

EXPERIMENTAL RESEARCH ON VIBRATION DAMPERS EFFICIENCY

J. Ondrouch and A. Bilošová

Department of Mechanics
Technical University of Ostrava, Czech Republic

Abstract: A research on vibration dampers efficiency, which was carried out at the Department of Mechanics of the Technical University of Ostrava is described in this paper. A cantilever beam was used as a test specimen. Its frequency response functions at the reference point were measured and natural frequencies, damping ratios and accelerances were evaluated on the test specimen without damper and with three types of dampers. The efficiency of vibration reduction of particular dampers was evaluated.

Keywords: vibration, damper, efficiency

1 INTRODUCTION

The aim of the research on vibration dampers efficiency was to find out, which kind of damper and which damping material is the most effective in vibration reduction. A cantilever beam was used as a test specimen. Three types of dampers are discussed in this paper:

- plates of a shape geometrically similar to the cantilever beam, which were attached crosswise to the cantilever's free end
- plates of the same length and width as the cantilever's ones mounted lengthwise
- cylindrical rubber dampers

The research was carried out in order to get more knowledge about damping and damping measurements, because for several years, research on railway wheel dampers have been performed at the Department of Mechanics.

2 MEASUREMENT CONDITIONS AND EQUIPMENT USED

The measurement set-up is shown at Figure 1. A steel cantilever beam with the dimensions of 20mm × 100 mm × 400 mm was used as a test specimen. Experimental modal analysis of the test specimen without damper was performed in order to find out modal frequencies and corresponding modal shapes. The first two bending modes were used for further evaluation. The test specimen was excited with the help of dynamic exciter using random noise signal. The reference point (point of both excitation and placement of accelerometer) was on the free end of the cantilever on its axis of symmetry in order not to excite the torsion mode.

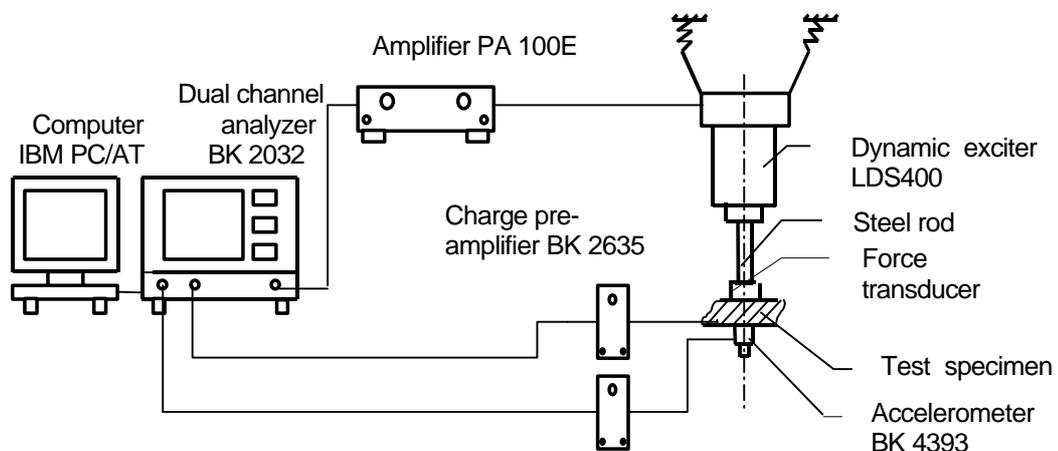


Figure 1. Measurement scheme

3 EVALUATION OF MEASUREMENTS

In each case (test specimen without damper and with dampers), two frequency response functions at the reference point were measured - FRF in the frequency band 0-200 Hz, in which the first bending mode occurred, and FRF in the frequency band 400-800 Hz, in which the second bending mode occurred. Natural frequencies, damping ratios and accelerances were evaluated from the FRFs. FRFs measured on the test specimen without damper are shown at Figure 2 and the corresponding values are listed in Table 1.

