Damping Identification and Joint Modeling with Thin Layer Elements

Pfaffenwaldring 9, 3. OG

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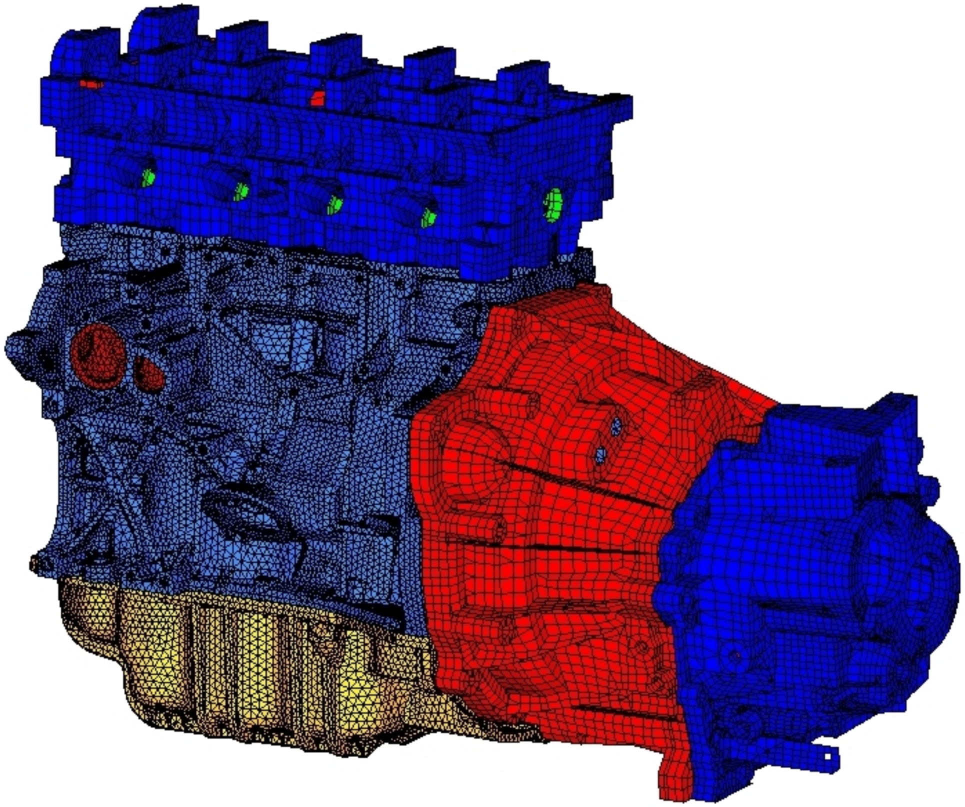
February 9-12, 2009, Orlando, Fl

Overview

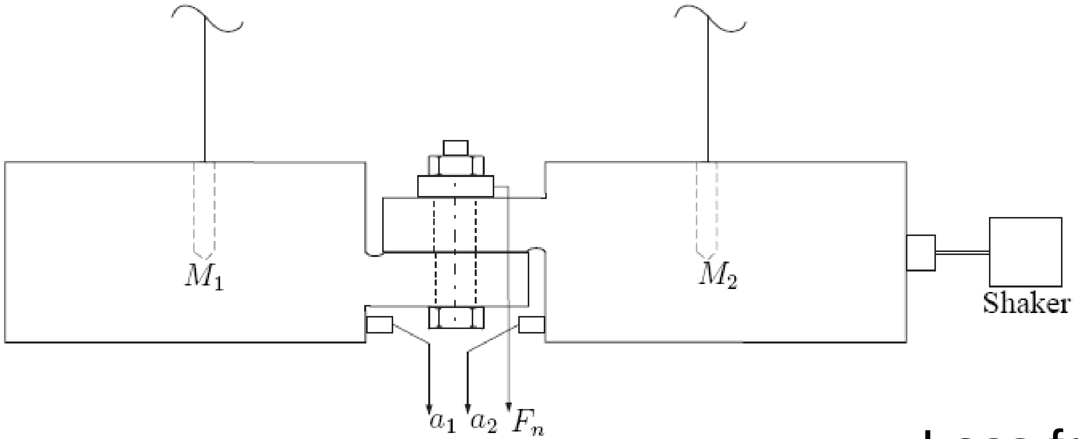
- Motivation
- Joint damping parameters
- Test structure
- FE – model description
- Comparison between FE simulation and experiment

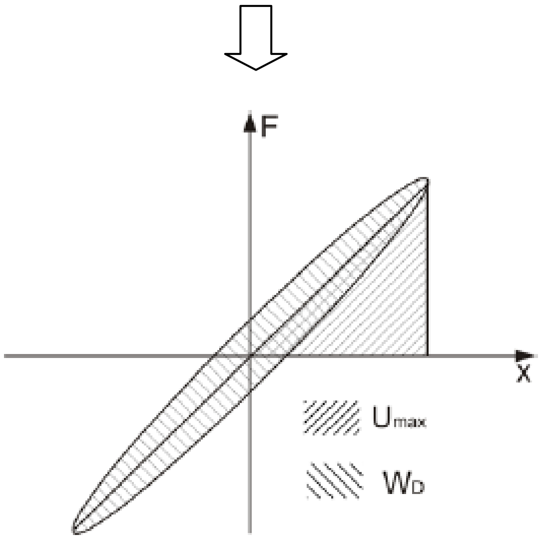
Motivation

- Prediction of damping in a structure before the prototype is available
- Estimation of a structure independent joint parameters
- Constant hysteretic damping
- Application of damping locally at the joint interface



Joint patch damping – measurement set-up





$$\Delta x = \iint a_1 dtdt - \iint a_2 dtdt$$

$$F_t = M_1 a_1$$

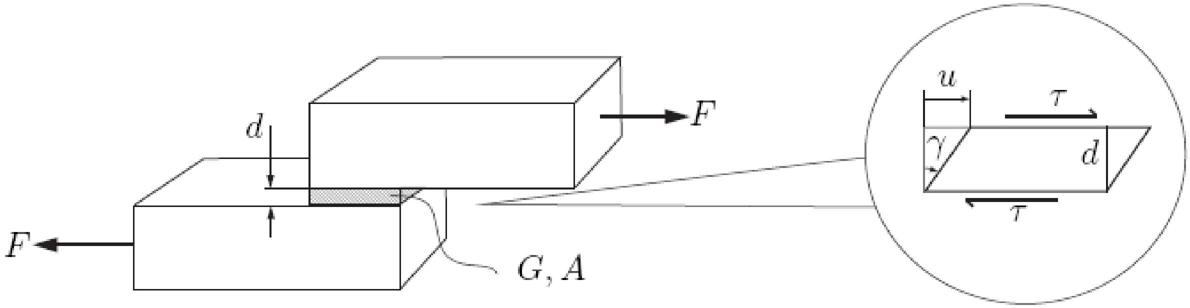
Loss factor and stiffness determination from hysteresis diagram

$$\chi = \frac{W_D}{2\pi U_{\max}}$$

$$F_t = c\Delta x$$

Stiffness of the generic joint

Calculation of shear modulus from the experiment



$$\left.\begin{aligned} \tau &= G\gamma \approx G\frac{u}{d} \\ \tau &= \frac{F}{A} \end{aligned}\right\}$$

