

Testing results of the Turtle® Case: Packing case for the transport of art

Vibration tests

Hengelo Ov., April 19 2001

Author: Ir. W.I. Witbreuk
Carried out for: Turtle B.V.
Reference: 00074B02-R01-3

Summary

In assignment of Turtle B.V., E.Co Engineering & Consultancy B.V. investigated the vibration characteristics of the Turtle® Case. The Turtle® Case is used for the transportation of art, in particular paintings.

The vibration tests are carried out by B. Wolbert and ir. S. Wolbers from the laboratory for Applied Mechanics (Mechanical Engineering, University of Twente (Enschede, The Netherlands)). The analysis and drawn conclusions are made by E.Co Engineering & Consultancy B.V. and checked by B. Wolbert from the University of Twente.

The measured acceleration inside the case are in all directions a factor 1×10^{-3} to 1×10^{-6} smaller than the incoming acceleration on the outside of the case for both the lower frequency range (2-12 Hz), as for the higher measured frequency range (till 500 Hz).

No part of this report may be reproduced, copied, translated in any form, without the prior written permission of Turtle B.V.

Information provided in this report is intended to be accurate and reliable. In no event will E.Co Engineering & Consultancy B.V. be liable for damage during transport with the Turtle® Case. This limitation will apply even if this rapport describes the possibility of such damage.

Table of contents

Summary	2
1. Introduction	4
2. Literature	5
3. Measurement set up	6
4. Results	11
5. Conclusions	16

1. Introduction

In assignment of Turtle B.V. E.Co Engineering & Consultancy B.V. investigates the Turtle® Case. The Turtle® Case is used for the transportation of art (in particular paintings).

To find out three types of characteristics of the Turtle® Case three different types of tests are carried out:

1. vibration test;
2. drop test;
3. temperature and humidity-test;

This report reflects the results of the vibration tests. The tests are carried out at the laboratory for Applied Mechanics (Mechanical Engineering, University of Twente (Enschede, The Netherlands)).

In chapter 2 two articles are described, which relate to the field of vibrations tests of packing cases for art. In chapter 3 the measurement set up in the laboratory is described.

In chapter 4 the results of the vibrations tests are reflected.

2. Literature

There are two articles analysed in the field of testing of packing case for the transport of paintings:

1. David Saunders, '*Monitoring shock and vibration during the transportation of paintings*', National Gallery Technical Bulletin, Volume 19, 1998
2. S. Staniforth, '*The testing of packing cases for the transport of paintings*', cited in note 1, pp.10-12; T. Green and S. Hackney, 'The Evaluation of a Packing Case for Paintings', *International Council of Museums Committee for Conservation, 7th triennial meeting*, Copenhagen 1984, 84-121-6.

The article of Staniforth described a vibration test in the range of 5-500 Hz. In this range the most energetic vibrations during transport are:

- 5-70 Hz for transport by road vehicles;
- 300-500 Hz for transport by aircraft.

The tests are been carried out in the range of 0-500 Hz.

3. Measurement set up

In the laboratory for Applied Mechanics a painting (a thin wooden plate fixed in a frame, thickness 2 mm) in a medium large Turtle® is tested for its vibration characteristics.

The size of the frame is 74x95cm. The weight of the case is 90 kg.

The painting inside the Turtle® case is provided with three very light acceleration sensors (see figures 1 and 2, type B&K 4374):

- x-sensor on the short side of the frame in the x-direction;
- y-sensor on the long side of the frame in the y-direction;
- z-sensor on the painting in the z-direction (perpendicular to the painting, in the middle of the plate);

