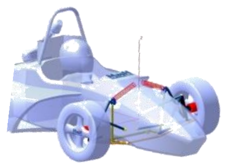
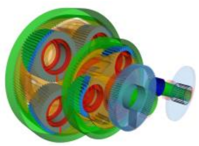




DampIT: A Tool for the Identification of Physical Damping Coefficients of a Multibody System Model

SIMULIA Multibody Simulation User Group Meeting 2017

A. Rezaeian, J. Ruhnke, S. Hauptmann

MesH Engineering GmbH

Alireza.Rezaeian@mesh-engineering.de

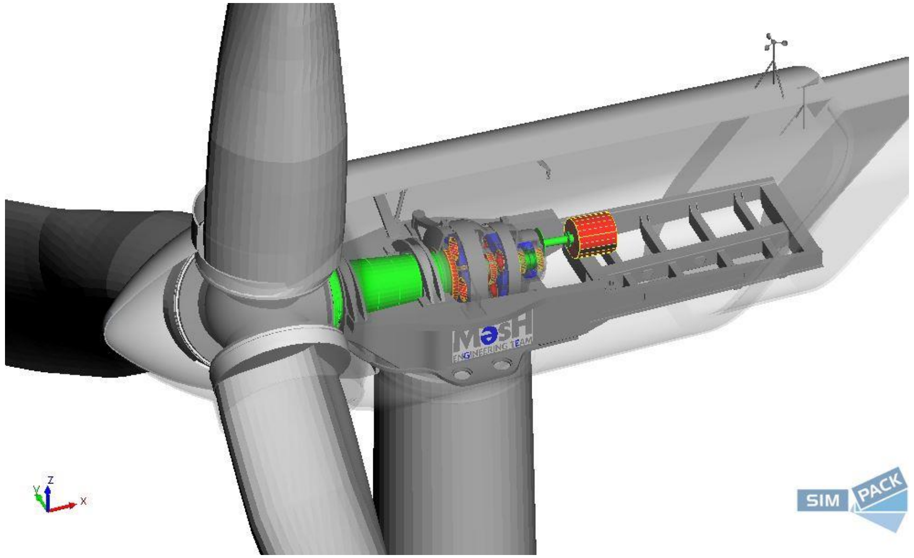
Wind@mesh-engineering.de

MesH ENGINEERING TEAM

Content

- Motivation
- Objective
- Basic Principles
- Damping Coefficients Identification Process
- DampIT: Implementation of the Process
- Application of DampIT
- Conclusions

Motivation



- 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

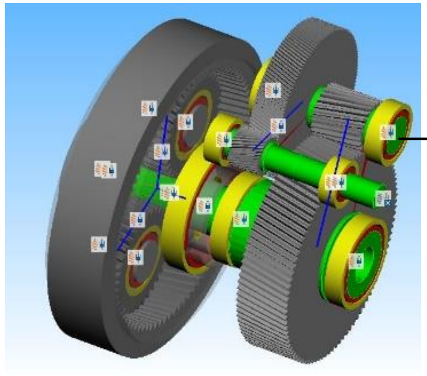
⇨ A system can be described by both physical and modal structural data.

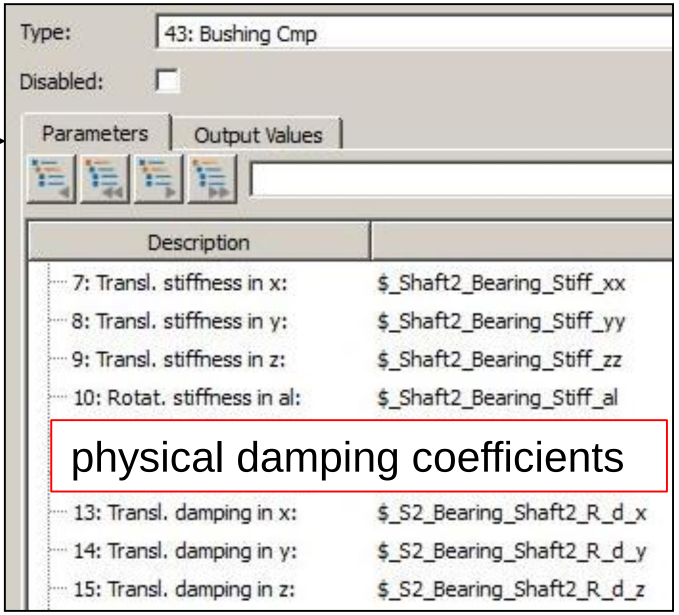
MeSH ENGINEERING TEAM

Motivation

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

  There are often uncertainties about these coefficients.