Experimentally determined shear modulus

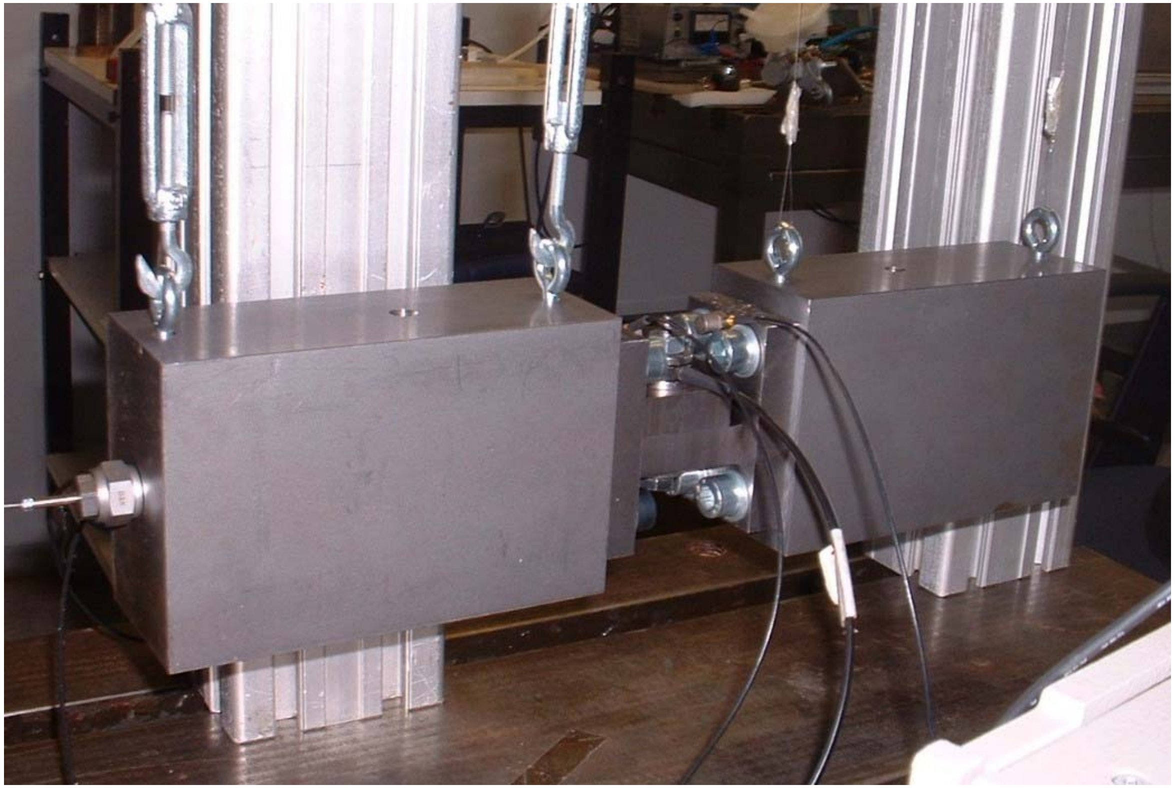
$$F \approx \frac{GA}{d} u = c u \quad \Longrightarrow \quad G = \frac{cd}{A}$$

Joint patch damping – experiment

Interchangeable patch samples

Parameter estimation at different frequencies

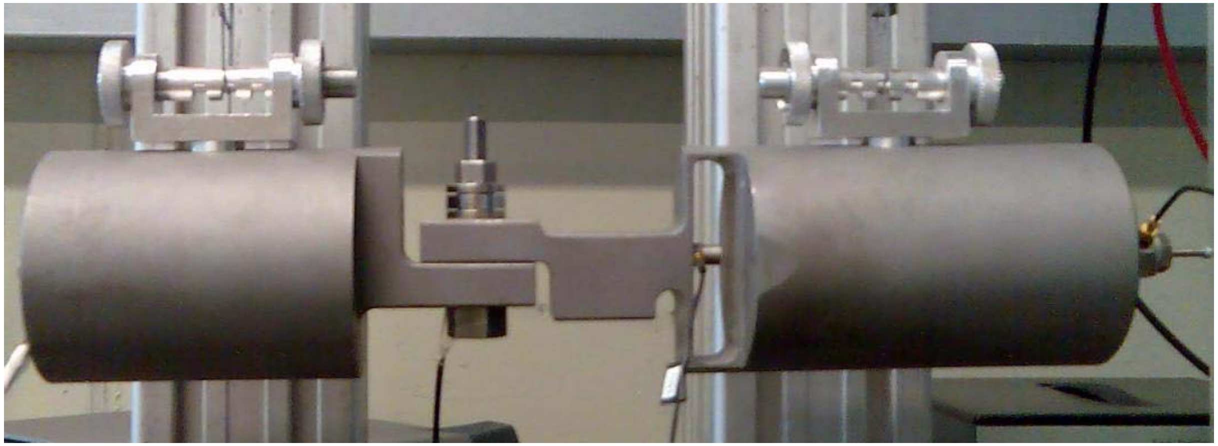
Careful alignment of the masses is necessary in order to avoid bending in the joint



Joint patch damping – experiment with a leaf spring (resonator system)

Allows to achieve good excitation in axial direction; bending in the joint is reduced

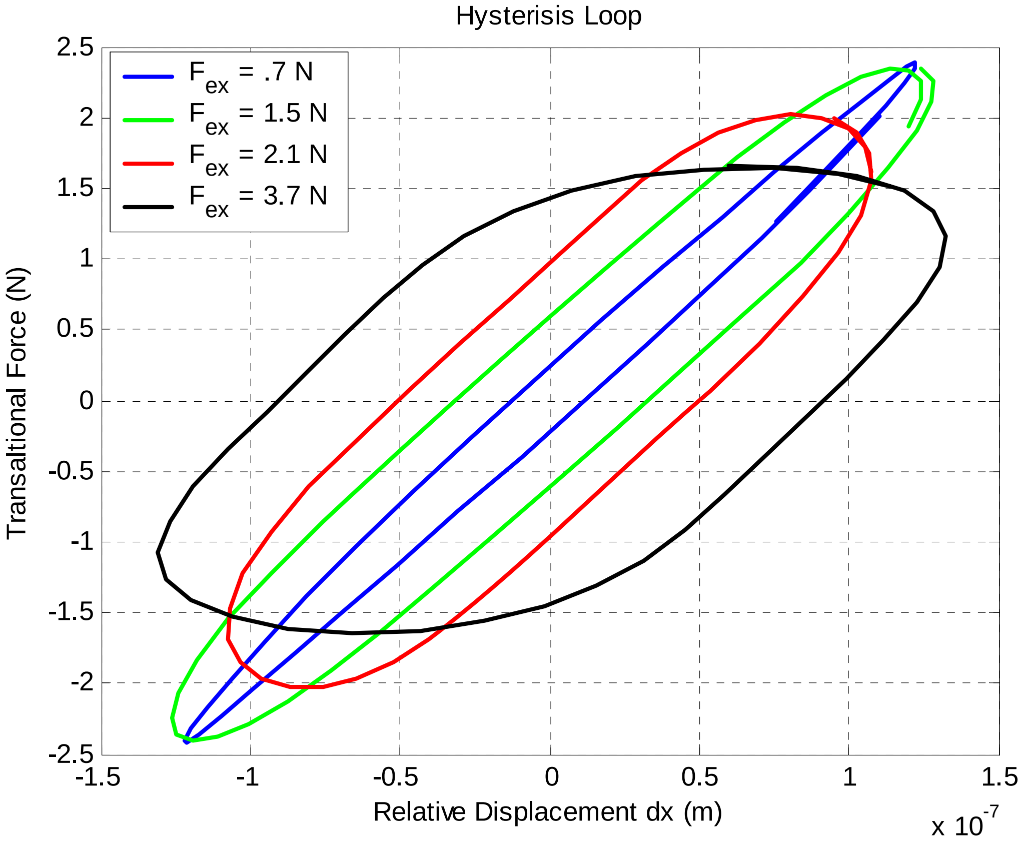
Joint parameters can be measured only for one frequency