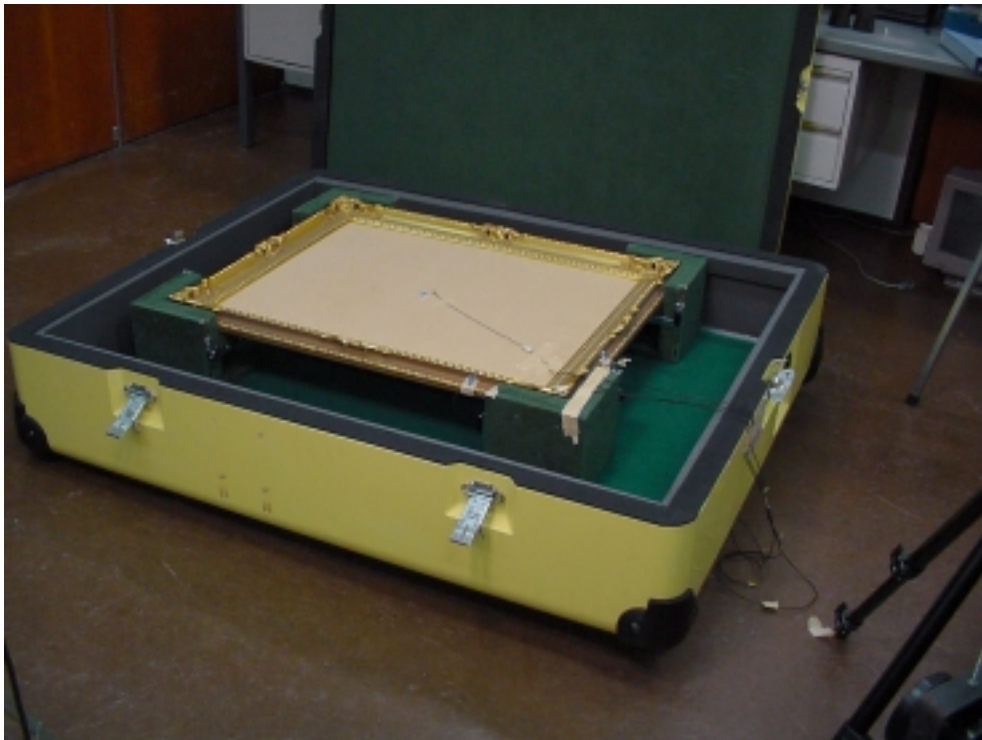


figure 1: Open Turtle® case with three acceleration sensors inside (on each coordinate axis) on the painting

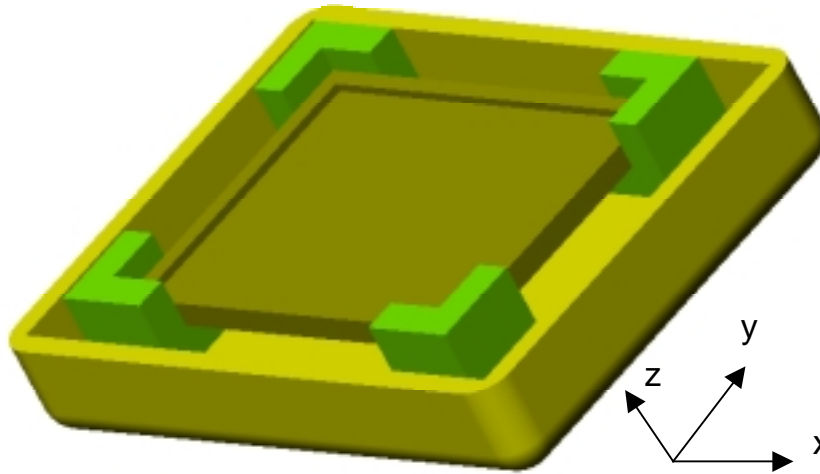


figure 2: Open Turtle® case with coordinate system

During the tests the outside of the case is excited in the three directions of the coordinate system (see figure 3-5). Between the excitor and the case, force and acceleration sensors (B&K Impedance Head, type 8001) are installed, for recording the incoming signals (see figure 6). During these tests the case is positioned on four rubbers. The Rigid Body Mode (rubbers with case) has an eigenfrequency of around 4 Hz (see figure 7). During the tests, the case was in the same way positioned as it will be during transport (with the exception of the test in the y-direction).