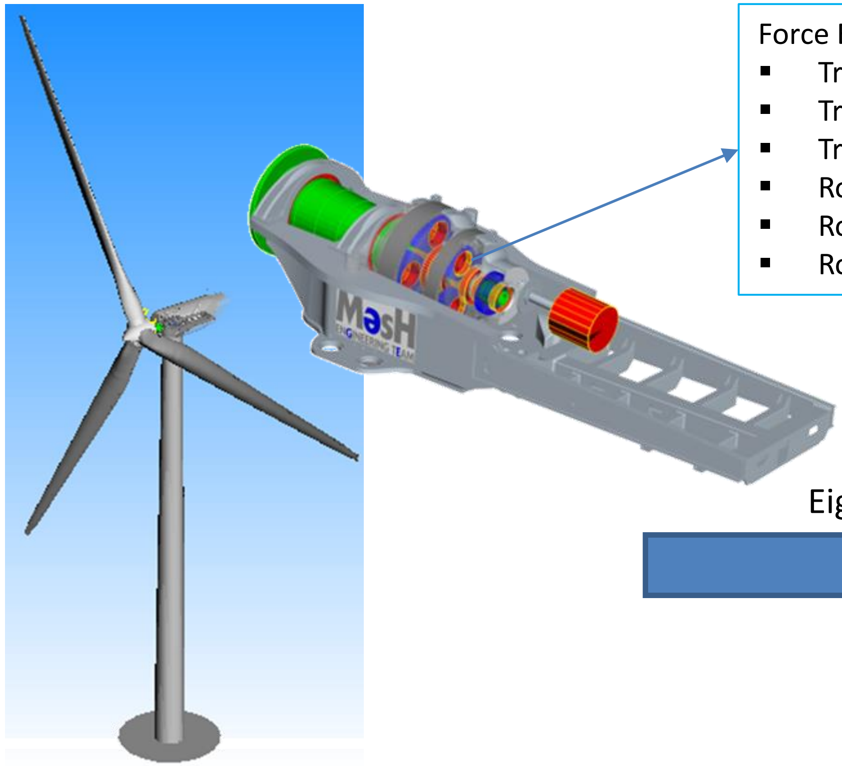
- modal damping:
    a) measurements (e.g. experimental modal analysis)
    b) empirical values (e.g. 2%)

  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



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

Eigenvalue Analysis

Modal Damping

Nat. Damping
0.01999861551243265
0.01999983119224296
0.02000004140786139
.
.
.
0.01999861551243265
0.01999983119224296
0.02000004140786139

⇨ **DampIT: <u>Damping</u> <u>I</u>dentification <u>T</u>ool**

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 $[A]$ ⇨ eigenfrequencies/modal damping

- Linear system matrix $[A]$ is function of mass $[\mathrm{M}]$, stiffness $[\mathrm{K}]$ and damping $[\mathrm{C}]$ 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:

$$\text{if } [M], [K] = const. \quad ⇨ \quad D_j = \frac{-R_j}{\sqrt{\left({R_j}^2 + {I_j}^2\right)}} = f([C])$$

R_j: real part of eigenvalue, I_j: imaginary part of eigenvalue

Damping Coefficients Identification Process

- Selection of the physical damping coefficients in model:

$$[c1, c2, \dots, ck]$$

with consideration of model symmetry and DOFs of the model components

- Identification of linear system matrix as a function of selected damping coefficients:

$$A(c1, c2, \dots, ck)$$

- Calculation of modal damping of $[A]$ via eigenvalue analysis

- Identification of $(c1, c2, \dots, ck)$ so that modal damping corresponds to predefined values.

