MILITARY TECHNICAL INSTITUTE
Laboratory for experimental strength
Belgrade, Ratka Resanovića 1, Phone (011) 2508-308, fax (011) 2508-474

Defence
Top secret
For Internal Use Only

R E P O R T

DYNAMIC TESTING OF DAMPER MADA HQ Kanada type - ABSORBER OF SEISMIC ENERGY – SYSTEM DC90

No. 155/06-03-02

Customer:	**"SYSTEM DC90", 11307 Belgrade-Boleč, 67 Smederevski put**	
Customer order:	**No. 08/2658-1 from 20.10.2015.**	
Specimen:	**2 dampers MADA HQ Kanada type**	
Way of sampling:	**Sampled by the customer: yes**	**Sampled by laboratory: no**
Specimen reception date:	**26.10.2015.**	
Testing method:	**Dynamic testing**	
Enviromental conditions:		
Testing equipment:	**Servohydraulic system MTS**	
Measuring equipment:		
Measuring uncertainity:		
Testing period:	**26.10.2015.**	

CONTENTS:

Translated by	Developed by	Reviewed by	Approved by
Test engineer	Test engineer	Head of the laboratory	Head of Aeronautical Department
Gragutin Georgijević, BSc.	**Zorana Dančuo, BSc.**	**Srdja Perković, BSc.**	**Vojislav Dević, BSc.**

1. DELIVERED SPECIMENS

To conduct a test the customer delivered two specimens of damper MADA HQ Kanada type (the absorber of seismic energy developed by “SYSTEM DC90”). The view of the delivered damper specimen with the devices for the load application is represented in *Figure 1*.

Figure 1 Damper – the absorber of seismic energy MADA HQ Kanada type

2. CUSTOMER ORDER

The Customer ordered to conduct the dynamic loading test on MADA HQ Kanada type damper (the absorber of seismic energy developed by “SYSTEM DC90”) according to the Test Program. The testing results of the delivered specimen should meet the quality requirements in the aspect of the energy damping.

3. TESTING PROCEDURE

The testing is performed by means of MTS Servohydraulic System, *Figure 2* and *3*. This system with the maximum range of ± 500kN and 150 mm, works in the following modes:

- Load control mode,
- Strain control mode,
- Stroke control mode.

The edges of the testing specimen and the loading device are fixed by the jaw clutches designed for the flat specimens, see *Figure 3*. Owing to the corresponding stiffness of the loading device it is considered that the specimen deformation is equal to the actuator’s stroke.

Figure 2 Control and data acquisition system MTS

Figure 3 Test set-up of MADA HQ Kanada damper

The testing is performed in the stroke control mode (in this case the deformation of the testing specimen). In advance defined testing programme was loaded into the PDP computer, while the sinusoidal alteration of the stroke is realized by the function generator. The recorded data (the values of the force and actuator stroke) measured by MTS System are transmitted to PC through A/D converter. Microsoft EXCEL software has been used to process the obtained measured data.

The testing is performed with the constant stroke slope of 0.2 full scale per second (with variable frequency depending on the stroke level), and the data acquisition frequency was 100 samples per second. *Figure 4* illustrates the short segment of the specimen deformation variations as well as the number of measured data acquisition points. To avoid the huge amount of the obtained data, only summary graphical diagrams are presented in the Report, while the original measured values and complete analysis, as well as movies created during the test, are given separately in e-form.

Figure 5 shows the view of the broken specimen after the test.