Joint patch damping – resonator system

Measurement of the hysteresis for small contact pressure

Contact pressure – 33 N/cm^2



Macro and micro slip behavior

Varied stiffness and dissipation

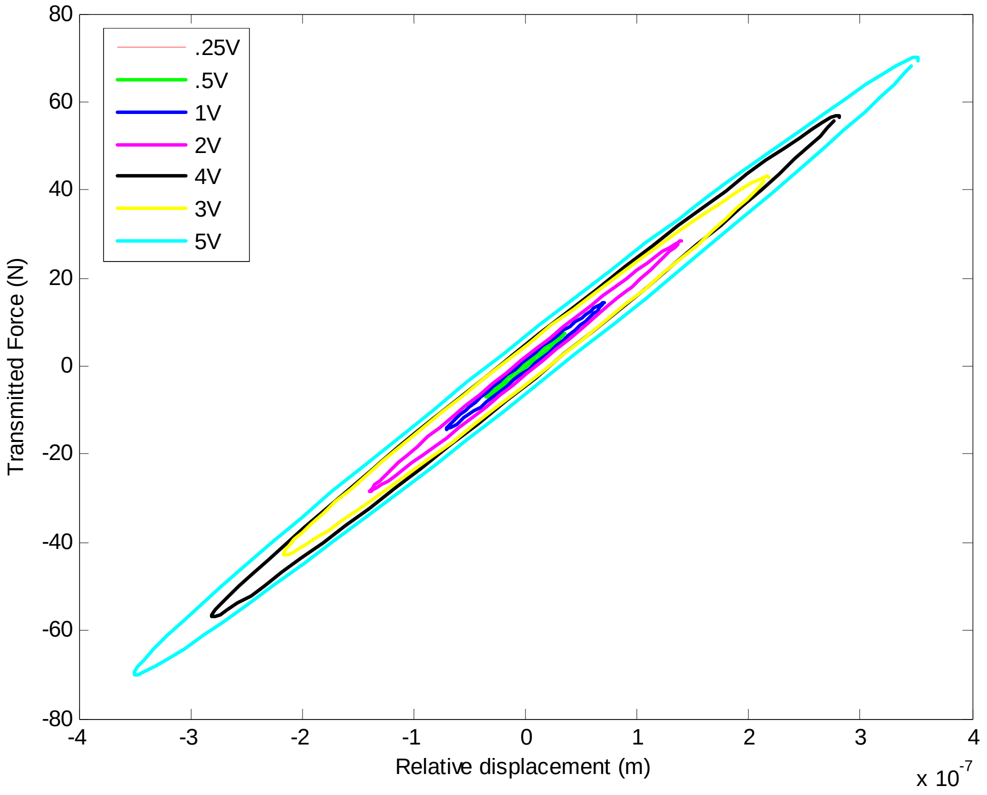
Joint patch damping

Measurement of the hysteresis for high contact pressure

Contact pressure – 1.2 kN/cm^2

No sliding occurs – only micro slip behavior

Constant stiffness and dissipation



Joint patch damping

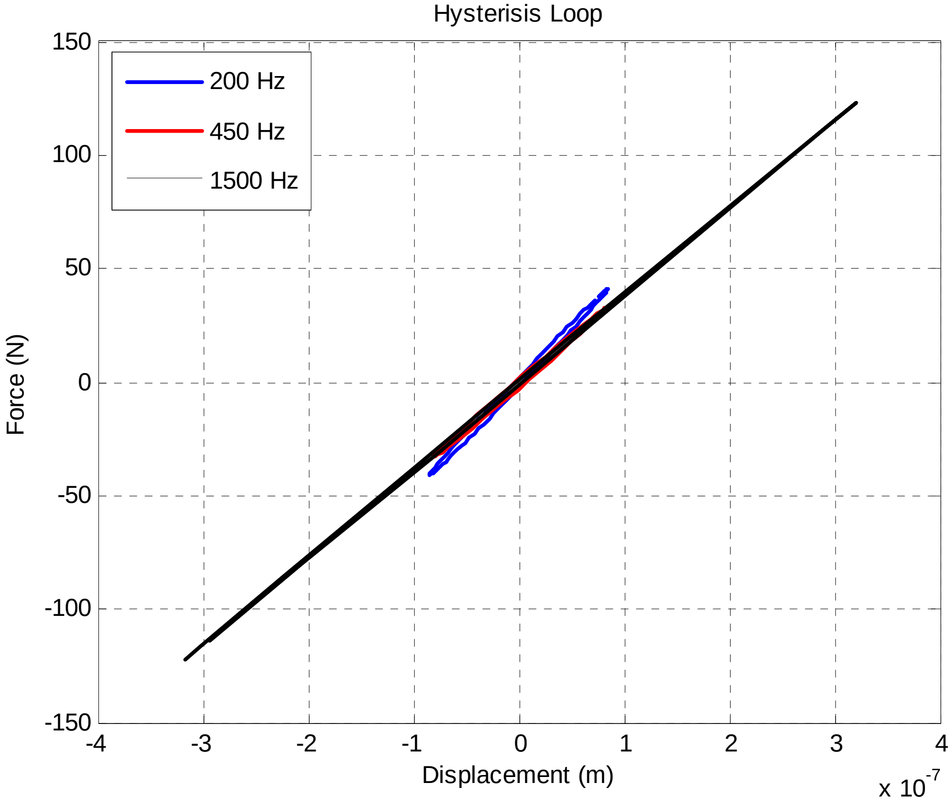
Measurement of Hysteresis at variable frequencies for high contact pressure