Iterative determination of damping coefficients

Damping Coefficients Identification Process

- Selection of the physical damping coefficients in model:

$$[c1, c2, \dots, ck]$$

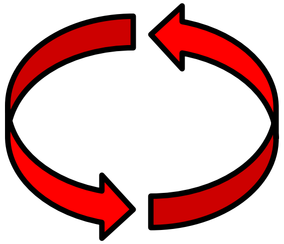
with consideration of model symmetry and DOFs of the model components

- Identification of linear system matrix as a function of selected damping coefficients:

$$A(c1, c2, \dots, ck)$$

- Calculation of modal damping of $[A]$ via eigenvalue analysis

- Identification of $(c1, c2, \dots, ck)$ so that modal damping corresponds to predefined values.

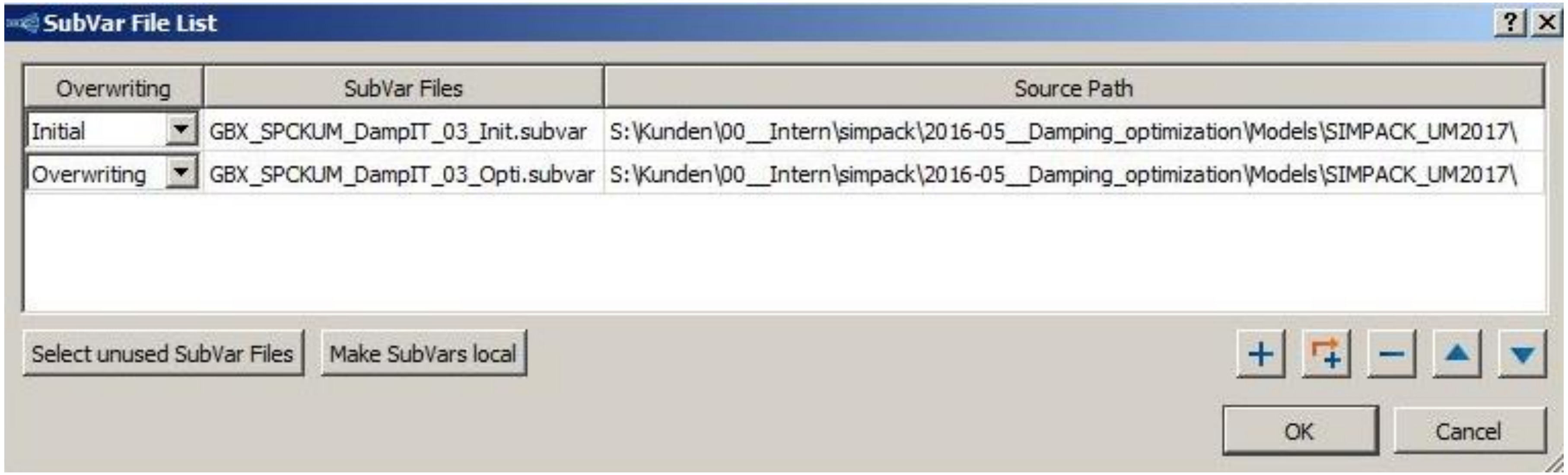


e.g. 1ms for *k=100*

Iterative determination of damping coefficients ⇨ **numerical optimization problem**

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 summery of the user inputs
- Creation of a new SIMPACK model with the identified damping coefficients in a subVar file