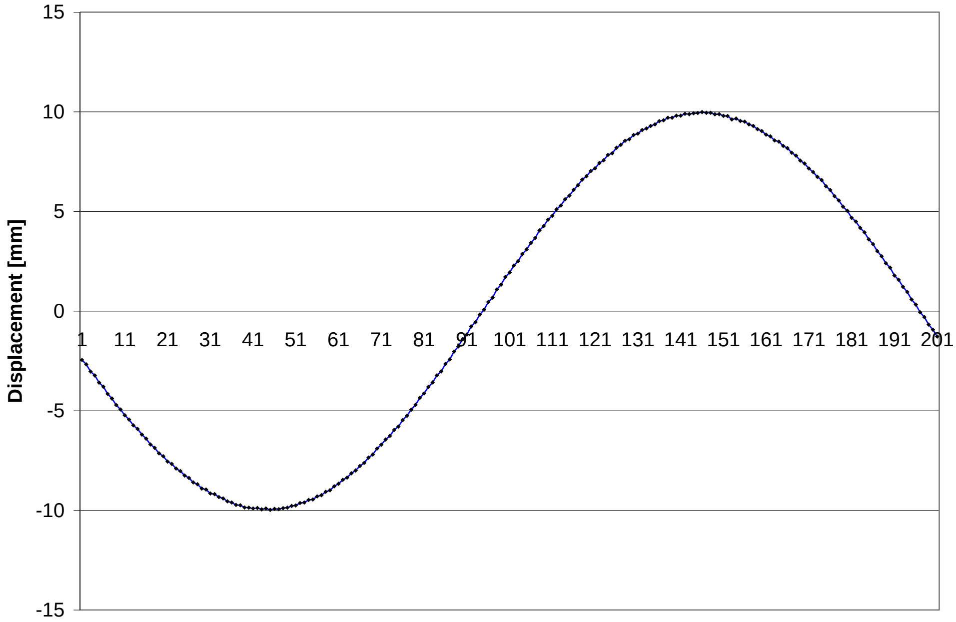


Figure 4 A short segment of the actuator's stroke and data acquisition points

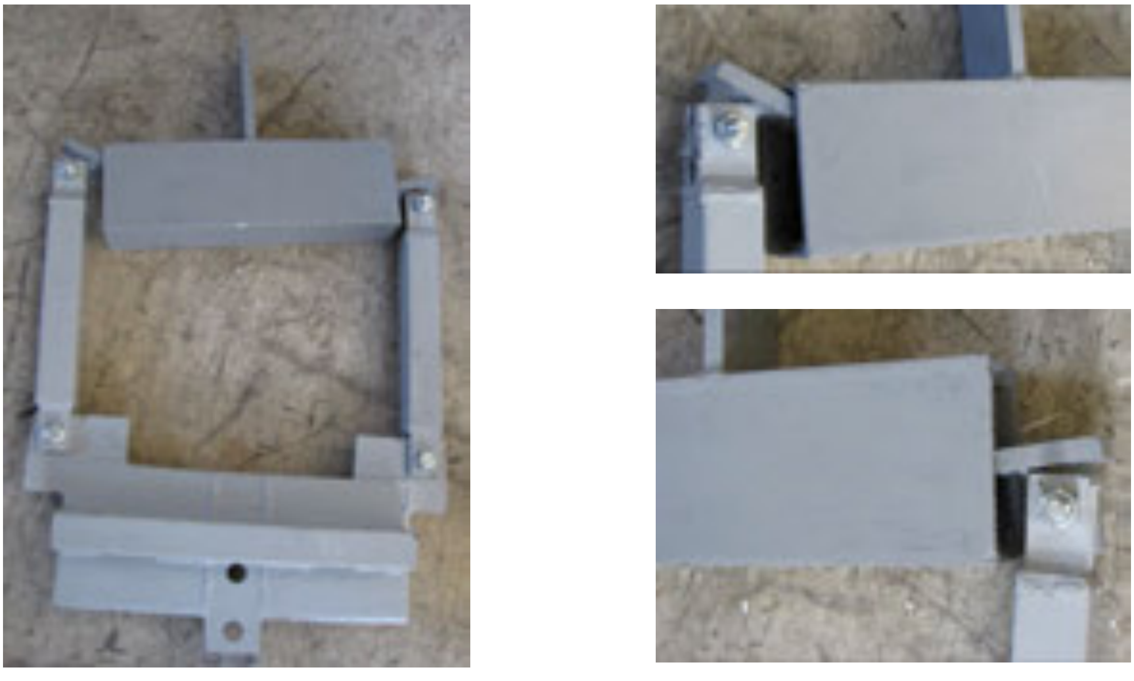


Figure 5 The broken specimen after the test

4. FIRST SAMPLE

4.1 Testing

The first specimen loading started with four cycles of ±10mm, ±20mm, ±30mm, ±40mm and ±50mm deformation amplitudes respectively, followed by six cycles of ±41mm deformation amplitude. Then the specimen broke at +50mm deformation.

Figure 6 presents the complete time history of the first specimen deformation and force, while the *Figure 7* presents the complete hysteresis (force vs. deformation).

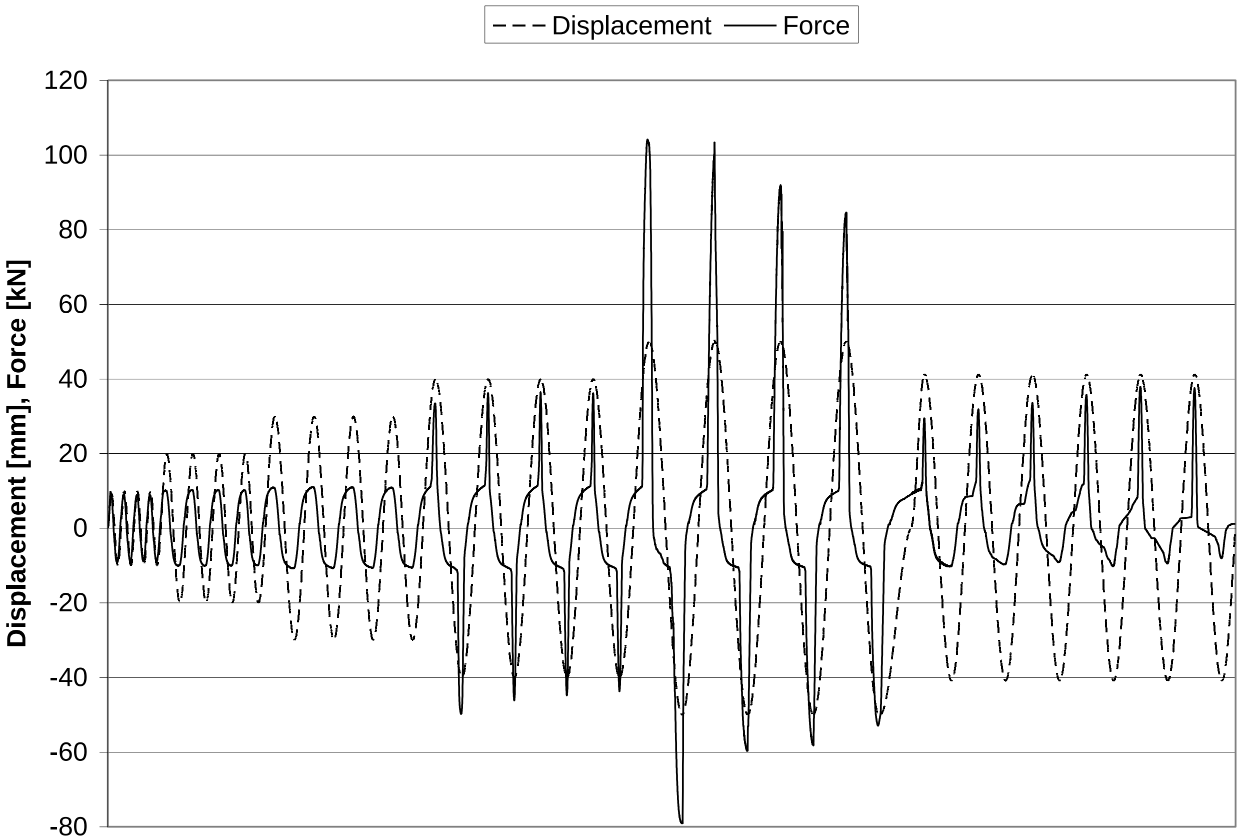


Figure 6 The first specimen complete time history of the deformation and force

For the sake of better sight, the partial time history of force and deformation are given in *Figure 8* as follows:

- *Figure 8a* – the first two blocks with four cycles ±10mm and ±20mm each,
- *Figure 8b* – third and fourth block with four cycles ±30mm and ±40mm each,
- *Figure 8c* – fifth block with four cycles ±50mm,
- *Figure 8d* – the last block with six cycles ±41mm.