figure 3: Turtle® case vibration test with the excitation in the x-direction



figure 4: Turtle® case vibration test with the excitation in the y-direction



figure 5: Turtle® case vibration test with the excitation in the z-direction

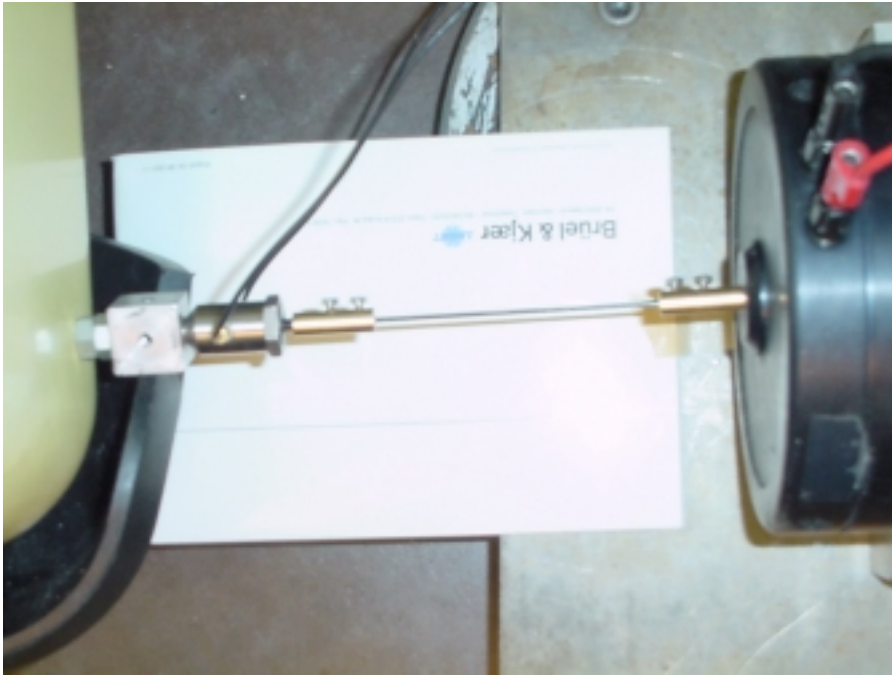


figure 6: Force- and acceleration-sensors in line of the exciator



figure 7: The case is during the tests supported on four rubbers

Remarks:

1. The acceleration recorded by the three accelerometers were compared with the input force and acceleration;
2. The tests were performed in two most energetic vibrations in the various form of transport:
 - 2-12 Hz
 - 0-500 Hz
3. The used method of testing is by a random vibrational scale. This method is a common used method. Still this does not represent exactly the random nature of vibrational input during transport, but is been seen as a very well method of approach;
4. The magnitude of the vibration was adjusted for each frequency on 2G ($= \pm 19.6 \text{ m/s}^2$).
5. The results of these tests are described in chapter 4.

4. Results

In this chapter the results of the tests are presented.

The presented results are two types of figures:

1. response curves presented as a logarithmic plot of G , the acceleration recorded by the accelerometers, against frequency. There are four accelerometers:
 - a. sensor on the outside of the case, in the excitation-direction ($X_{acc\ exc}$);
 - b. x-sensor on the short side of the frame in the x-direction (X_{ac});
 - c. y-sensor on the long side of the frame in the y-direction (Y_{ac});
 - d. z-sensor on the painting in the z-direction (perpendicular to the painting, Z_{ac});

2. transfer function curves presented as a logarithmic plot of G against frequency. The presented transfer functions are the three transfer functions between the recorded incoming force at the outside of the case (in the line of the excitor) and the measured acceleration on:
 - a. x-sensor on the short side of the frame in the x-direction (transfer $F_{acc\ exc} - X_{acc}$);
 - b. y-sensor on the long side of the frame in the y-direction (transfer $F_{acc\ exc} - Y_{acc}$);
 - c. z-sensor on the painting in the z-direction (perpendicular to the painting (transfer $F_{acc\ exc} - Z_{acc}$));

The first type of curves gives us the information about the attenuating characteristic of the case in the different directions. The second type of curve gives us the information of the eigenfrequencies of the packing case.