MəsH ENGINEERING TEAM

Application of DampIT: Example 1

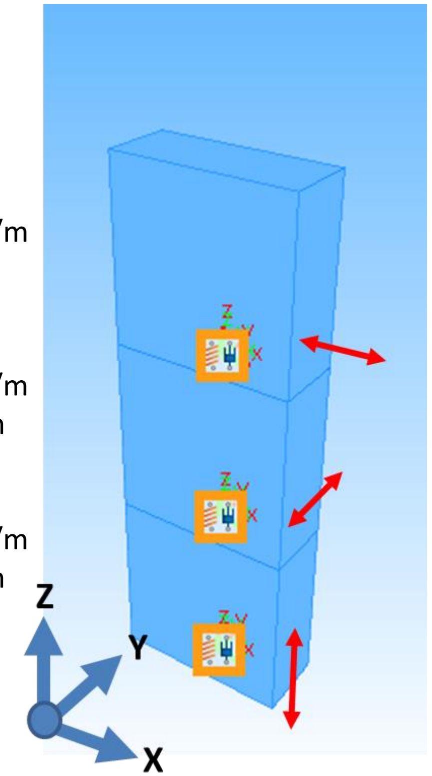
3 Masses-3 Springs-3 dampers-system:

- with 3 DOFs
- 3 damping coefficients as identification variables
- user defined modal damping: 2%

m3=3 Kg
K3=5000 N/m
c3=8 Ns/m

m2=5 Kg
K2=2000 N/m
c2=20 Ns/m

m1=2 Kg
K1=1000 N/m
c1=10 Ns/m



initial damping coefficients

Name	Value
SubVars	
$_damping_1	10
$_damping_2	20
$_damping_3	8

initial modal damping

Nat. Damping
0.04999842366473031
0.07905694150420949
0.03265986323710904

DampIT

optimized damping coefficients

Name	Value
SubVars	
$_damping_1	4.0000242197017
$_damping_2	5.05960155090949
$_damping_3	4.89898962837953

opt. modal damping

Nat. Damping
0.01999861551243265
0.01999983119224296
0.02000004140786139

Application of DampIT: Example 2

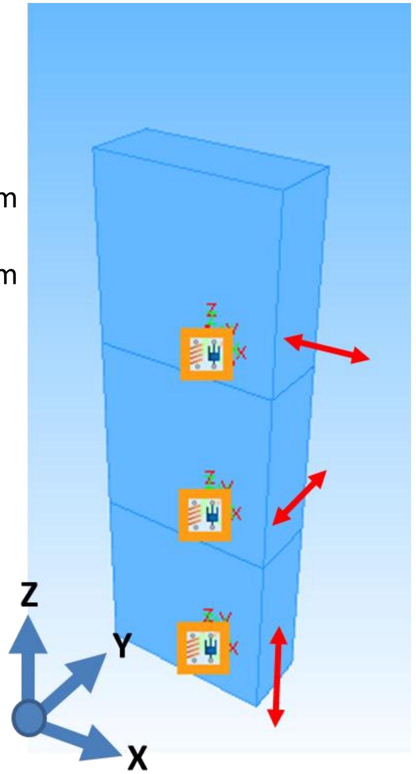
3 Masses-4 Springs-4 dampers-system:

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

m3=3 Kg
K3_1=8000 N/m
C3_1=20 Ns/m
K3_2=5000 N/m
C3_2=30 Ns/m

m2=5 Kg
K2=2000 N/m
c2=20 Ns/m

m1=2 Kg
K1=1000 N/m
c1=10 Ns/m



fixed value: C3_1=20   DampIT variables: c1, c2, c3_2

DampIT

optimized damping coefficients

Name	Value
SubVars	
$_damping_1	3.99999297751847
$_damping_2	5.05964943035937
$_damping_3	0

opt. modal damping

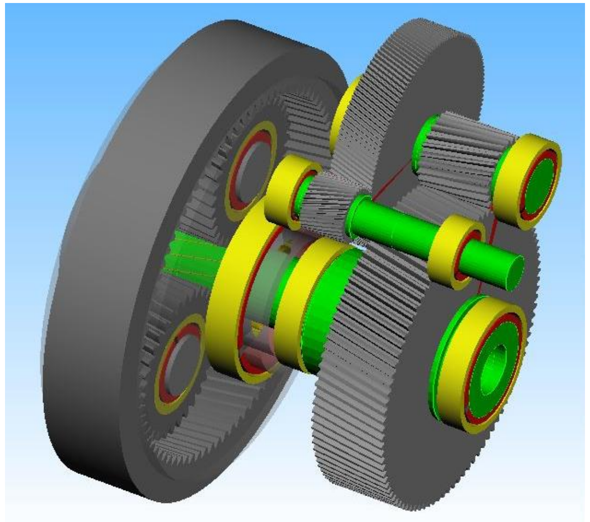
Nat. Damping
0.0199986155124326 5
0.0200000204523863 8
0.0506369683541833 3