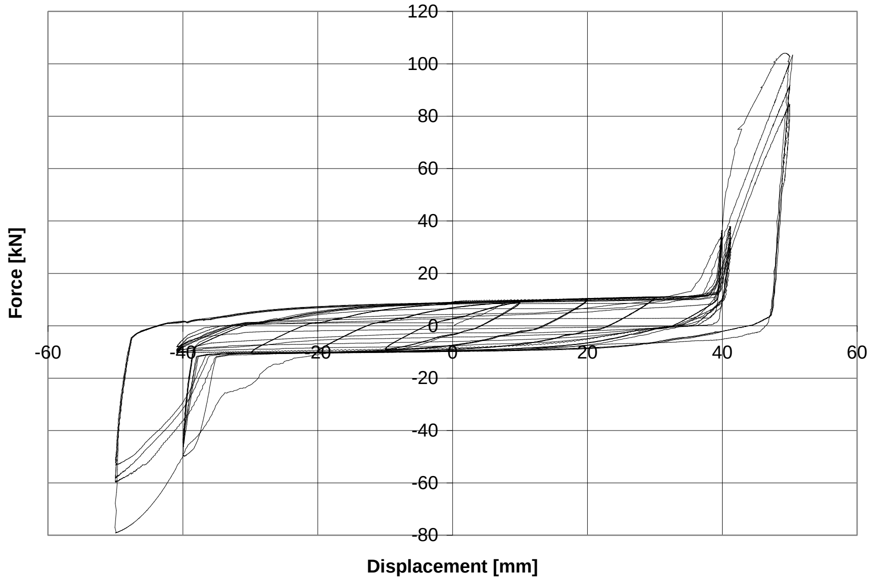
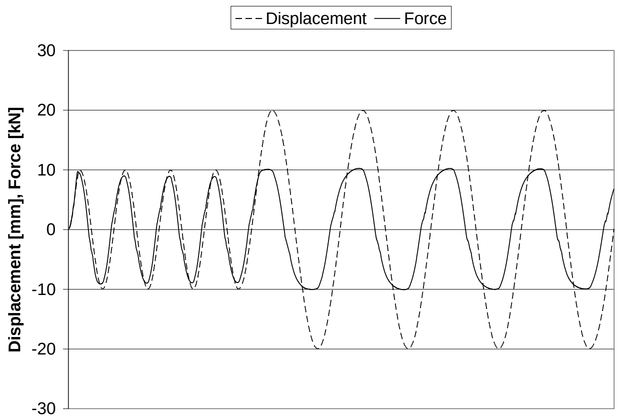
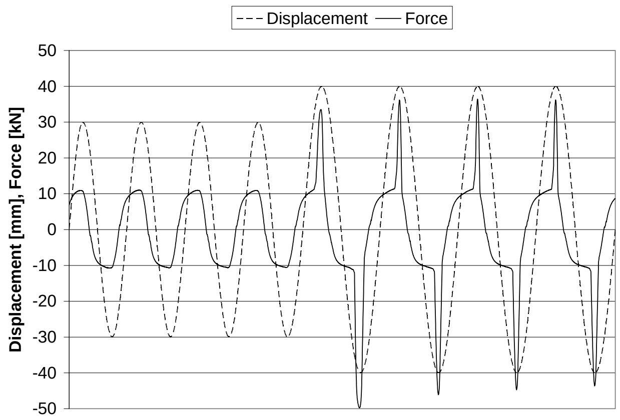


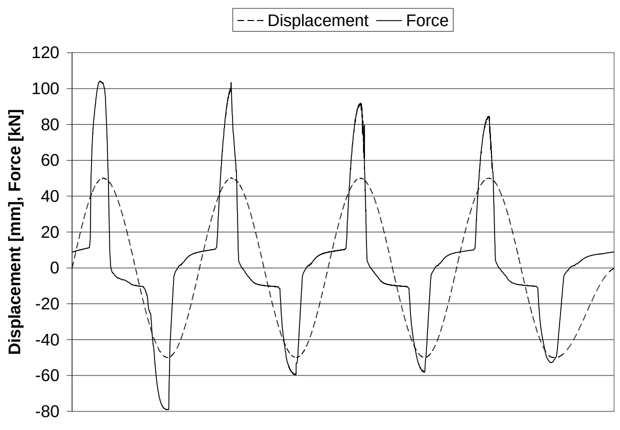
Figure 7 The first specimen complete hysteresis (force vs. deformation)



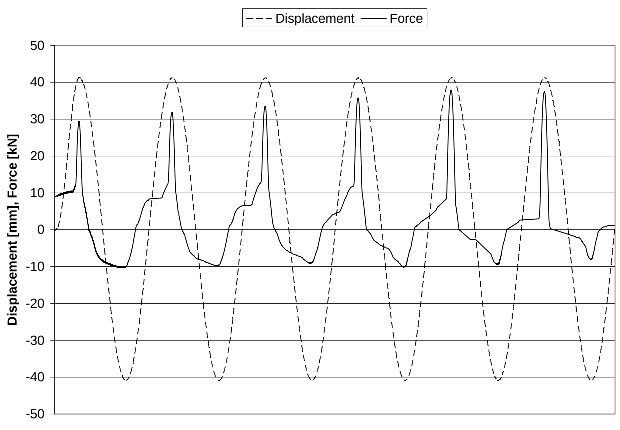
Слика 8a



Слика 8b



Слика 8c



Слика 8d

Figure 8 The first specimen partial time history of force and deformation

Partial hysteresis are shown in *Figure 9*, as follows:

- *Figure 9a* – first three blocks with four cycles each,
- *Figure 9b* – fourth block with four cycles,
- *Figure 9c* – fifth block with four cycles,
- *Figure 9d* – the last block with six cycles.