Table 1. Measured values - test specimen without damper

Test specimen	freq #	freq [Hz]	b_r [-]	acc [kg^{-1}]
without damper	1	92.14	0.0120	24.40
	2	572.54	0.0044	53.01

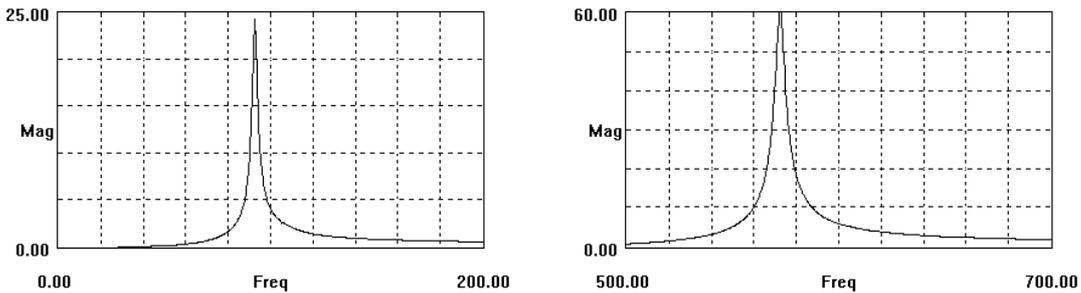


Figure 2. Frequency response functions - test specimen without damper

3.1 Test specimen with plate crosswise dampers

Steel plates with the dimensions geometrically similar to the test specimen, some of them equipped with a damping layer, were mounted in their middle using tie-plates to the free end of the test specimen, so that they created a pair of cantilever beams. Five types of those dampers were used:

- damper #0 - single steel plate of the thickness 2mm
- damper #1 - steel plate with 1mm thick plastic layer
- damper #2 - steel plate with 2 mm thick plastic layer
- damper #3 - steel plate with 2mm thick plastic layer and with metal grid layer
- damper #4 - two steel plates with 2mm plastic layer between them

The dampers were tuned to the first bending frequency of the test specimen either by changing their length or by adding distributed masses on their ends. Frequency response functions measured on the test specimen with the best damper (damper #3) are shown at Figure 3.

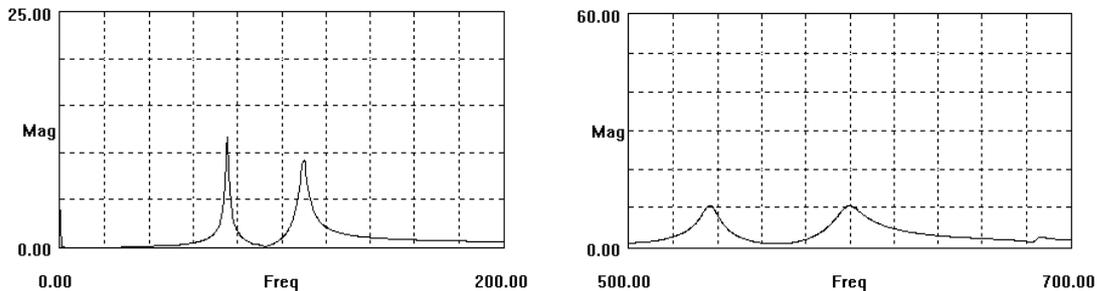


Figure 3. Frequency response functions - test specimen with damper #3

The following criteria were taken into account for evaluation of dampers efficiency:

- decrease of the accelerance in the vicinity of the first and the second natural frequencies in the comparison to the test specimen without damper
- the width of the frequency band, in which the accelerance decreases to the 10% of the value without damper
- the damping ratio value

Both the first and the second natural frequency split into two frequency peaks, which are numbered 1a and 1b (the first natural frequency) and 2a and 2b (the second natural frequency) in the Table 2. Measured values together with the evaluation of dampers efficiency for the test specimen with plate dampers are stated in the Table 2.