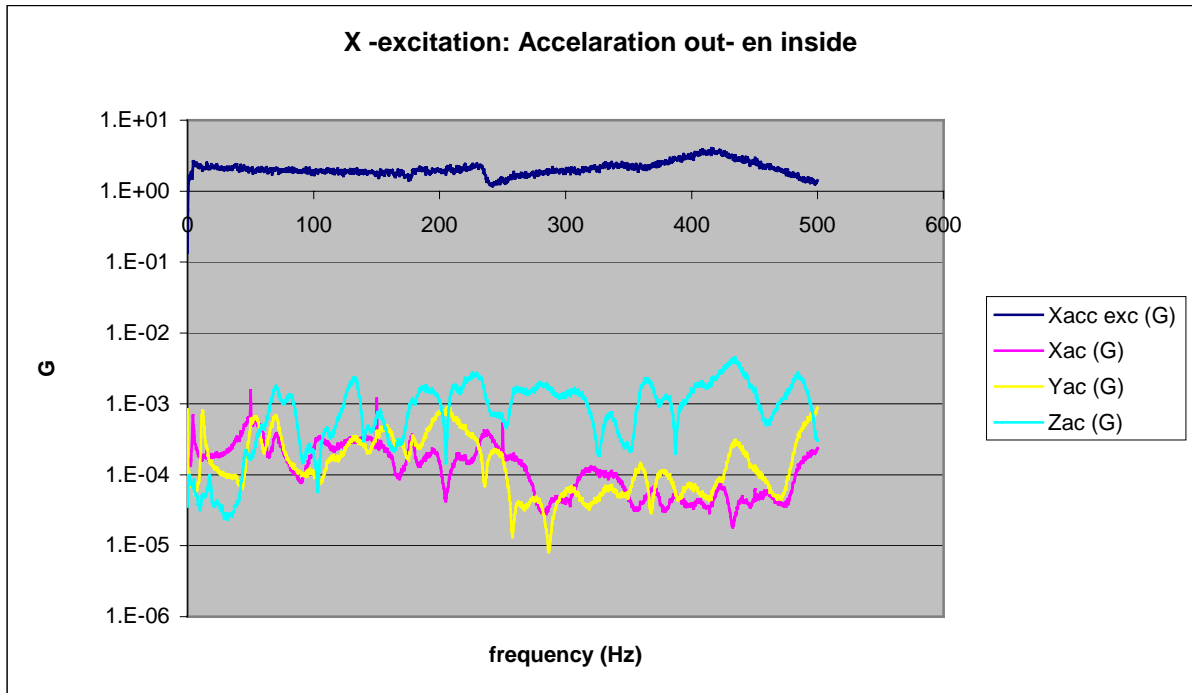


figure 8: Response curve: Excitation in the X-direction for the frequency range 0-500 Hz

Comparing the incoming acceleration with the response accelerations on the painting, there is a maximum damping factor of 1.6×10^{-3} in the Z-direction. The minimum damping factor is 5.8×10^{-6} in the X-direction. Up to 230 Hz the damping factors in the three directions are approximately the same. For the higher frequency range (250-500 Hz) the damping factor in Z-direction increases or remain constant, whereas in the X and Y-direction the factor decreases.

