Iterative pole-zero model updating using Generic Parameters

Citation for published version (APA):

Document status and date:
Published: 27/11/2015

Please check the document version of this publication:
• A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.
• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at: openaccess@tue.nl
providing details and we will investigate your claim.
Introduction
A crucial step in the control of a high-tech system is having a very accurate dynamic model of the system from actuators to sensors and to the unmeasured performance variables. A (reduced) Finite Element (FE) dynamic model may be a good candidate apart from the fact that its accuracy is often limited, since it does not fully match with the real structure. Using a FE model updating algorithm the accuracy of FE model can be significantly improved. An Iterative Pole-Zero (IPZ) model updating procedure is proposed that updates the eigenvalues of the stiffness and/or damping matrix. These are considered as the generic parameters needed to update the FE dynamic model. Updating the poles and zeros is done using estimates from measured Frequency Response Functions (FRFs).

Case Study
Consider the mass-spring-damper system in Fig. 1. The original model consists of six point masses $m_i = 1$ kg, six springs $k_i = 10^6$ N/m, and six viscous dampers $c_i = 10$ Ns/m $(i = 1,\ldots,6)$. This results in a system mass $M_n$, damping $C_n$, and stiffness matrix $K_n$, respectively.

In general, the original model differs from the real structure. Assume a similar structure which differs in terms of spring stiffnesses $K_2 = k_6 = 1.2 \times 10^6$ N/m and viscous damping constants $c_1 = c_5 = 5$ Ns/m. This structure is called the experimental model. It is assumed that FRF $H_{11} = Y_{11} / U$ can be measured and FRF $H_{41} = Y_{41} / U$ corresponds to the unmeasured performance variable. The poles of the original $H_{11}$ can be calculated via the eigenvalue problem

$$\left( \lambda_2^2 M_n + \lambda_2 C_n + K_n \right) u_0 = 0, \quad (1)$$

while the zeros are calculated via

$$\left( \lambda_2^2 M_5 + \lambda_2 C_5 + K_5 \right) u_2 = 0, \quad (2)$$

where $M_5$, $C_5$, $K_5$ are the substructure matrices. These matrices can be derived from $M_n$, $C_n$, $K_n$ by deleting the column and row corresponding to the actuator and sensor DOFs.

Generic Parameter Assignment
If no information is available on possible locations of errors in the stiffness and damping matrix, it is proposed to use only a limited number of eigenvalues of the stiffness and damping matrix as generic parameters to be updated. For instance, eigenvalue decomposition of the stiffness matrix is given by

$$K_n = V \Sigma V^{-1} = V \Sigma V^T, \quad (3)$$

where $V$ is a square matrix containing column-wise the real static stiffness mode shapes, and $\Sigma = \text{diag}(\sigma_1,\ldots,\sigma_n)$ is a diagonal matrix containing the corresponding real eigenvalues of the stiffness matrix.

Iterative Pole-Zero Model Updating
IPZ model updating is a procedure which tries to minimize the following pole and zero error functions iteratively by updating the generic parameters

$$e'_2 = (\lambda_2^0 - \lambda_2^i) W_2 (\lambda_2^0 - \lambda_2^i), \quad (4)$$

$$e'_1 = (\lambda_2^0 - \lambda_1^i) W_1 (\lambda_2^0 - \lambda_1^i), \quad (5)$$

where $W_1 > 0$ and $W_2 > 0$ are weighting matrices.

Simulation Results and Conclusions
The IPZ model updating is performed on the original $H_{11}$ using the measured poles and zeros from the experimental $H_{11}$. In Fig. 2, the original, experimental, and updated FRFs $H_{11}$ and $H_{41}$ are shown. 0 dB is 1 m/N. It is clear that, in contrast to the original $H_{11}$, the updated $H_{11}$ matches very well with the experimental $H_{11}$. Furthermore, as a result of IPZ model updating using $H_{11}$, the updated unmeasured variable reflected by $H_{41}$ also matches well with the experimental $H_{41}$ in contrast to the original $H_{41}$.

Figure 2: Original, experimental, and updated $H_{11}$ (top) and $H_{41}$ (bottom) after IPZ model updating.

References