Table 2. Measured values and evaluation of dampers efficiency - plate crosswise dampers

Test specimen	freq #	freq [Hz]	b_r [-]	acc [kg^{-1}]	decrease of acc to [%]	freq band [Hz]
damper #0	1a	83.78	0.0118	13.63	56	12
	1b	105.29	0.0081	13.65	56	
	2a	553.15	0.0041	37.23	70	51
	2b	627.61	0.0020	30.66	58	
damper #1	1a	82.54	0.0082	17.70	73	9
	1b	102.55	0.0098	14.90	61	
	2a	549.87	0.0043	30.50	58	42
	2b	611.59	0.0032	27.20	51	
damper #2	1a	80.05	0.0076	14.06	58	11
	1b	99.75	0.0135	13.80	57	
	2a	531.67	0.0050	10.73	20	38
	2b	587.86	0.0042	38.00	72	
damper #3	1a	75.18	0.0098	11.83	48	22
	1b	109.35	0.0172	9.33	38	
	2a	536.56	0.0082	11.01	21	45
	2b	598.43	0.0126	11.02	21	
damper #4	1a	69.33	0.0121	7.26	30	32
	1b	112.22	0.0172	9.84	40	
	2a	562.98	0.0044	38.50	73	44
	2b	591.02	0.0032	16.67	31	

3.2 Test specimen with plate lengthwise dampers

Steel plates with two dimensions equal to the dimensions of the cantilever test specimen, equipped with damping layers, were used as dampers. This type of damper was mounted to the top surface of the test specimen, so that it was forced to deflect together with the cantilever and worked on the base of energy dissipation. Three different damping layers were used:

- damper #5 - plastic and metal grid layer oriented oblique to the longitudinal axis
- damper #6 - plastic and metal grid layer oriented parallel with the longitudinal axis
- damper #7 - plastic layer

Frequency response functions measured on the damper #6 are shown at Figure 4.

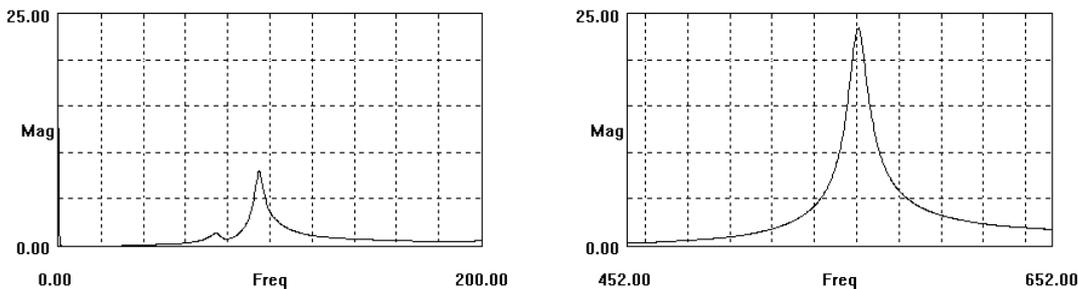


Figure 4. Frequency response functions - test specimen with damper #6

With this type of damper, the frequency peaks didn't split, so that only two evaluating criteria of dampers efficiency were taken into account:

- decrease of the accelerance in the vicinity of the first and the second natural frequencies in the comparison to the test specimen without damper
- the damping ratio value

Table 3. Measured values and evaluation of dampers efficiency - plate lengthwise dampers

Test specimen	freq #	freq [Hz]	b_r [-]	acc [kg^{-1}]	decrease of acc to [%]
damper #5	1	86.49	0.0136	16.36	67
	2	540.00	0.0101	18.79	35
damper #6	1	94.43	0.0259	8.22	34
	2	560.30	0.0080	23.57	44
damper #7	1	85.25	0.0131	16.10	66
	2	524.88	0.0067	31.18	59

3.2 Test specimen with cylindrical rubber dampers

This type of damper was designed as a one degree of freedom damper. It was realized with the help of rubber cylindrical spring. Two different dimensions of the cylindrical spring were used:

damper #8 - diameter 18mm, height 20 mm

damper #9 - diameter 25 mm, height 20mm

The dampers were tuned to the first natural frequency of the test specimen with the help of masses attached to them. To reduce vibrations of the test specimen, each time two equal dampers were used, placed on the edges of the cantilever on its free end. Frequency response functions measured on the test specimen with the damper #9 are shown at Figure 5.