Contact pressure – 2 kN/cm^2

Stiffness and damping are nearly frequency independent in the measurment range

$$\chi \approx 0.06$$

$$c \approx 490\, kN / mm$$



Experimental modal analysis – test structure 1

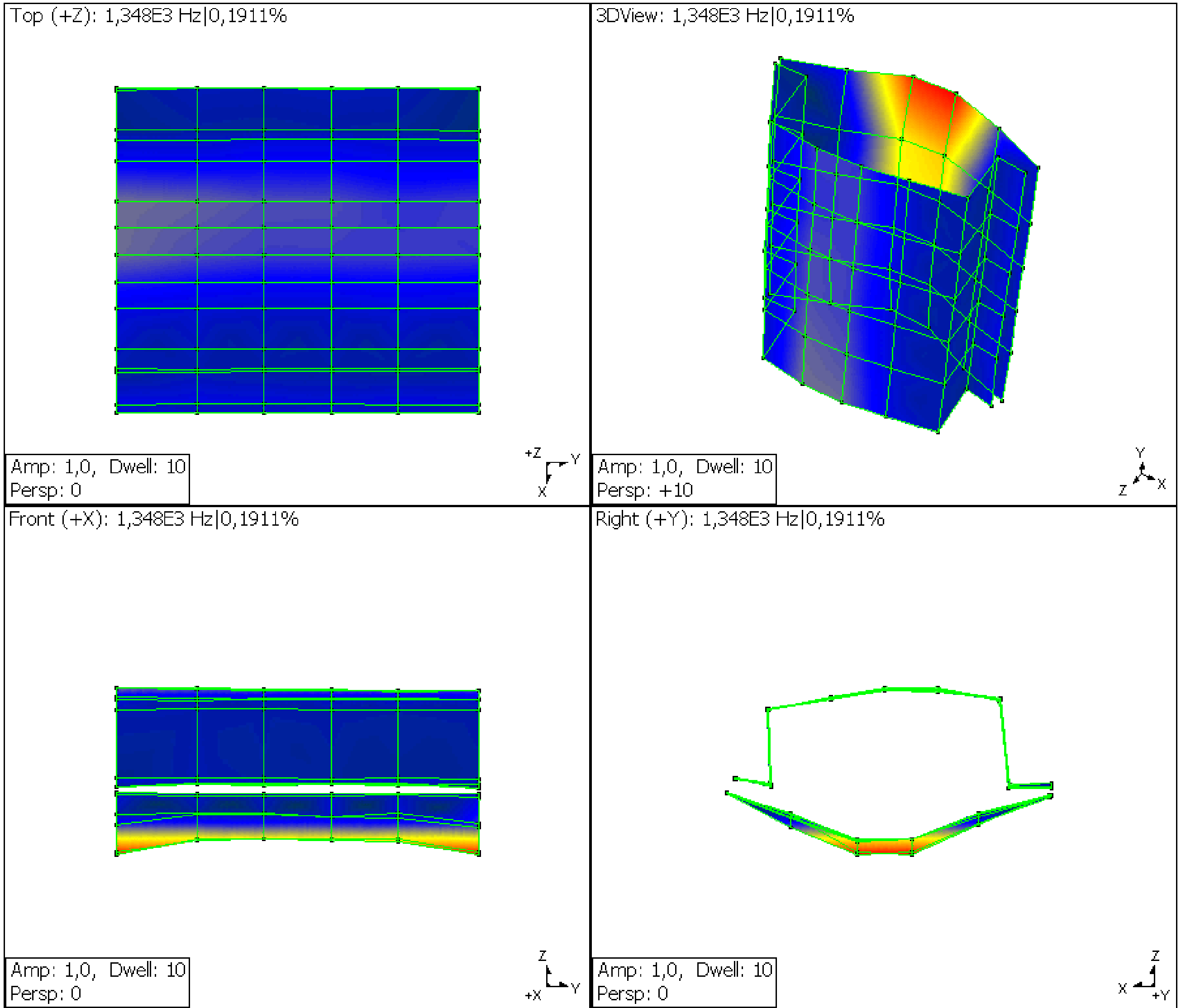
Mounting torque:
14 Nm

Roughness of the joint surface:
Rz 6.3

Boundary conditions:
free-free

Experimental modal analysis – test structure

Mode with the highest measured damping



Top (+Z): 1,348E3 Hz|0,1911%

Amp: 1,0, Dwell: 10
Persp: 0

3DView: 1,348E3 Hz|0,1911%

Amp: 1,0, Dwell: 10
Persp: +10

Front (+X): 1,348E3 Hz|0,1911%

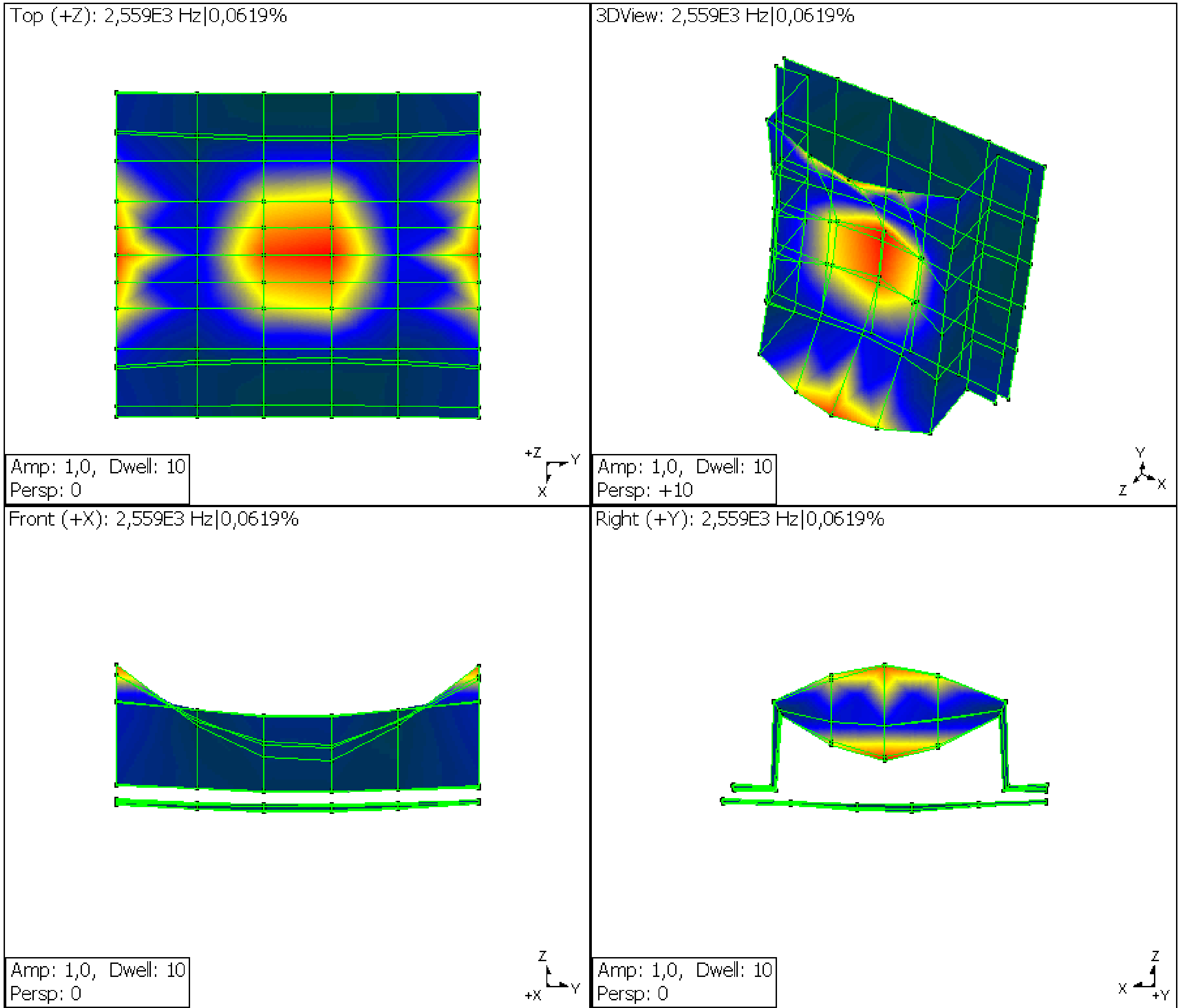
Amp: 1,0, Dwell: 10
Persp: 0

Right (+Y): 1,348E3 Hz|0,1911%

Amp: 1,0, Dwell: 10
Persp: 0

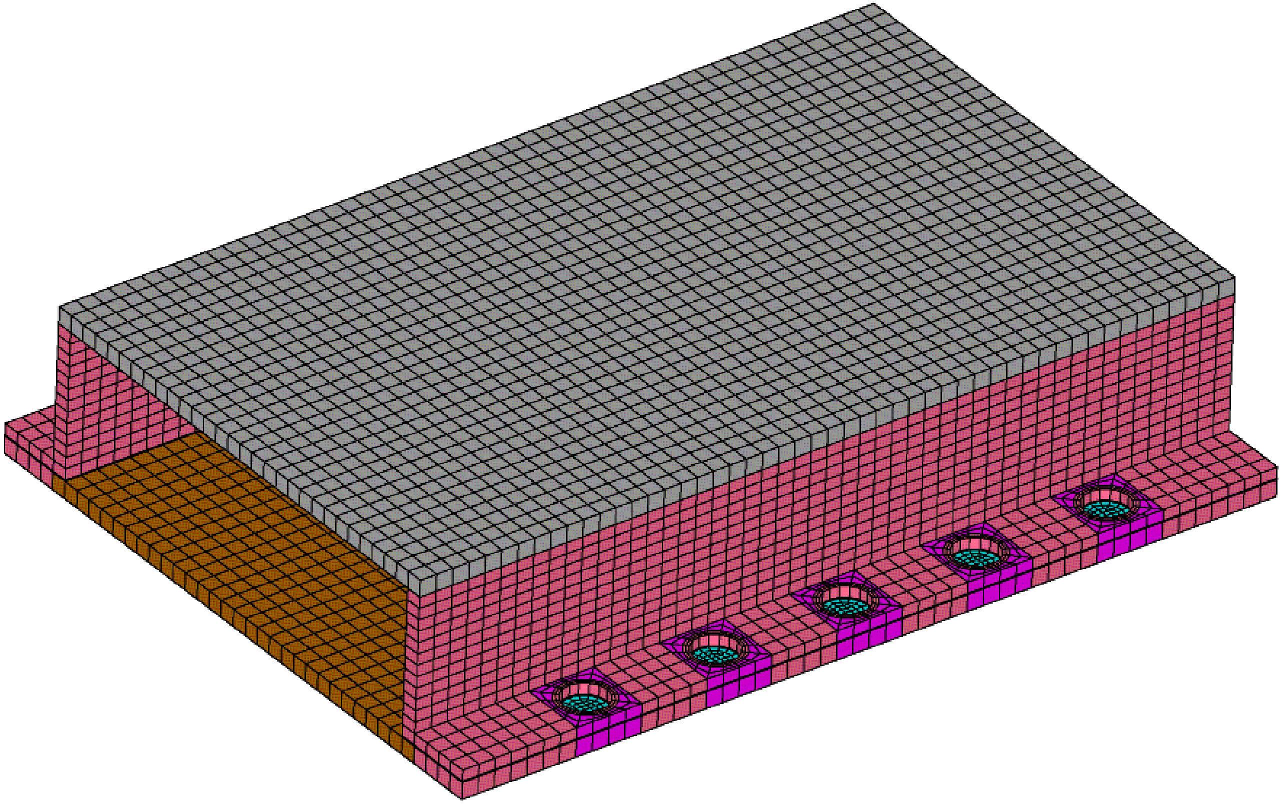
Experimental modal analysis – test structure