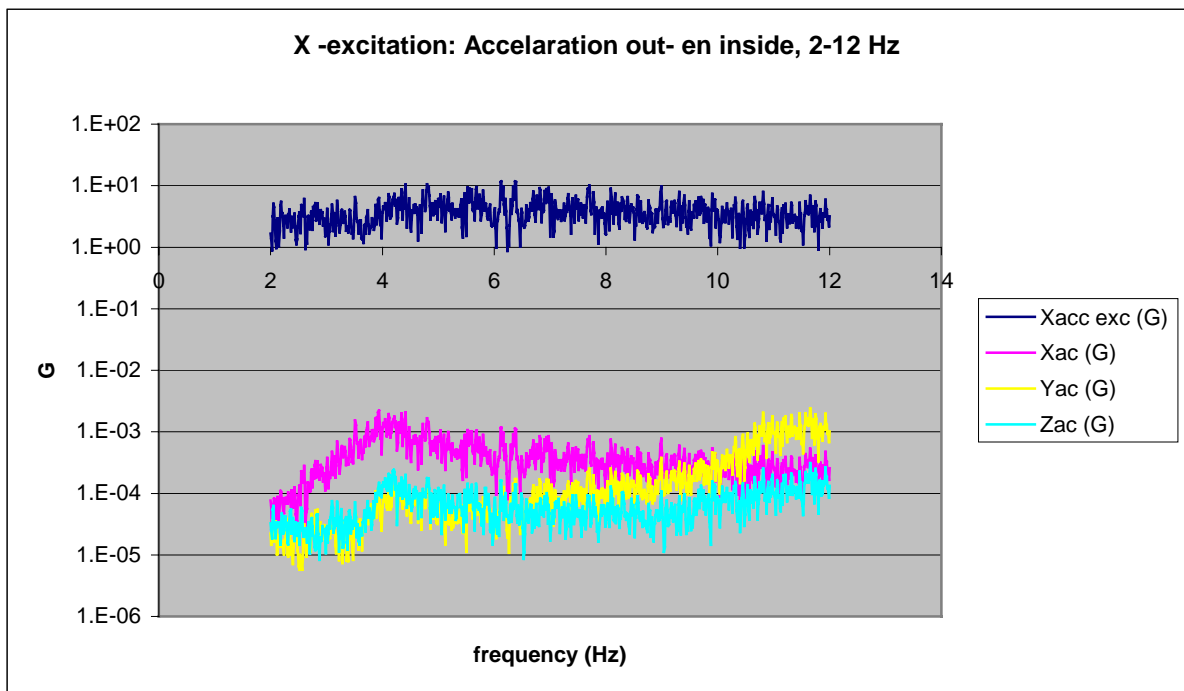


figure 9: Response curve: Excitation in the X-direction for the frequency range 2-12 Hz

In the range of 2-12 Hz, the response curves are comparable. Only in the X-direction there is a resonance at 4 Hz. This is probably eigenfrequency of the used support-rubbers in the cross direction (x-direction).

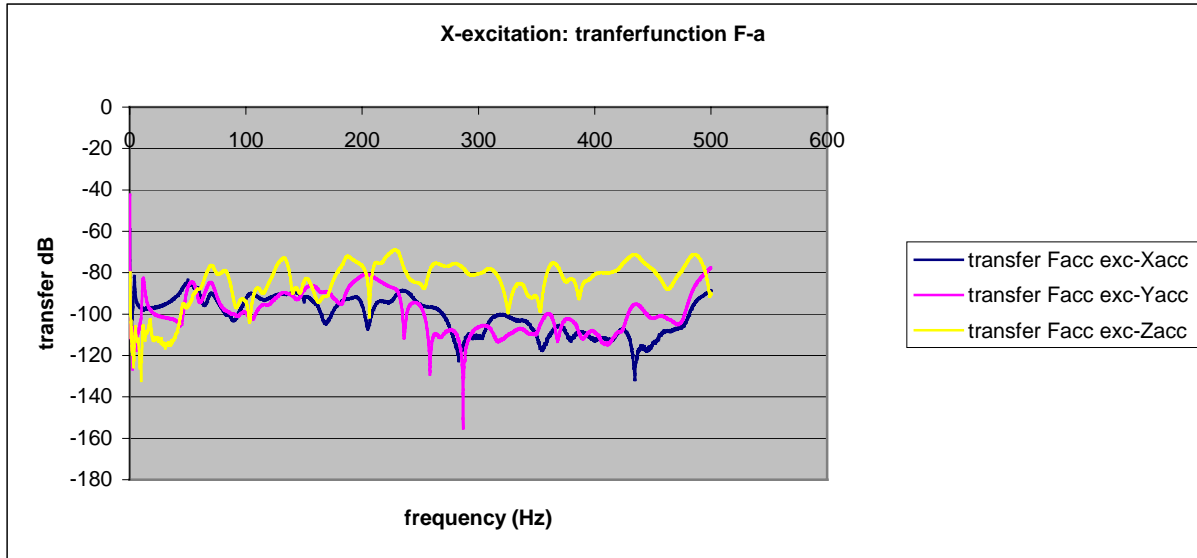


figure 10: Transfer function: Excitation in the X-direction for the frequency range 0-500 Hz