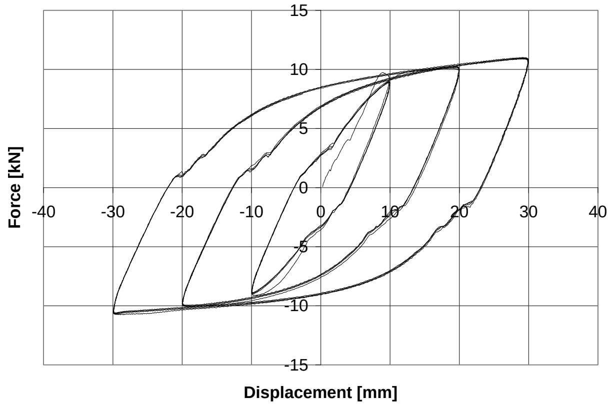


Figure 9a

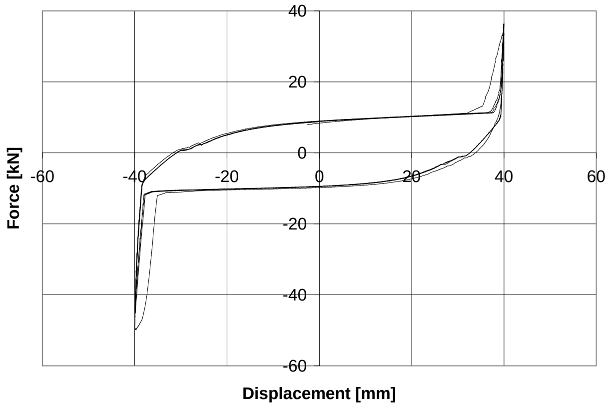


Figure 9b

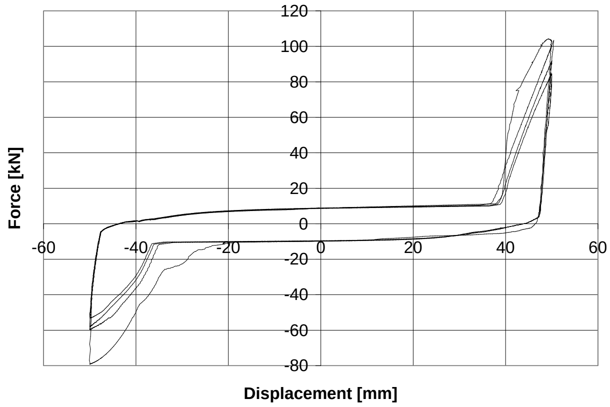


Figure 9c

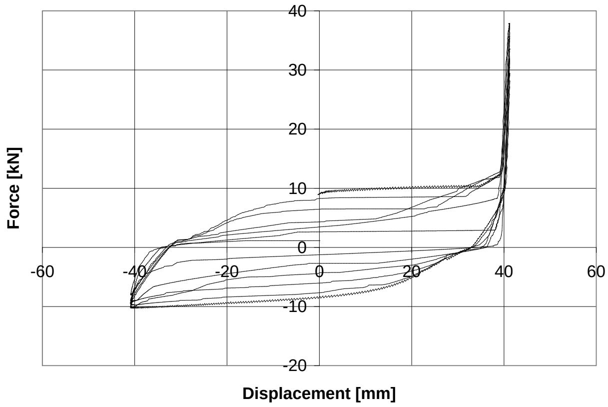


Figure 9d

Figure 9 The first specimen partial hysteresis (force vs. deformation)

4.2 Data analysis

Test data are shown as follows:

- Deformation versus number of cycles at maximum/minimum force level, *Figure 10*,
- Maximum/minimum force versus number of cycles, *Figure 11*,
- Absorbed energy versus number of cycles, *Figure 12*.

On the contrary to the "smuth" hysteresis, in this case the maximum/minimum deformation is not allways in the same point where the maximum/minimum force is.