Mode with the lowest measured damping



Implementation of the local damping modeling in the FE-simulation

Modeling of damping with the thin layer elements



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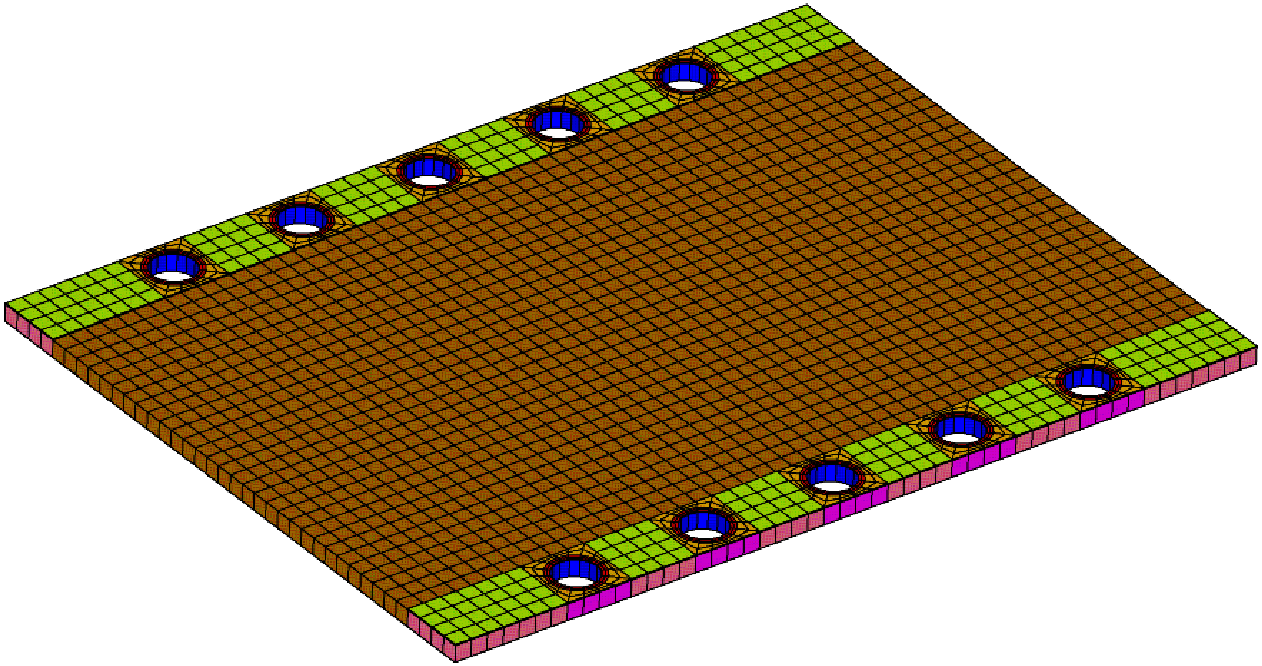
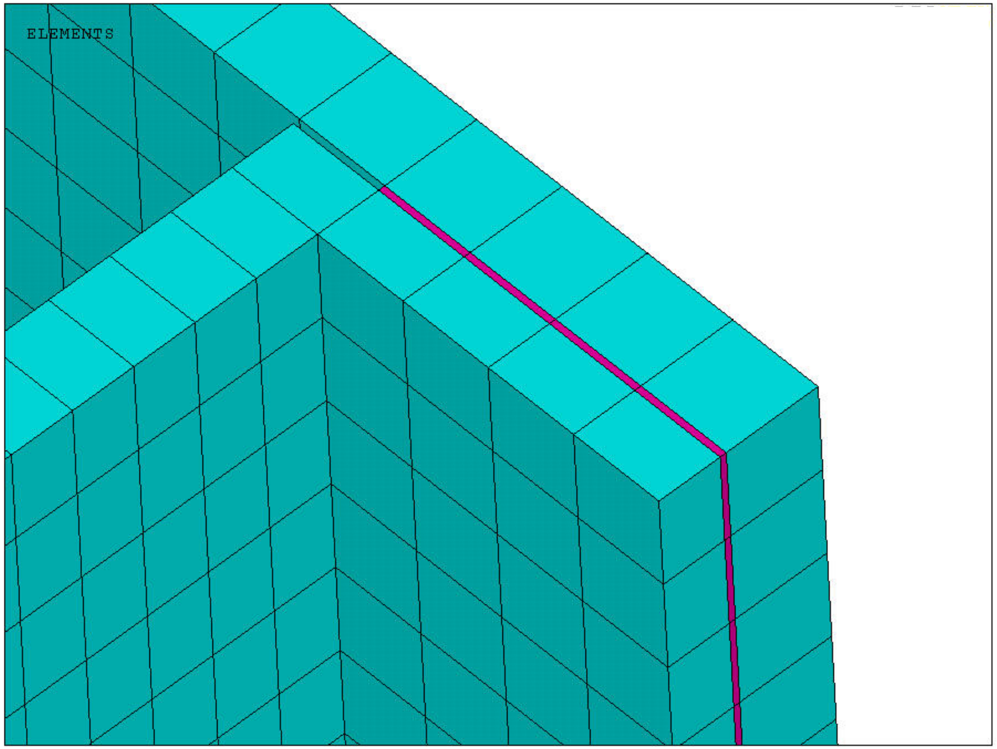
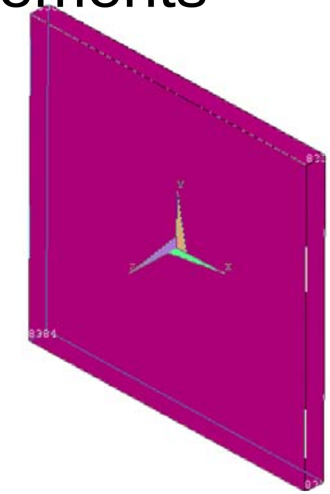
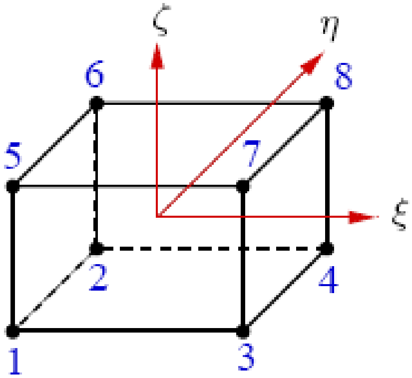


Implementation of the local damping modeling in the FE-simulation – thin layer elements







Brick or penta elements with up to 1:1000 thickness to length ratio

Implementation of the local damping modeling in the FE-simulation – orthotropic material behavior in the joint

MAT9 Solid Element Anisotropic Material Property Definition

$$\begin{bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \sigma_{zz} \\ \sigma_{xy} \\ \sigma_{yz} \\ \sigma_{zx} \end{bmatrix} = \begin{bmatrix} E_1 & E_{12} & E_{13} & 0 & 0 & 0 \\ & E_2 & E_{23} & 0 & 0 & 0 \\ & & E_3 & 0 & 0 & 0 \\ & & & E_4 & 0 & 0 \\ & & & & E_5 & 0 \\ & & & & & E_6 \end{bmatrix} \begin{bmatrix} \varepsilon_{xx} \\ \varepsilon_{yy} \\ \varepsilon_{zz} \\ \varepsilon_{xy} \\ \varepsilon_{yz} \\ \varepsilon_{zx} \end{bmatrix}$$

E_3 – Normal stiffness

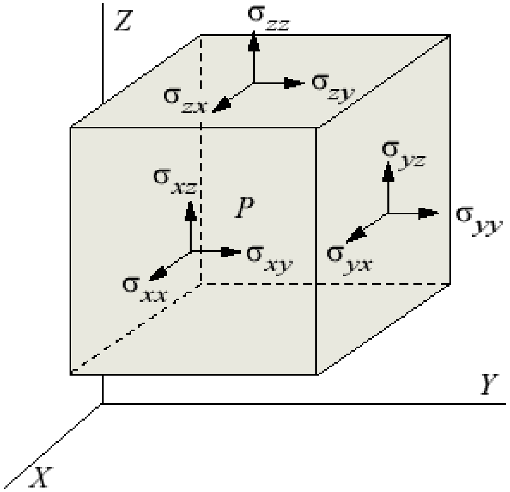
E_5, E_6 – Tangential stiffness

Other matrix elements are ignored

GE	Structural element damping coefficient. (Real)

To obtain the damping coefficient GE, multiply the critical damping ratio C/C_0, by 2.0.