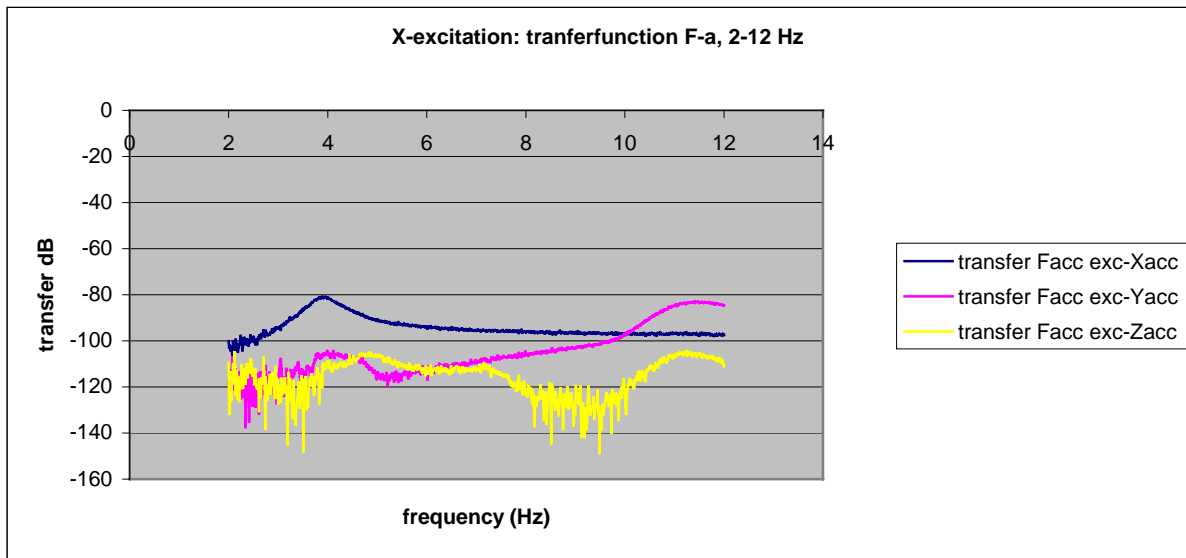


figure 11: Transfer function: Excitation in the X-direction for the frequency range 2-12 Hz

In the figures 10 and 11 the transfer function are presented. With these curves the eigenfrequencies can be determined. This information is for further investigations important.

In this report the main interest lies in the response curves. Therefore in the other two directions only the response curves are presented.