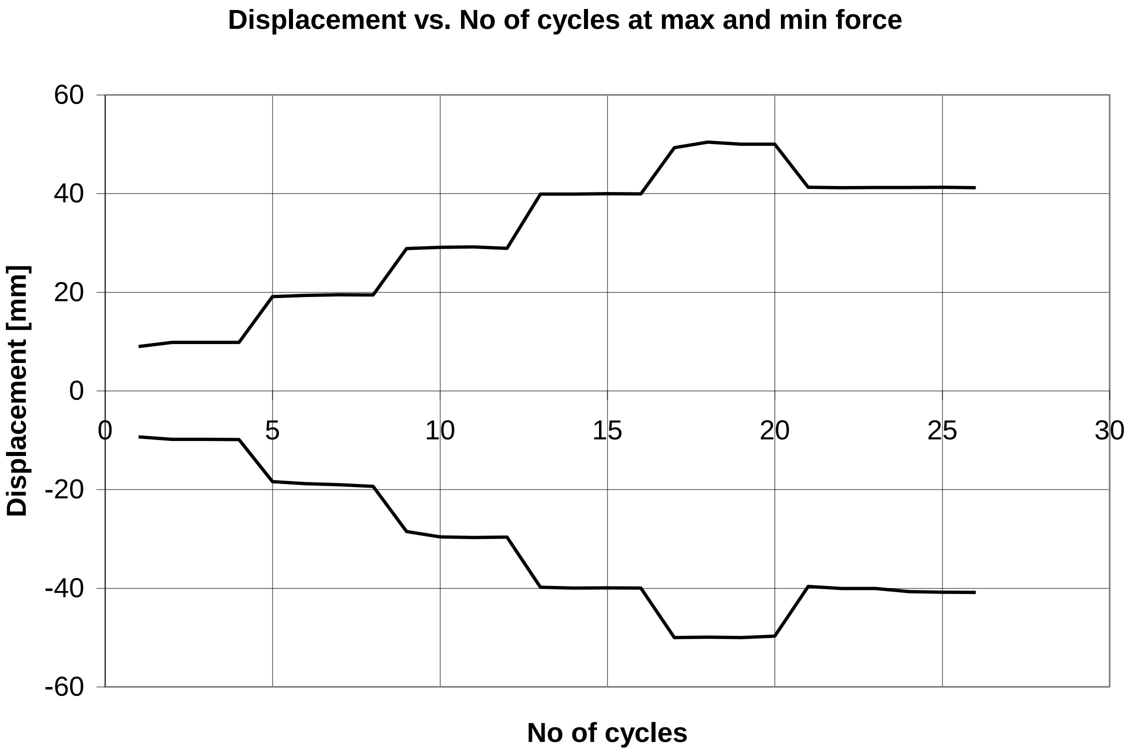


Figure 10 Deformation vs. number of cycles at maximum/minimum force level

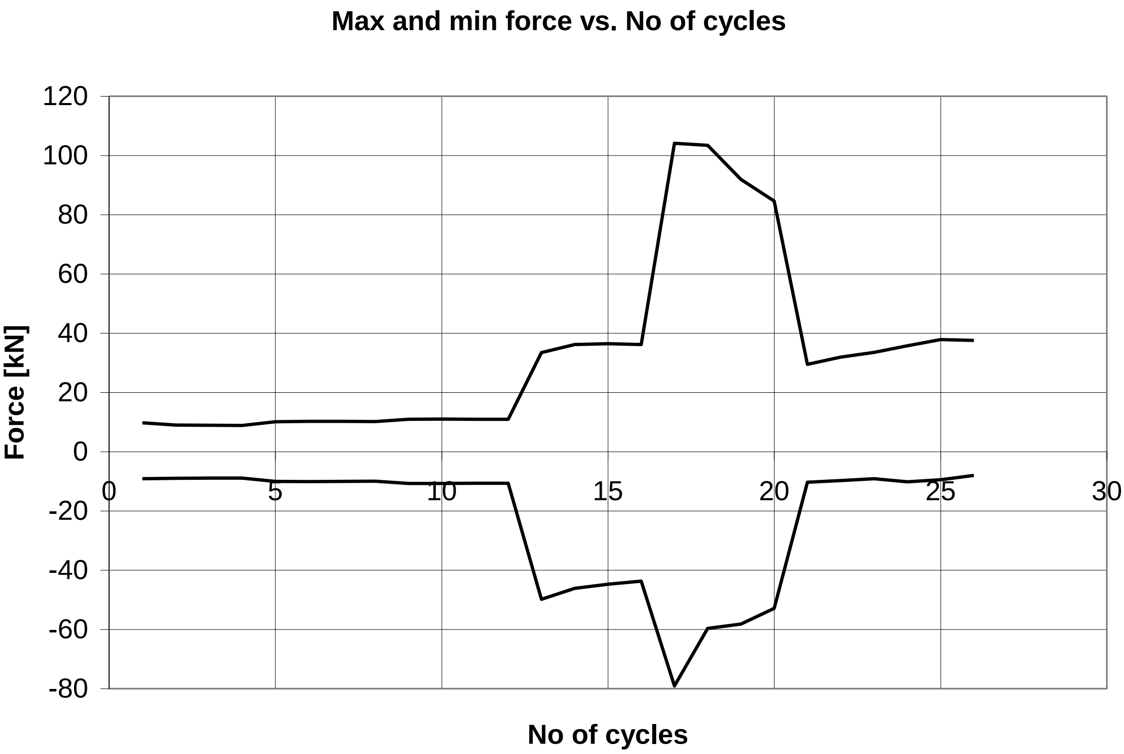


Figure 11 Maximum/minimum force vs. number of cycles

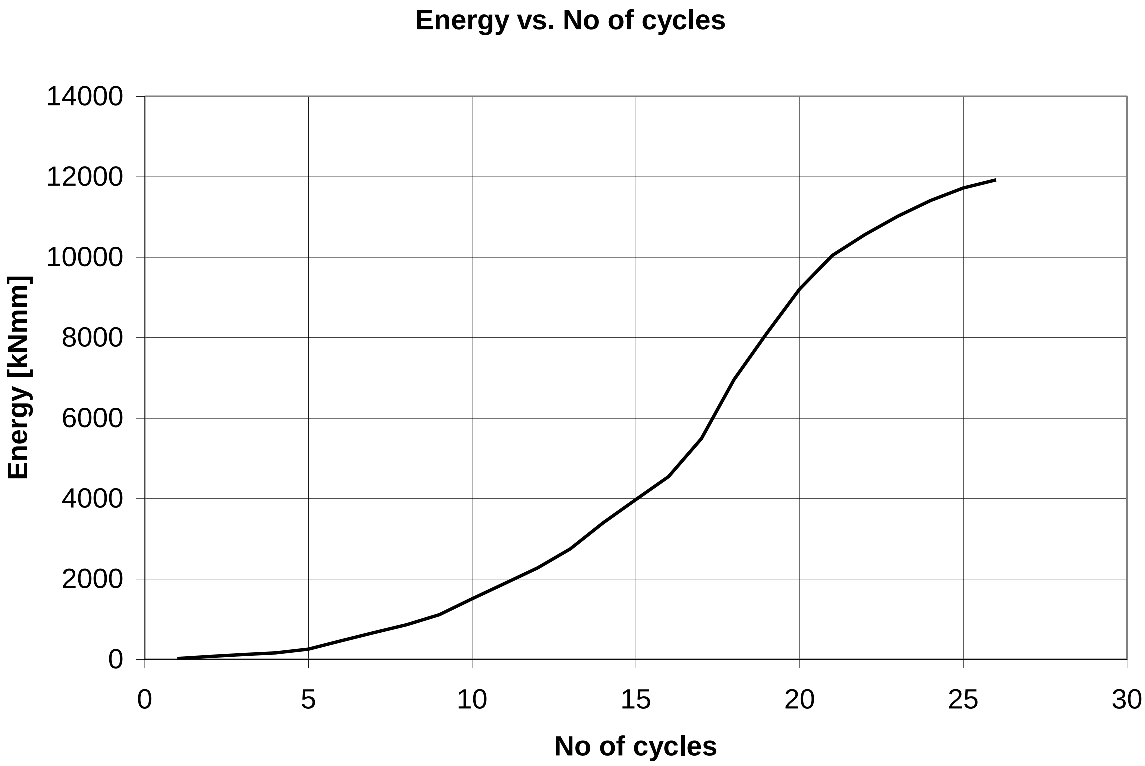


Figure 12 Absorbed energy vs. number of cycles

The increase of deformation of damper specimen is followed by the similar growth of force causing the growth of absorbed energy, see *Figure 9*. The first damper was not broken even after 26 cycles. Refering to the curve gradient in *Figure 12*, the conclusion is that there is still damping capacity in this damper.

The total absorbed energy of this damper is 12000 kNmm. It can be seen in *Figure 9* that the domain where the absorbed energy is maximal the deformation amplitude is ± 40 mm and force amplitude ± 10 kN.

5. SECOND SAMPLE

5.1 Testing

The second specimen loading started with one cycle of ±40mm, two cycles of ±45mm and two cycles of ±50mm, and then four cycles of +52/-55mm, two cycles of +52/-58mm and one cycle of +50/-60mm deformation amplitudes respectively. At the end there were two cycles ±40mm, ±30mm, ±20mm each and 25 cycles of ±10mm practically in the poscolapsed regime.

Figure 13 presents the complete time history of the second specimen deformation and force, while the *Figure 14* presents the complete hysteresis (force vs. deformation).