MSC.Nastran 2005, Quick Reference Guide



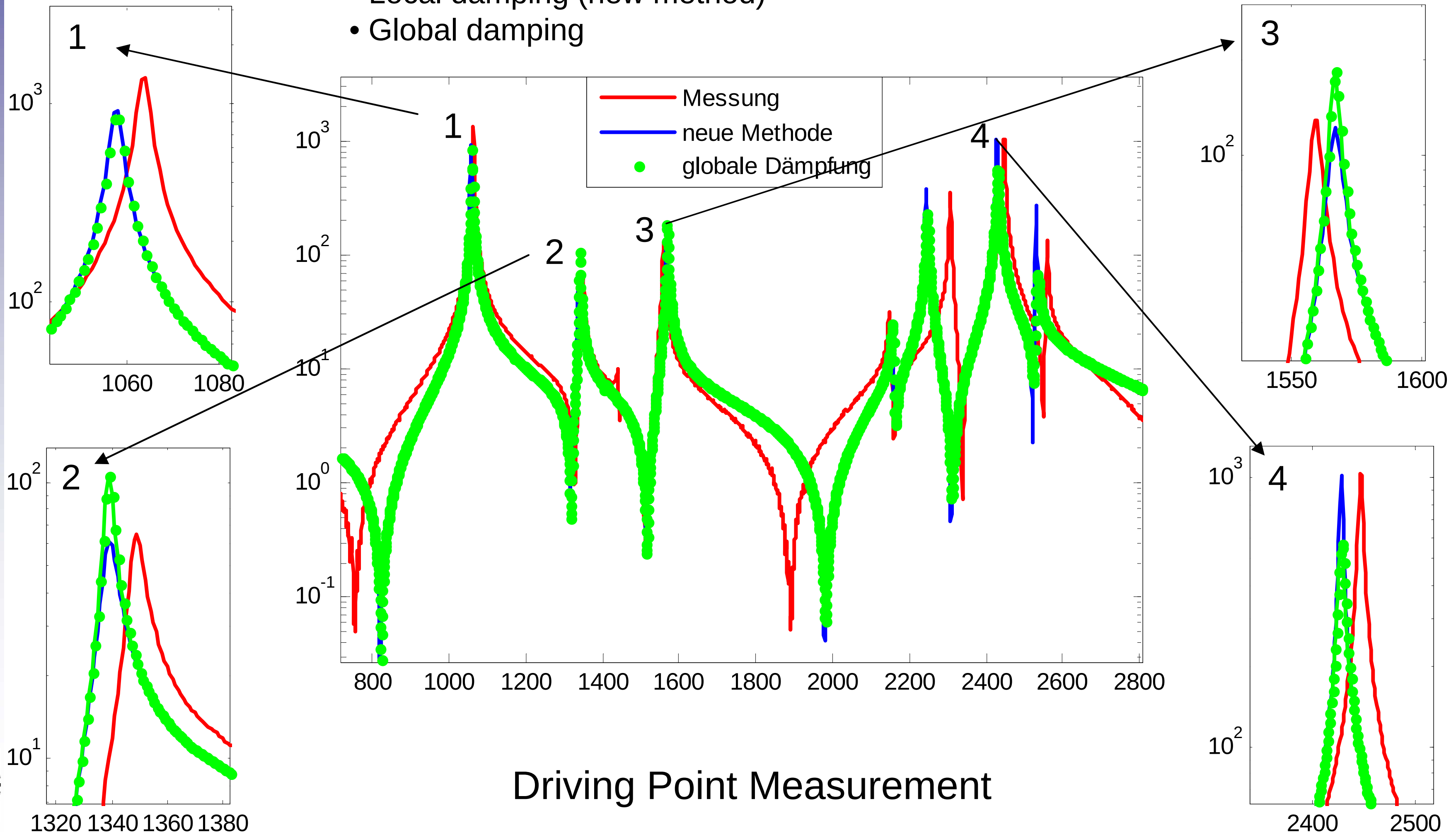
Nastran Material Parameter GE = Loss factor χ

Implementation of the local damping modeling in the FE-simulation – comparison between experiment and simulation

Mode Nr	Experimental Freq (Hz)	Simulated Freq (Hz)	Difference (%)	Experimental Damping (%)	Simulated Damping (%)	Difference (%)
1	1063	1057	-0,5	0,110	0,107	-2,5
2	1348	1339	-0,7	0,191	0,204	6,9
3	1441	1406	-2,4	0,107	0,114	7,1
4	1558	1567	0,6	0,147	0,178	21,6
5	2149	2155	0,3	0,143	0,179	25,1
6	2307	2244	-2,7	0,077	0,072	-6,1
7	2447	2428	-0,8	0,086	0,065	-24,9
8	2559	2531	-1,1	0,062	0,026	-58,0
9	3372	3363	-0,3	0,116	0,110	-5,3
10	3713	3742	0,8	0,076	0,009	-87,7

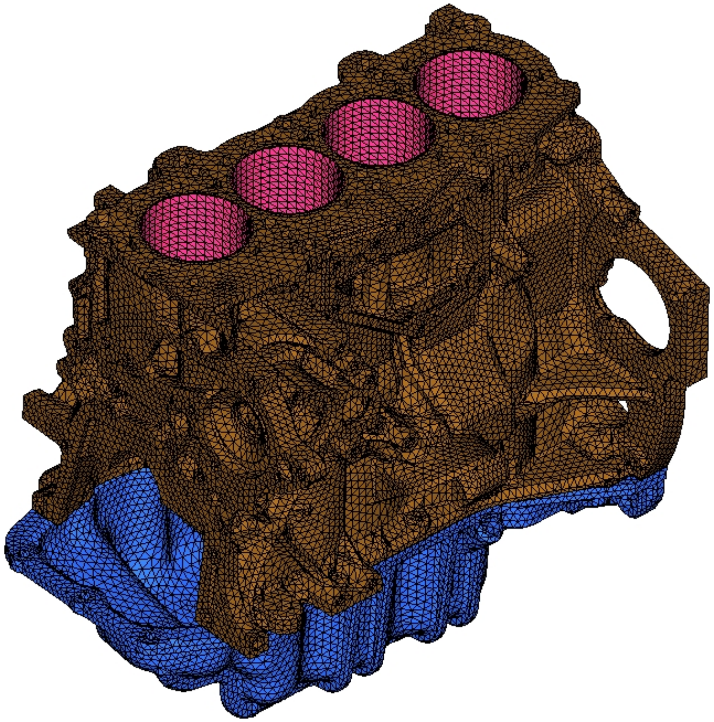
Implementation of the local damping modeling in the FE-simulation – comparison between experiment and simulation

- Measurement
- Local damping (new method)
- Global damping



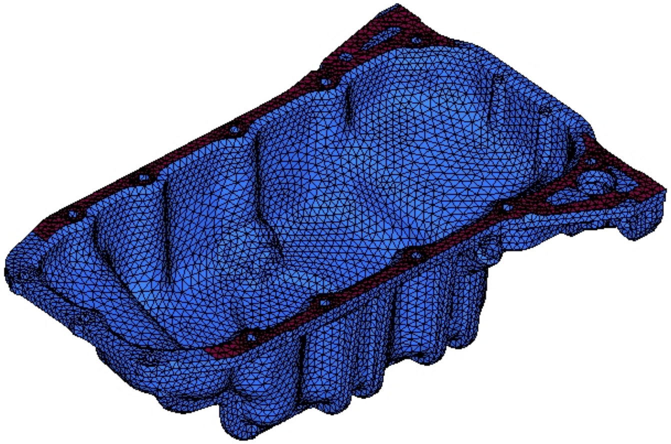
Driving Point Measurement

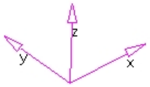
Simulation of Cylinder Block with Oilpan