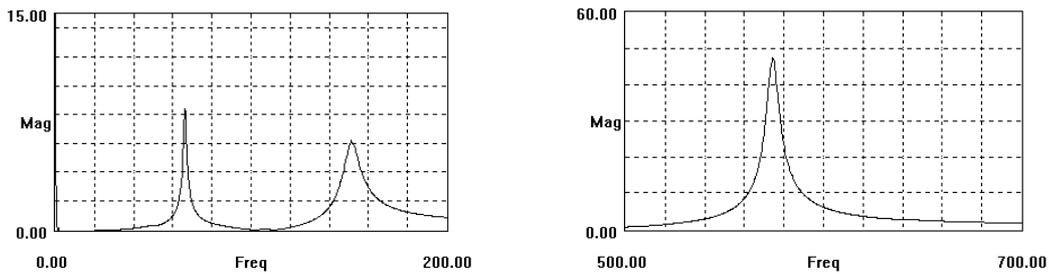


Figure 5. Frequency response functions - test specimen with damper #9

With this type of damper, only the first natural frequency peak split into two frequency peaks, the second natural frequency wasn't almost influenced with the presence of dampers. The same evaluation criteria as with the plate crosswise dampers were used for the evaluation of dampers efficiency, even if the second one (the width of the frequency band, in which the acceleration decreases to the 10% of the value without damper) was applied only for the first natural frequency. Measured values together with the evaluation of dampers efficiency for the test specimen with rubber dampers are stated in the Table 4. Measured values for the test specimen without damper are listed in this table, too, because repeated mounting of the test specimen was done, which slightly influenced the measured values.

Table 4. Measured values and evaluation of dampers efficiency - cylindrical rubber dampers

Test specimen	freq #	freq [Hz]	b_r [-]	acc [kg^{-1}]	decrease of acc to [%]	freq band [Hz]
without damper	1	92.32	0.0097	29.46		
	2	572.67	0.0044	56.41		
damper #8	1a	71.45	0.0146	7.30	25	42
	1b	123.62	0.0268	6.71	23	
	2	573.17	0.0047	52.58	93	
damper #9	1a	66.03	0.0128	8.45	28	73
	1b	150.66	0.0271	6.28	21	
	2	574.07	0.0054	47.61	84	

4 CONCLUSION

The performed research showed, that using dampers with continuously distributed parameters, it is possible to reduce the vibration amplitude significantly not only in the vicinity of one resonant frequency, which is the case of one degree of freedom damper, but in the vicinity of at least two lowest resonant frequencies.

Plate crosswise dampers should be placed near the antinodes of the damped structure and they are most effective in case that they are tuned in such a way, that the two split frequency peaks are of nearly the same accelerance. This is difficult to achieve by tuning using distributed masses. With this type of damper, accelerances of the first resonant frequency were reduced to 73 - 30% and accelerances of the second resonant frequency to 73 - 21% of the original value without damper. The most effective is the damper with plastic and metal grid damping layers.

Plate lengthwise dampers reduce vibration on both the first and the second resonant frequencies. Accelerances of the first resonant frequency were reduced to 67 - 34% and accelerances of the second resonant frequency to 59 - 35% of the original value without damper. More effective is again the damper with plastic and metal grid damping layers in comparison with plastic damping layer only.

Cylindrical rubber dampers are very effective in reducing vibration on the first resonant frequency, on which they were tuned. Accelerances of this frequency were reduced to 28 - 21% of the original value without damper. This type of damper has negligible influence on the second resonant frequency.

This research give us more knowledge about damping measurement and evaluation and about damping properties of several types of dampers. This knowledge will be helpful in solving practical industrial tasks.

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AUTHORS: J. ONDROUCH and A. BILOŠOVÁ, Department of Mechanics, Technical University of Ostrava, 708 33 Ostrava-Poruba, ul. 17. listopadu c. 15, Czech Republic