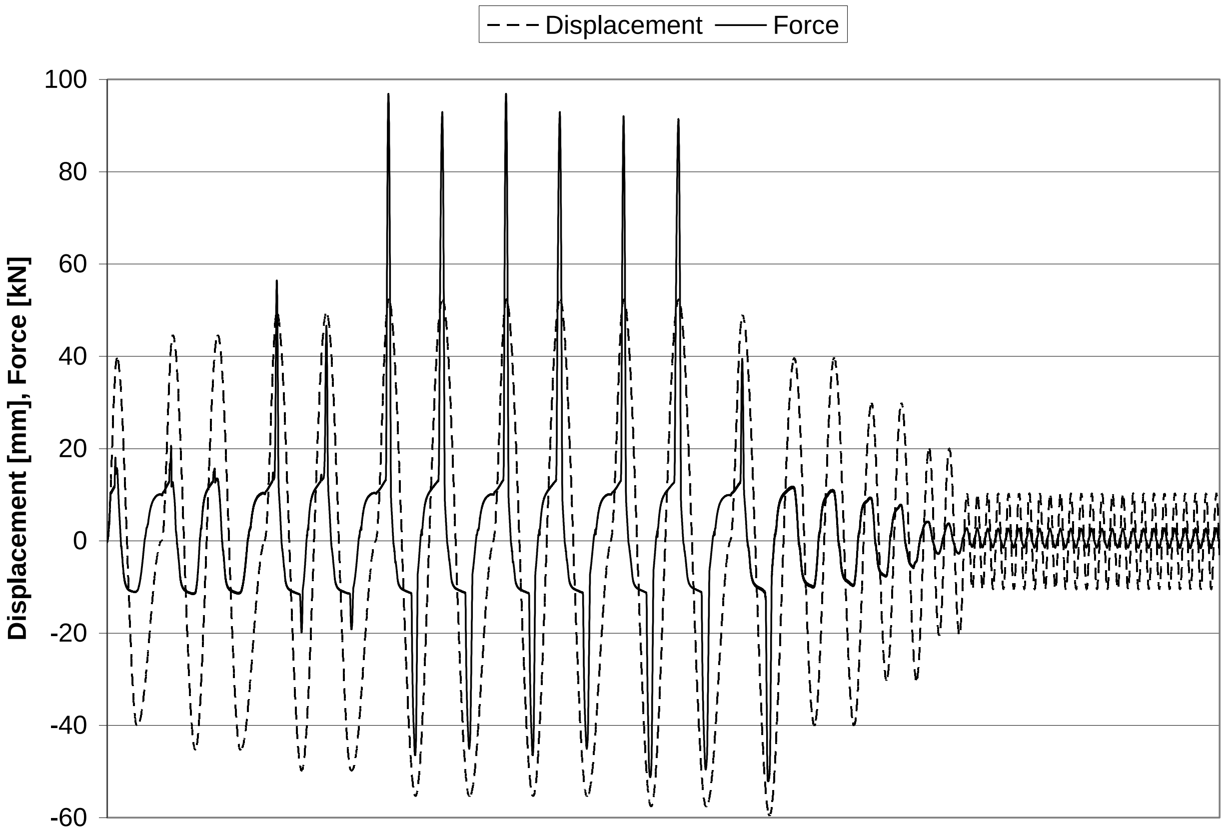


Figure 13 The second specimen complete time history of the deformation and force

For the sake of better sight, the partial time history of force and deformation are given in *Figure 15* as follows:

- *Figure 15a* – first five cycles (one cycle of ±40mm, two of ±45mm, two of ±50mm),
- *Figure 15b* – six cycles (four of +52/-55mm, two of +52/-58mm),
- *Figure 15c* – seven cycles (one cycle of +50/-60mm, two of ±40mm, two of ±30mm, two of ±20mm),
- *Figure 15d* – last 25 cycles of ±10mm.

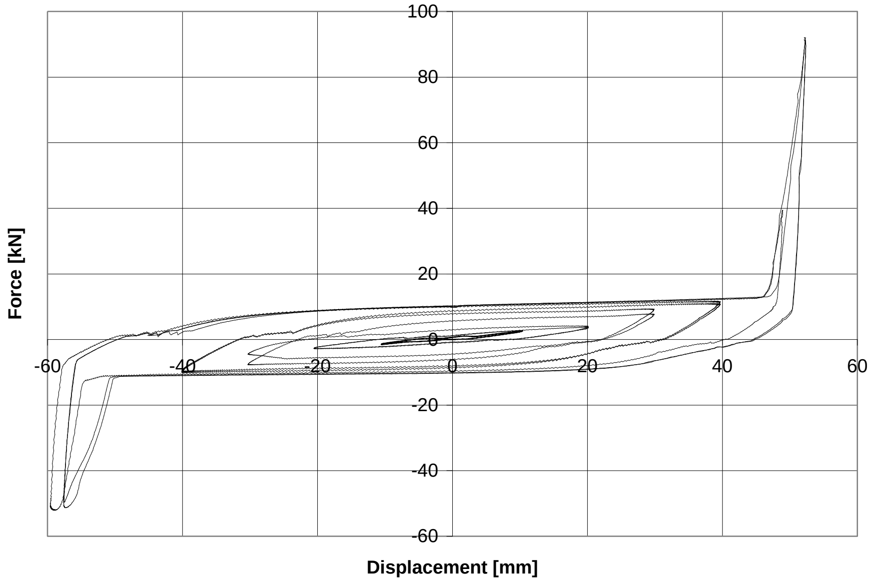


Figure 14 The second specimen complete hysteresis (force vs. deformation)

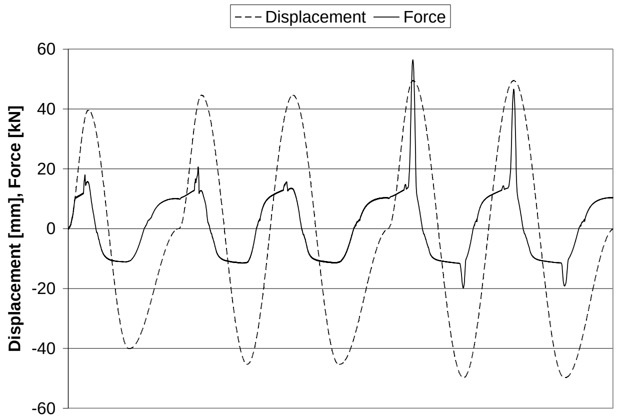


Figure 15a

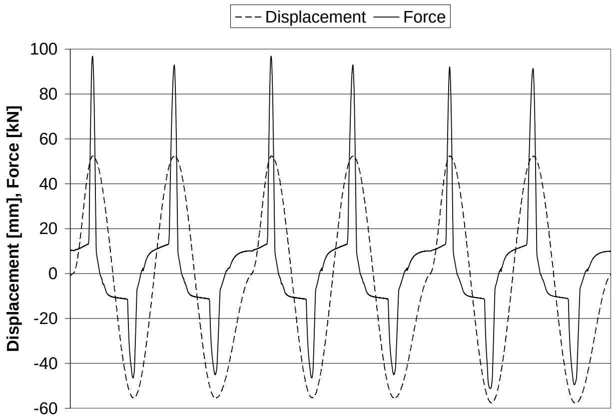


Figure 15b

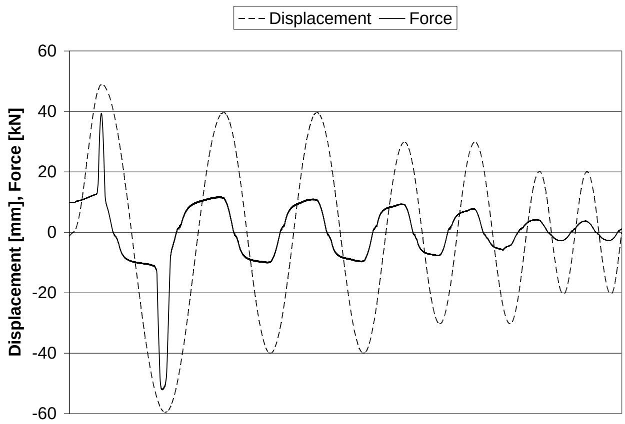


Figure 15c

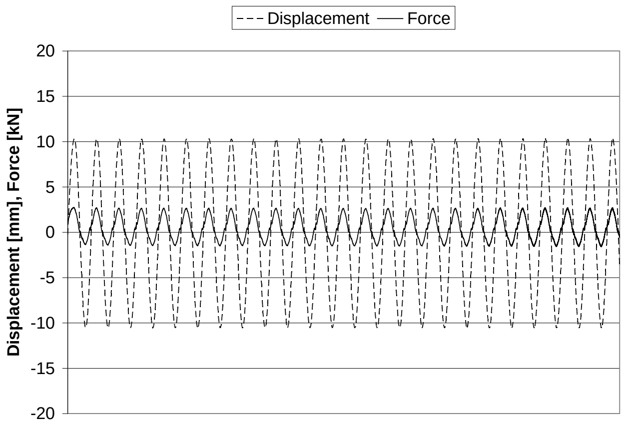


Figure 15d

Figure 15 The second specimen partial time history of force and deformation

Partial hysteresis are shown in *Figure 16*, as follows:
- *Figure 16a* – first three cycles,
- *Figure 16b* – fourth and fifth cyccle,
- *Figure 16c* – from sixth to twelve cycles,
- *Figure 16d* – last 43 cycles.