Cylinder Block – Oilpan

Meshing of the contact surfaces with conformed FE-Mesh

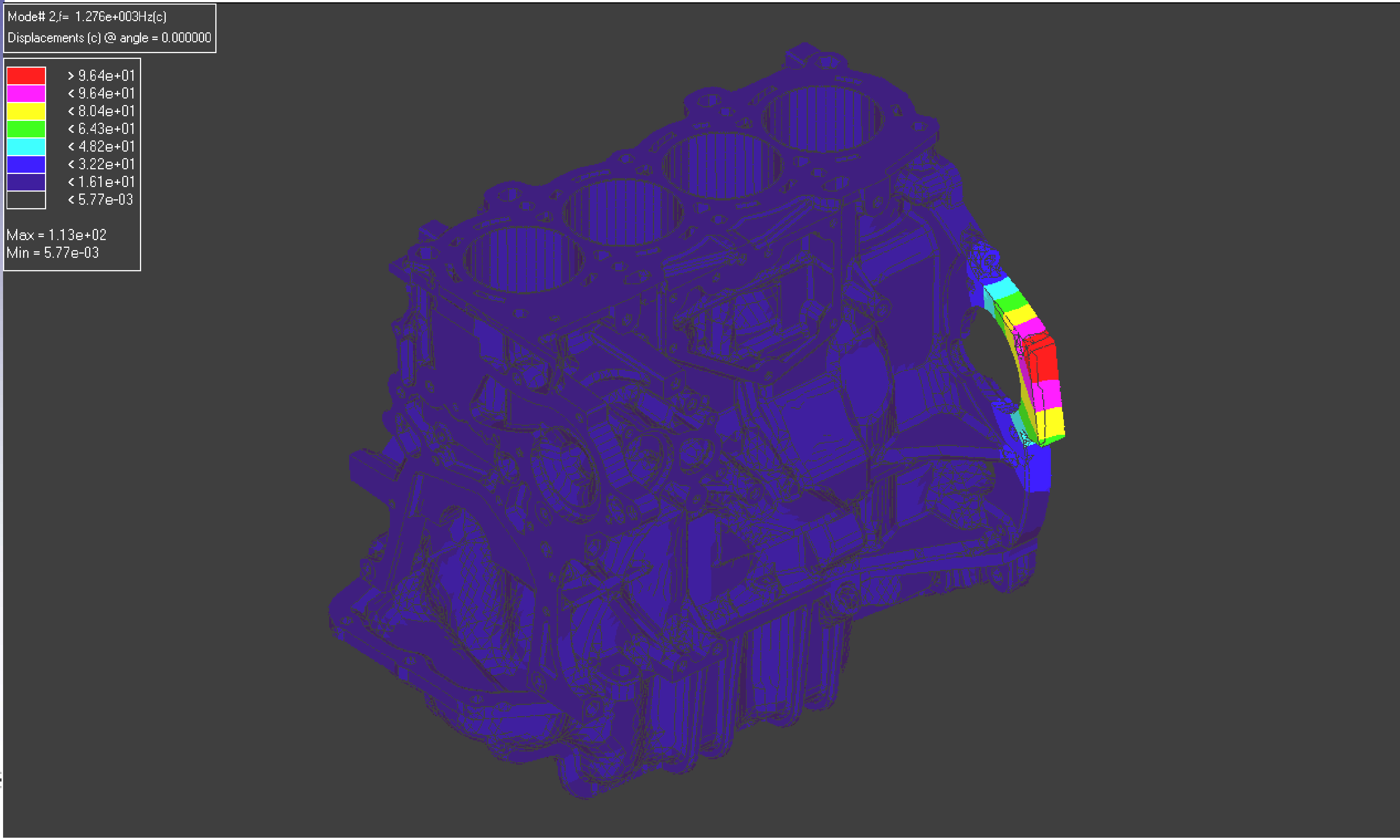




Implementation of the local damping modeling in the FE-simulation – comparison between experiment and simulation

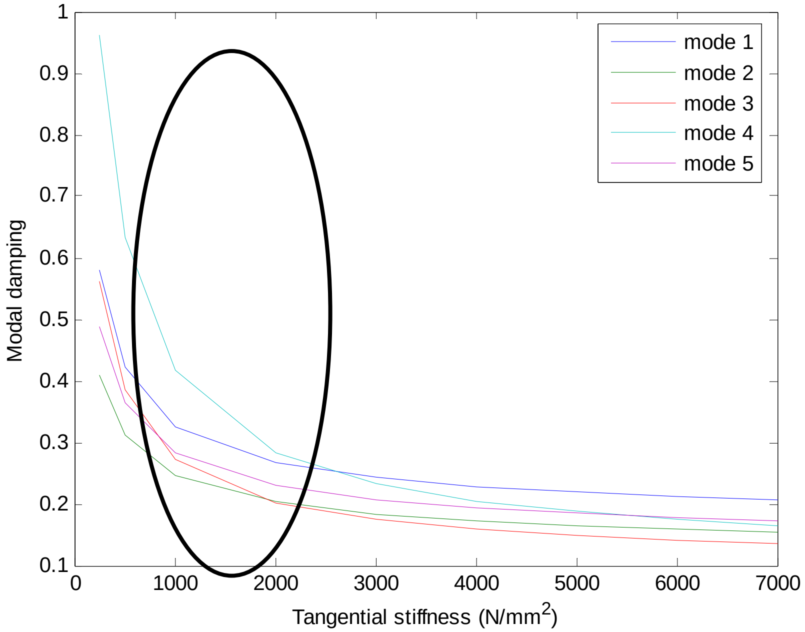
Mode Nr	Experimental Freq (Hz)	Simulated Freq (Hz)	Difference (%)	Experimental Damping (%)	Simulated Damping (%)	Difference (%)
1	1011	1008	-0,29	0,157	0,152	-3,2
2	1287	1317	**2,34**	0,214	0,117	-45,4
3	1305	1276	**-2,26**	0,049	0,060	22,1
4	1399	1403	0,25	0,143	0,130	-9,0
5	1558	1574	1,02	0,197	0,068	**-65,4**
6	1667	1674	0,45	0,191	0,099	-48,3
7	1849	1859	0,56	0,258	0,110	**-57,3**
8	1874	1900	1,38	0,196	0,083	**-57,8**
9	1910	1953	**2,26**	0,116	0,063	-45,5
10	1998	2059	**3,09**	0,174	0,125	-27,8
11	2052	2058	0,33	0,094	0,096	1,3
12	2226	2211	-0,65	0,096	0,126	30,3
13	2320	2300	-0,89	0,200	0,169	-15,5
14	2389	2415	1,08	0,198	0,127	-36,1
15	2493	2476	-0,67	0,128	0,091	-28,8

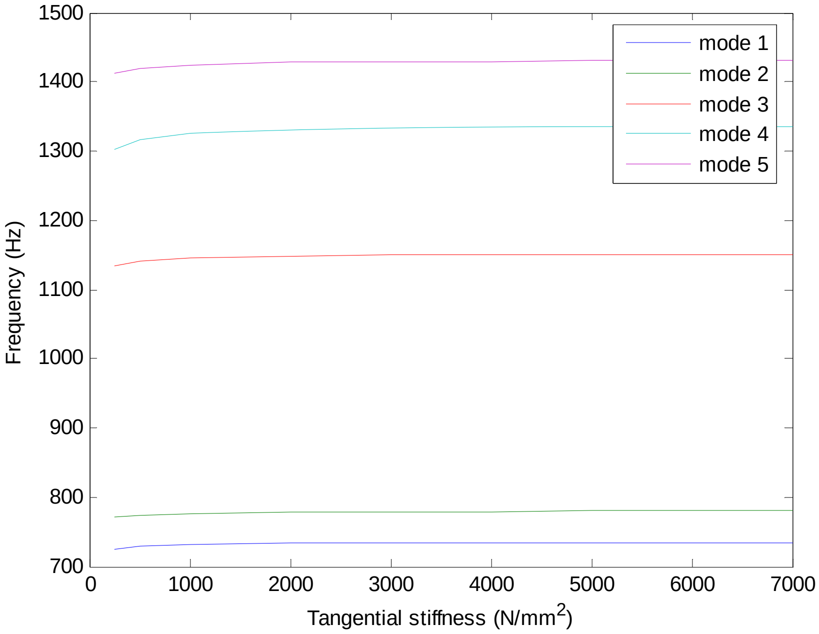
Simulation of Cylinder Block with Oilpan



