DampIT: A Tool for the Identification of Physical Damping Coefficients of a Multibody System Model

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A. Rezaeian, J. Ruhnke, S. Hauptmann

Mesh Engineering GmbH
Alireza.Rezaeian@mesh-engineering.de
Wind@mesh-engineering.de
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Simulation of a system requires accurate modelling of mass and stiffness distribution and proper consideration of damping components.

- Mass and stiffness values can be extracted from design data.
- Specification of properties of damping components (e.g. physical damping coefficients) is challenging.
- Damping coefficients significantly affect the model dynamic behavior and also the integration stability.

Mass, Stiffness and damping of a system can be defined in modal coordinates.

- Describing a system in modal coordinates simplifies the modelling approach.
- Equivalent systems have identical:
  a) eigenfrequencies
  b) modal damping
  c) mode shapes

A system can be described by both physical and modal structural data.
Motivation

- physical damping coefficients:
  a) measurements?
  b) empirical values?
  c) analytical formulas?
  d) function of stiffness/mass?

There are often uncertainties about these coefficients.

- modal damping:
  a) measurements (e.g. experimental modal analysis)
  b) empirical values (e.g. 2%)

Measured or empirical values for modal damping describe the global system behavior.

⇒ Modal damping values should be used as input.
Objective

Identification of the physical damping coefficients to achieve a predefined modal damping

Eigenvalue Analysis

Identification Coefficients

- Force Element i
  - Transl. damping in X
  - Transl. damping in Y
  - Transl. damping in Z
  - Rotat. damping in al
  - Rotot. damping in be
  - Rotat. damping in ga

Modal Damping

- Nat. Damping
  - 0.01999861551243265
  - 0.0199983119224296
  - 0.0200000414076139

⇒ DampIT: Damping Identification Tool
Basic Principles

- Linearization and determination of eigenfrequencies and modal damping are used to evaluate a model with modal structural data.

\[
\dot{X} = [A] \cdot [X]
\]

linear system matrix \([A]\) \(\Rightarrow\) eigenfrequencies/modal damping

- Linear system matrix \([A]\) is function of mass \([M]\), stiffness \([K]\) and damping \([C]\) matrices.

- If we consider the mass and stiffness matrices constant, a modal damping can be defined as a function of elements of the damping matrix:

\[
D_j = \frac{-R_j}{\sqrt{R_j^2 + I_j^2}} = f([C])
\]

\(R_j\): real part of eigenvalue, \(I_j\): imaginary part of eigenvalue
Damping Coefficients Identification Process

- Selection of the physical damping coefficients in model:
  \[ [c_1, c_2, \ldots, c_k] \]
  with consideration of model symmetry and DOFs of the model components

- Identification of linear system matrix as a function of selected damping coefficients:
  \[ A(c_1, c_2, \ldots, c_k) \]

- Calculation of modal damping of \([A]\) via eigenvalue analysis

- Identification of \((c_1, c_2, \ldots, c_k)\) so that modal damping corresponds to predefined values.

Iterative determination of damping coefficients
Damping Coefficients Identification Process

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Iterative determination of damping coefficients \(\Rightarrow\) **numerical optimization problem**

E.g. 1ms for \(k=100\)
DampIT: Implementation of the Process

- Combination of MATLAB and SIMPACK scripts
- Applicable to any SIMPACK model with linear dampers with constant damping coefficients
- An easily understandable user-interface section
- Validation of the calculated $[A]$ with the identified damping coefficients
- Provision of an ascii-file, which includes the results and a summary of the user inputs
- Creation of a new SIMPACK model with the identified damping coefficients in a subVar file

![SubVar File List](image)

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<tr>
<th>Overwriting</th>
<th>SubVar Files</th>
<th>Source Path</th>
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</table>
Application of DampIT: Example 1

3 Masses-3 Springs-3 dampers-system:
- with 3 DOFs
- 3 damping coefficients as identification variables
- user defined modal damping: 2%

\[
\begin{align*}
m_3 &= 3 \text{ Kg} \\
K_3 &= 5000 \text{ N/m} \\
c_3 &= 8 \text{ Ns/m} \\
m_2 &= 5 \text{ Kg} \\
K_2 &= 2000 \text{ N/m} \\
c_2 &= 20 \text{ Ns/m} \\
m_1 &= 2 \text{ Kg} \\
K_1 &= 1000 \text{ N/m} \\
c_1 &= 10 \text{ Ns/m}
\end{align*}
\]
Application of DampIT: Example 2

3 Masses-4 Springs-4 dampers-system:

- with 3 DOFs
- 3 of 4 damping coefficients were selected as identification variables
- user defined modal damping: 2%

$m_3=3 \text{ Kg}$
$K_{3_1}=8000 \text{ N/m}$
$C_{3_1}=20 \text{ Ns/m}$
$K_{3_2}=5000 \text{ N/m}$
$C_{3_2}=30 \text{ Ns/m}$

$m_2=5 \text{ Kg}$
$K_2=2000 \text{ N/m}$
$c_2=20 \text{ Ns/m}$

$m_1=2 \text{ Kg}$
$K_1=1000 \text{ N/m}$
$c_1=10 \text{ Ns/m}$

Fixed value: $C_{3_1}=20$
DampIT variables: $c_1$, $c_2$, $C_{3_2}$

Optimized damping coefficients

Opt. modal damping

0.019998615512493265
0.02000002045238638
0.0506396835418333
Application of DampIT: Example 3

3-Stage Gearbox of a wind turbine:

- with 59 DOFs
- 68 damping coefficients selected as identification variables
- user defined modal damping: 2%

stage 1: 3 planetary gears
stage 2: 1 gear /pinion
stage 3: 1 gear/pinion
Results:

![Graph showing improvement of modal damping distribution]

- Improvement of the modal damping distribution

*with initial damping coefficients*

*with optimized damping coefficients*
Application of DampIT: Example 3

Results:

higher percentage of number of modes with user defined modal damping 2%
Conclusions

- Specification of damping of a system in modal coordinates is easier than in physical coordinates.
- It is possible in a model to adjust the physical damping coefficients to achieve a predefined modal damping:
  
  a) DampIT: a tool for the identification of physical damping coefficients of a MBS-model to achieve a predefined modal damping was introduced.
  
  b) Application of this tool was demonstrated for different examples.
  
  c) Improvements of the damping coefficients using DampIT were shown and discussed.

⇒ DampIT is ready for customer application!