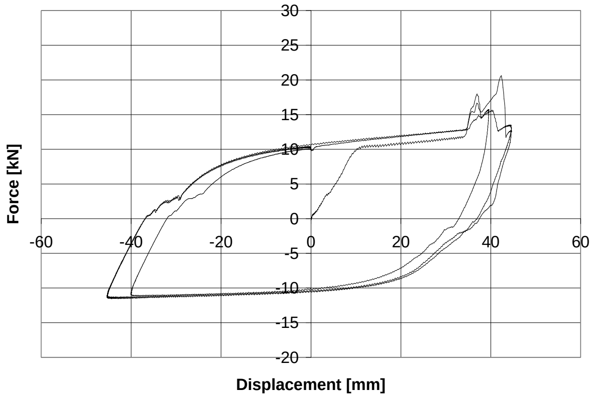


Figure 16a

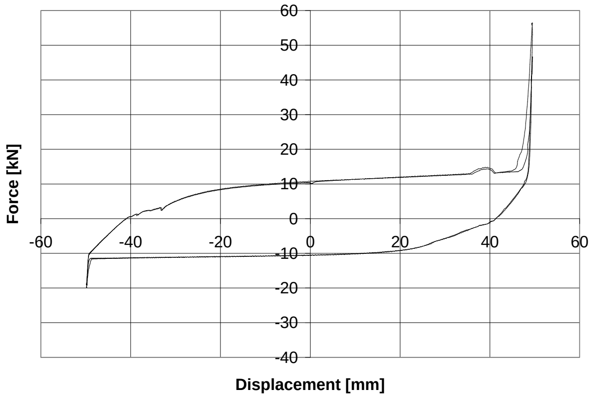


Figure 16b

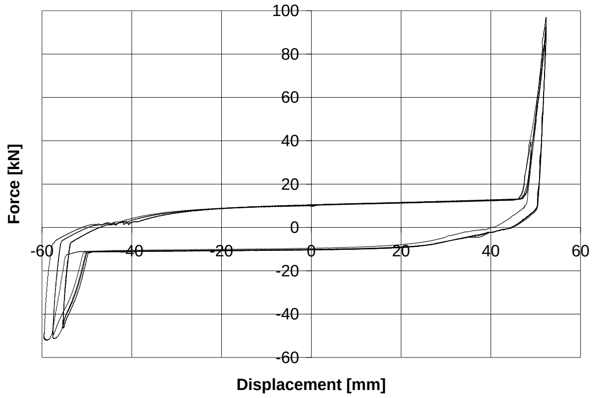


Figure 16c

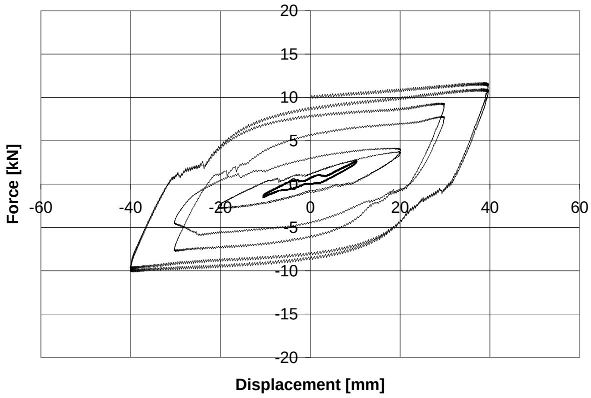


Figure 16d

Figure 16 The second specimen partial hysteresis (force vs. deformation)

5.2 Data analysis

Test data are shown as follows:
- Deformation versus number of cycles at maximum/minimum force level, *Figure 17*,
- Maximum/minimum force versus number of cycles, *Figure 18*,
- Absorbed energy versus number of cycles, *Figure 19*.

On the contrary to the “smooth” hysteresis, in this case the maximum/minimum deformation is not always in the same point where the maximum/minimum force is.