Sensitivity analysis

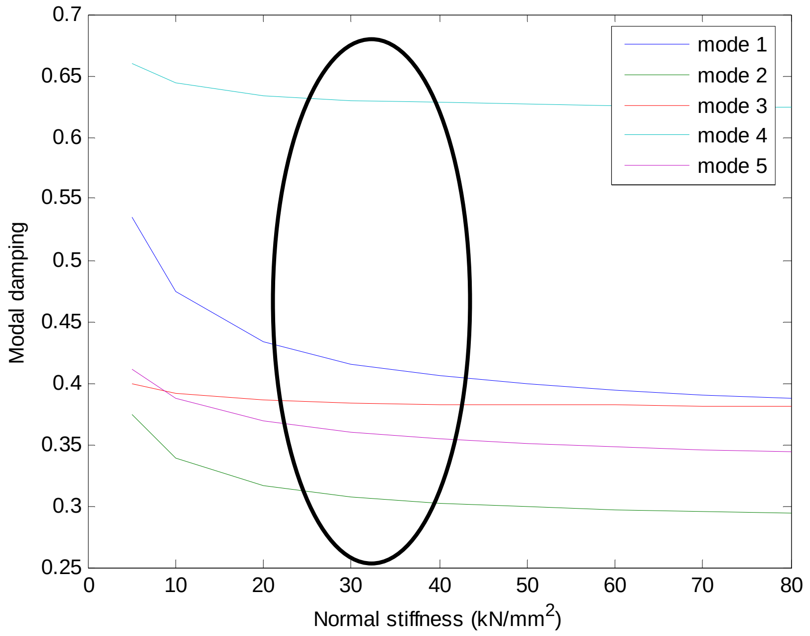
Sensitivity of the damping and eigenfrequencies due to the changes in the tangential stiffness of the thin layer elements

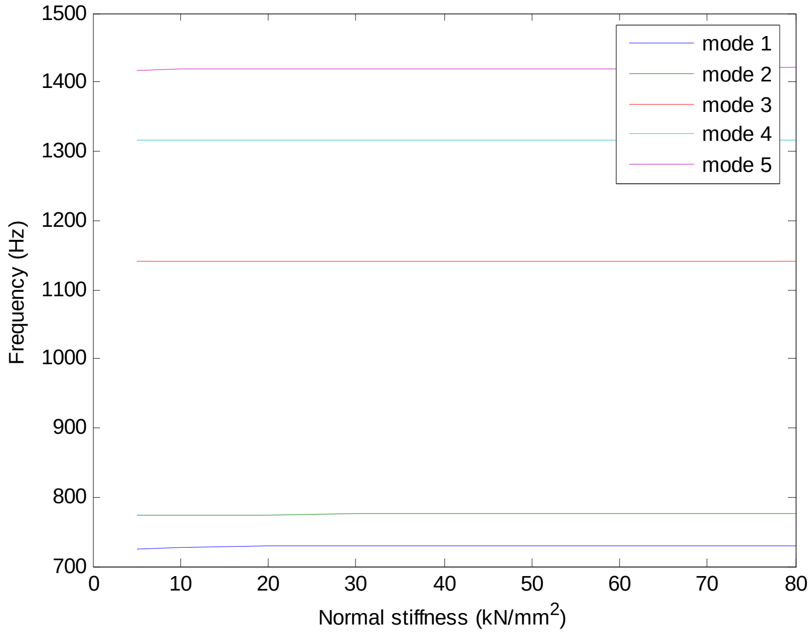




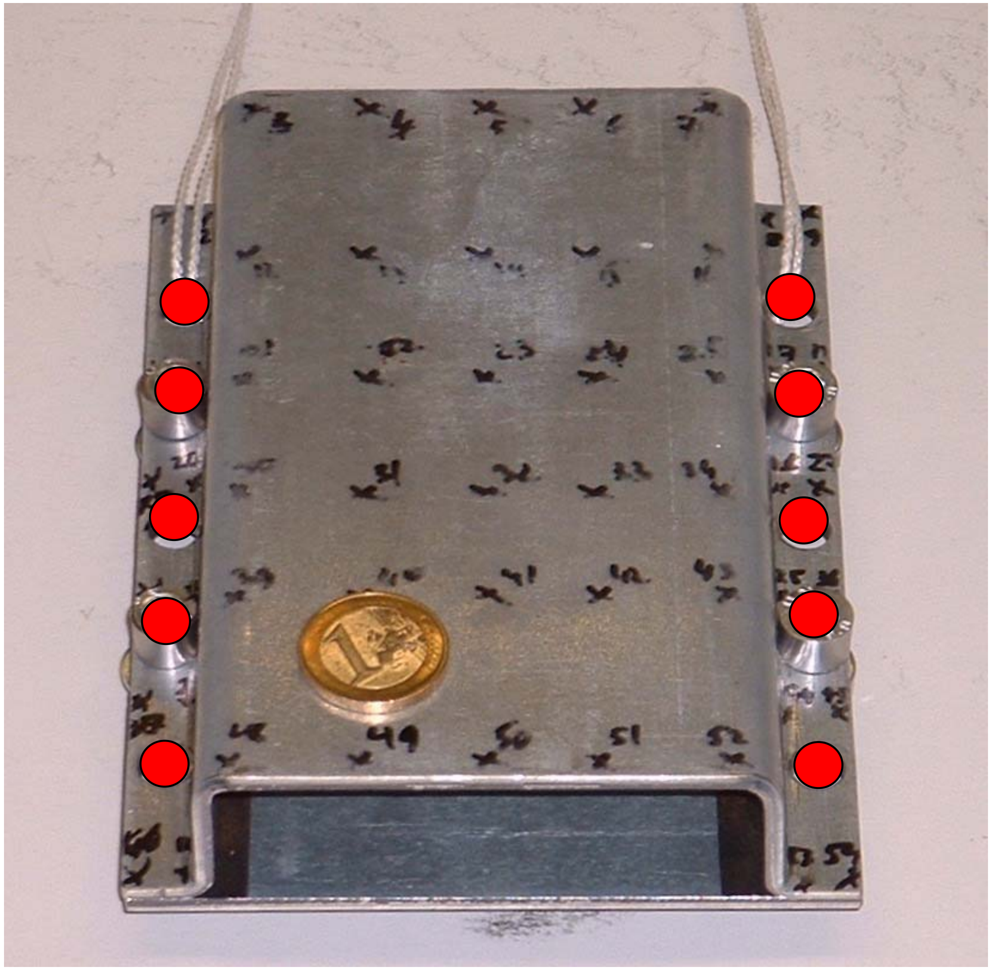
Sensitivity analysis

Sensitivity of the damping and eigenfrequencies due to the changes in the normal stiffness of the thin layer elements





Experimental Modal Analysis of the structure with variable number of bolts



Three measurements

10 bolts

6 bolts

4 bolts

Experimental Modal Analysis of the structure with variable number of bolts

Bolts #	10		6			4		
Mode Nr.	Freq (Hz)	Damping (%)	Freq (Hz)	Damping (%)	Difference (% Damping)	Freq (Hz)	Damping (%)	Difference (% Damping)
1	1063	0,1099	1060	0,127	16	1030	0,219	99
2	1348	0,1911	1320	0,266	39	1100	1,69	784
3	1441	0,1066	1430	0,147	38	1260	0,691	548
4	1558	0,1466	1520	0,189	29	1380	0,167	14
5	2149	0,1428	2100	0,17	19	1800	1,53	971
6	2307	0,0766	2320	0,0966	26	2280	0,341	345
7	2447	0,0863	2450	0,0974	13	2410	0,138	60
8	2559	0,0619	2550	0,0653	5	2550	0,161	160
9	3372	0,1162	3300	0,137	18	2680	0,644	454

Conclusions

- ➢ Joint patch damping shows only small frequency dependence, which allows the use of the constant hysteresis method
- ➢ FE-simulation with the thin layer elements containing orthotropic material properties shows good correlation with experimental results
- ➢ Method works for the joints with regularly distributed contact pressure; objective classification of the pressure distribution in the joints and applicability of the method should be investigated