984.

Revision History

30 Nov 06	Initial release of Version 1.2-1
12 Dec 06	Release of Version 1.2-2. Improved exception handling for .odb version upgrade requirement; no change to MAC results.
31 May 07	Release of Version 1.3-1. Included compatibility check for first modes of the two .odb files.
08 Jun 08	Release of Version 1.4-1. Changed numerator term calculation to be component-based instead of magnitude-based.
30 Sep 08	Release of Version 1.4-2. Added additional checks for zero values.
08 Mar 11	Release of Version 2.1-1. Using Numpy.
11 May 11	Release of Version 2.1-2. Fix backward compatibility issues with 6.7, 6.8 and 6.9.
16 Jun 11	Release of Version 2.1-3.
08 Apr 15	Version 2.1-3 temporarily removed, Version 1.4-2 restored
07 May 2020	Version 1.4-3. Fixed an issue with Numeric module. Use numpy from Abaqus/CAE 2020 onwards.

KEYWORDS **MAC, orthogonality, correlation, correlate, modal, modal testing, plugin, plug-in, customization, gu**

ATTACHMENT Answer_3146_Fig2.png | Answer_3146_Eq1.gif | Answer_3146_Eq3.gif | Answer_3146_Fig3.png | Answer_3146_Eq2.gif | Answer_3146_Fig4a.png | MAC_1_4-3.zip

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