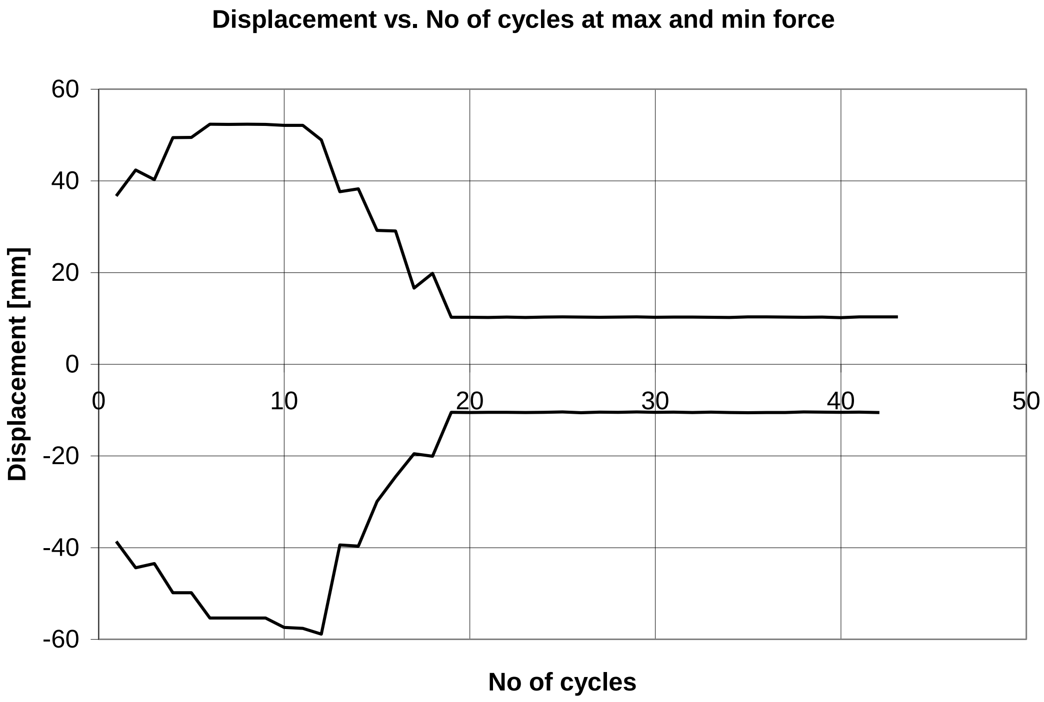


Figure 17 Deformation vs. number of cycles at maximum/minimum force level

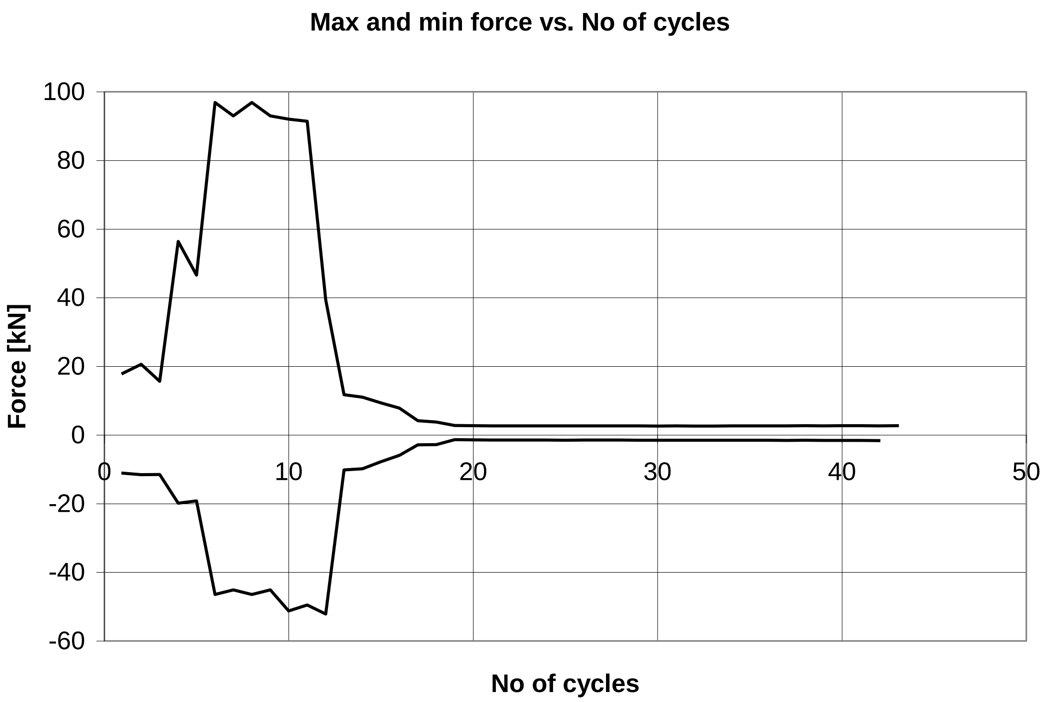


Figure 18 Maximum/minimum force vs. number of cycles

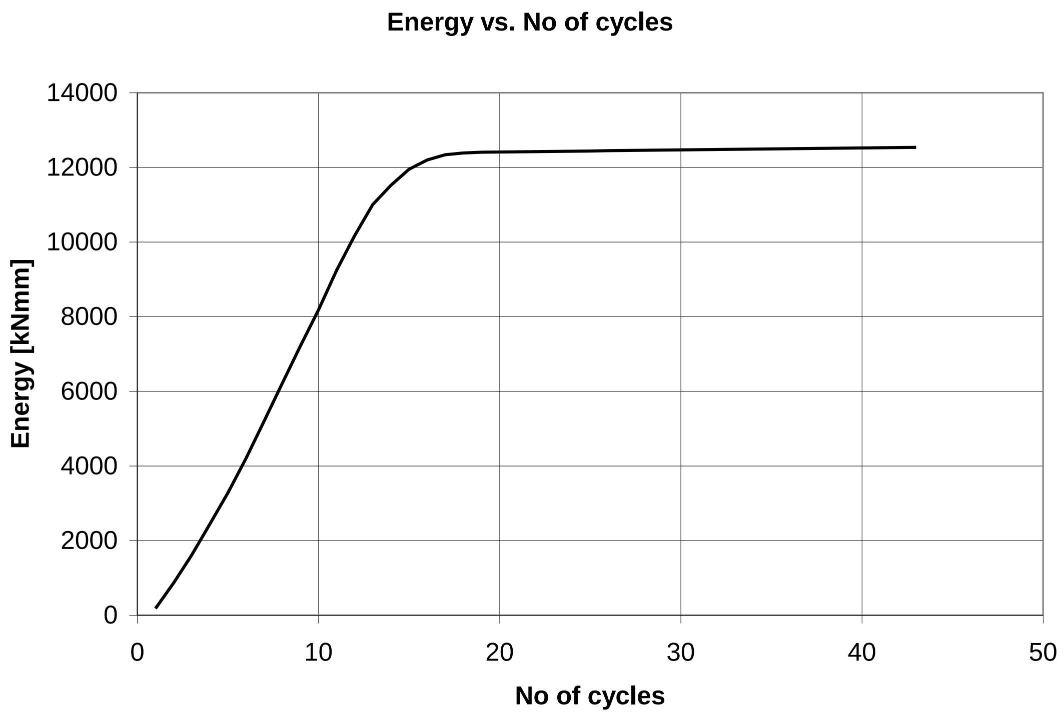


Figure 19 Absorbed energy vs. number of cycles

As san be seen in *Figure 19* the second damper absorbed about 90% of total energy up to the 13 cycles and practically all of energy up to the 17 cycle. After 17 cycle the quantity of absorbed energy could be neglected. Total absorbed energy is 12500 kNmm. It can be seen in *Figure 16* that the domain where the absorbed energy is maximal the deformation amplitude is ± 40 mm and force amplitude ± 10 kN.

6 CONCLUSION ABOUT DAMPER MADA HQ Kanada type

The objective of the testing was to investigate the quality of the damper MADA HQ Kanada type in aspect of energy damping as well as to check the calculated domain of the damper usage.

These tests proved the good coinciding of the test results for the whole damper series. The behaviour of both specimen is consistent regardless of the different loading spectrum.

The recommended area of use the tested damper is in domain where the deformation amplitude is ±40mm and force ±10kN with the dampened energy about 12000kNmm. The amount of the energy absorption in time (the consumption of the damper capacity) depends on the load severity, i.e. the deformation amplitude.

This test results could be used as a line of direction for designing the real dampers of this type by varying the deformation and force parameters for the corresponding application on concrete objects.

It is also important that this damper has a high material plasticity reserve (post-collapse capacity) even after the construction degradation, when it can no longer take the load on both sides.