MESH ENGINEERING TEAM

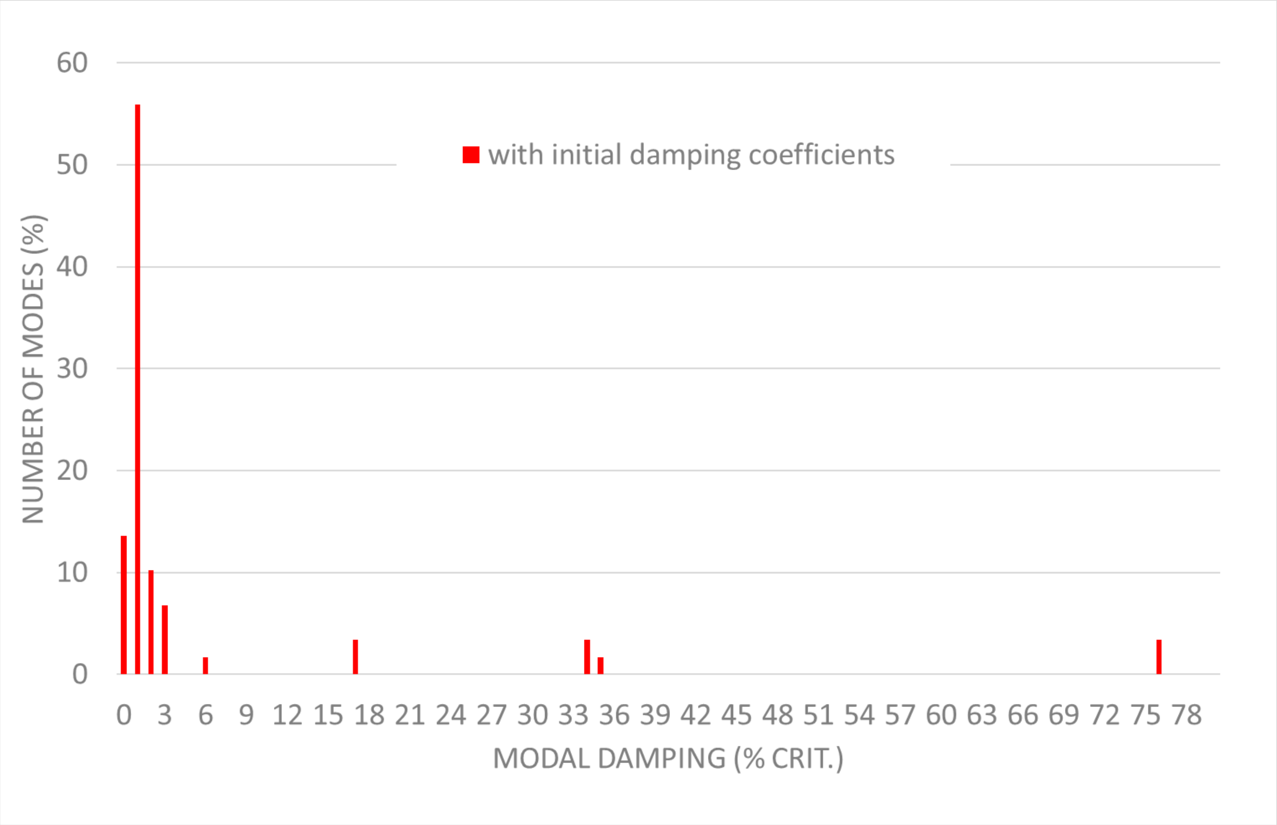
Application of DampIT: Example 3

3-Stage Gearbox of a wind turbine:

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

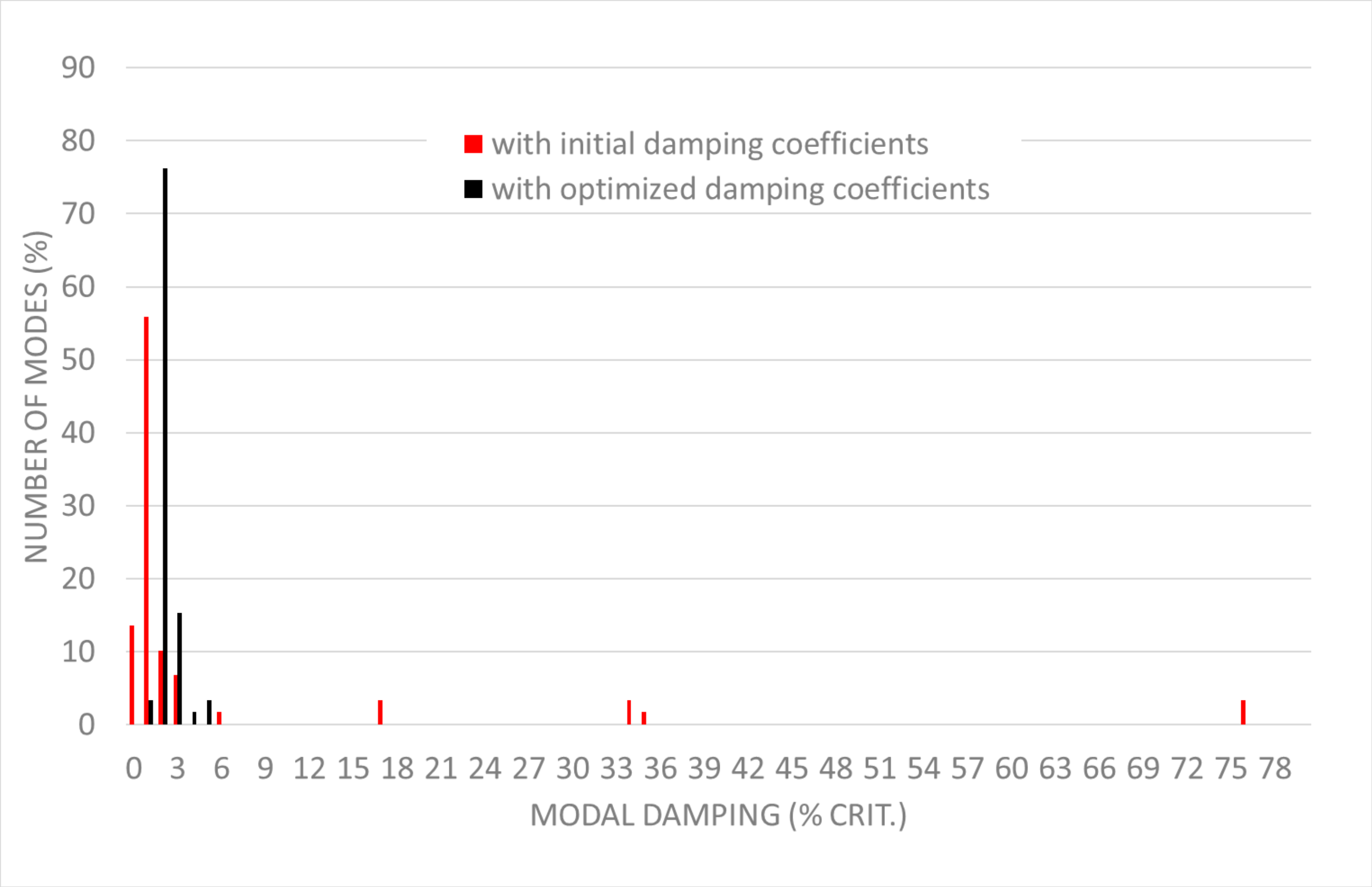


stage 1: 3 planetary gears
stage 2: 1 gear /pinion
stage 3: 1 gear/pinion



Application of DampIT: Example 3

Results:

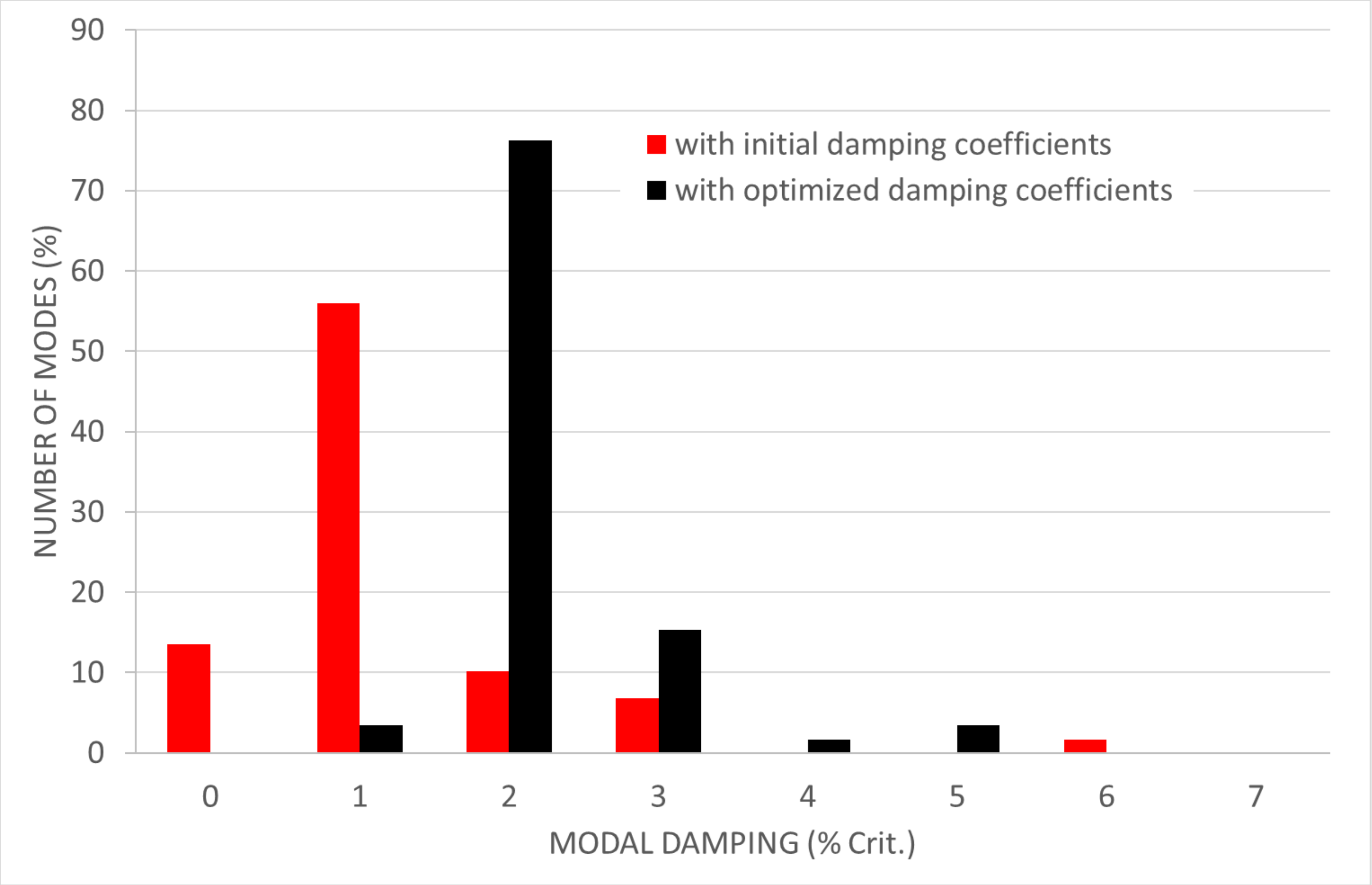


improvement of the modal damping distribution

MəsH ENGINEERING TEAM

Application of DampIT: Example 3

Results:



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

MəsH ENGINEERING TEAM

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!**