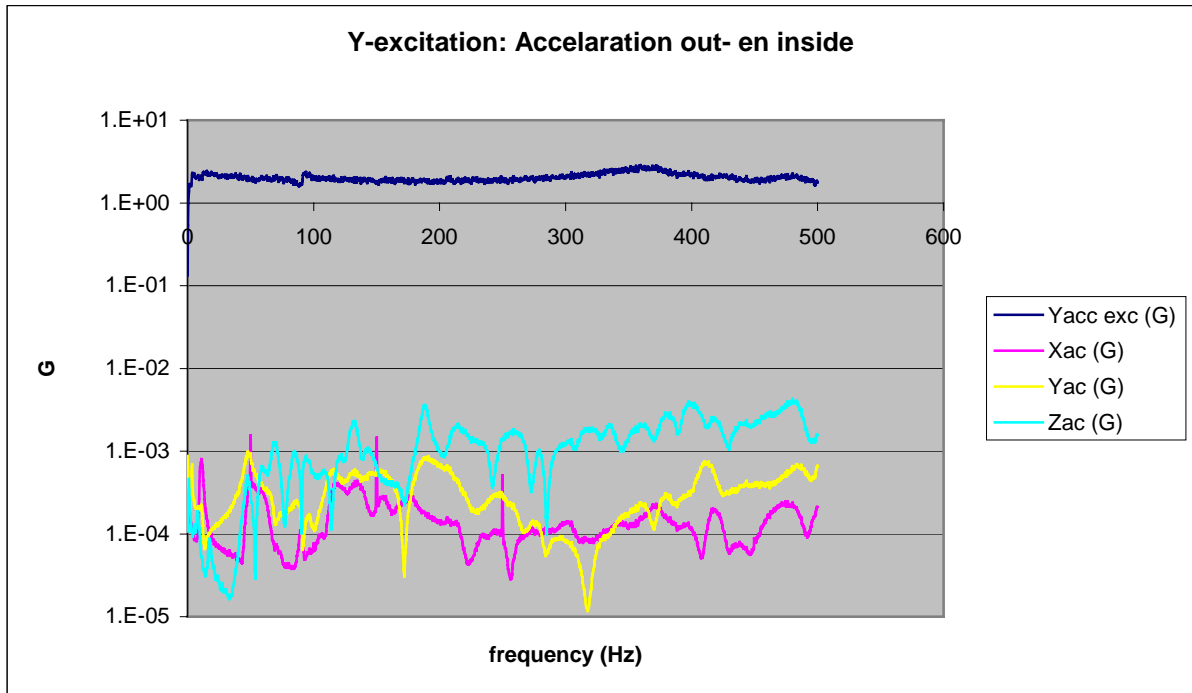


figure 12: Response curve: Excitation in the Y-direction for the frequency range 0-500 Hz

The Y-direction is the most relevant, since it is the direction in which the case is transported. Comparing the incoming acceleration with the response accelerations on the painting, there is a maximum damping factor of 1.9×10^{-3} in the Z-direction. The minimum damping factor is 7.6×10^{-6} , also in the Z-direction. For the lower frequencies (figure 12) there are also determined high attenuate terms.

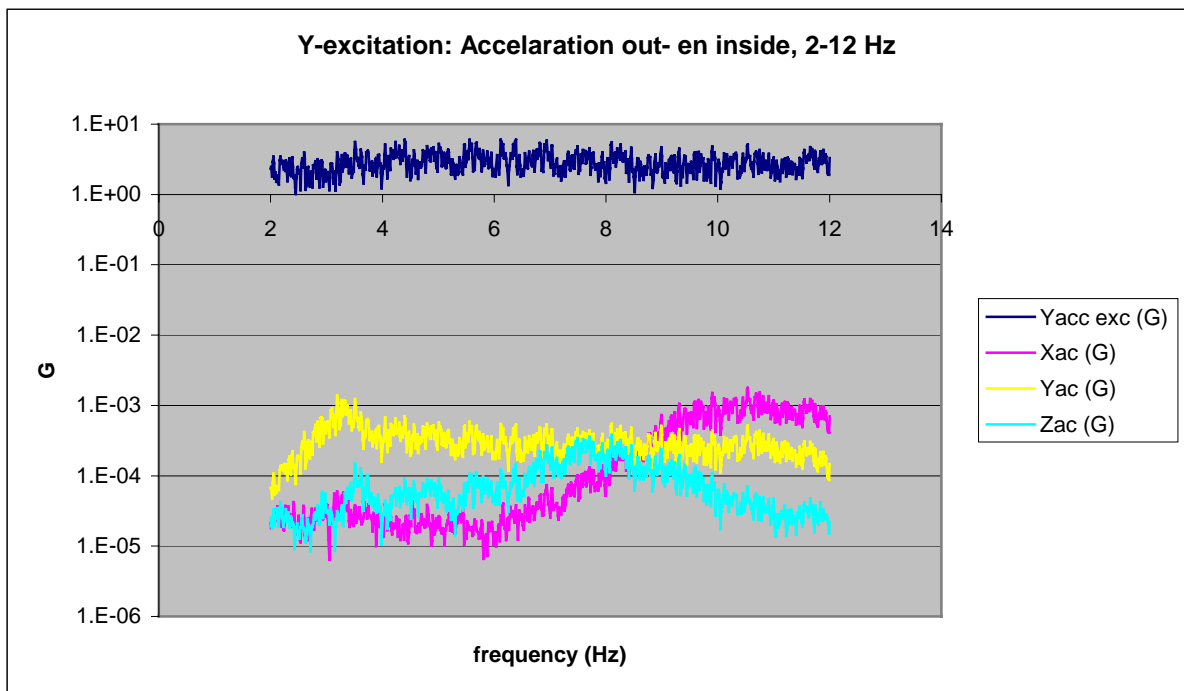


figure 13: Response curve: Excitation in the Y-direction for the frequency range 2-12 Hz

When the Turtle Case is excited in the Z-direction the maximum damping factor is 2.2×10^{-3} in the Z-direction. The minimum damping factor is 6.5×10^{-6} , in the Y-direction. For the lower frequencies (figure 14) there are also determined high attenuate terms.

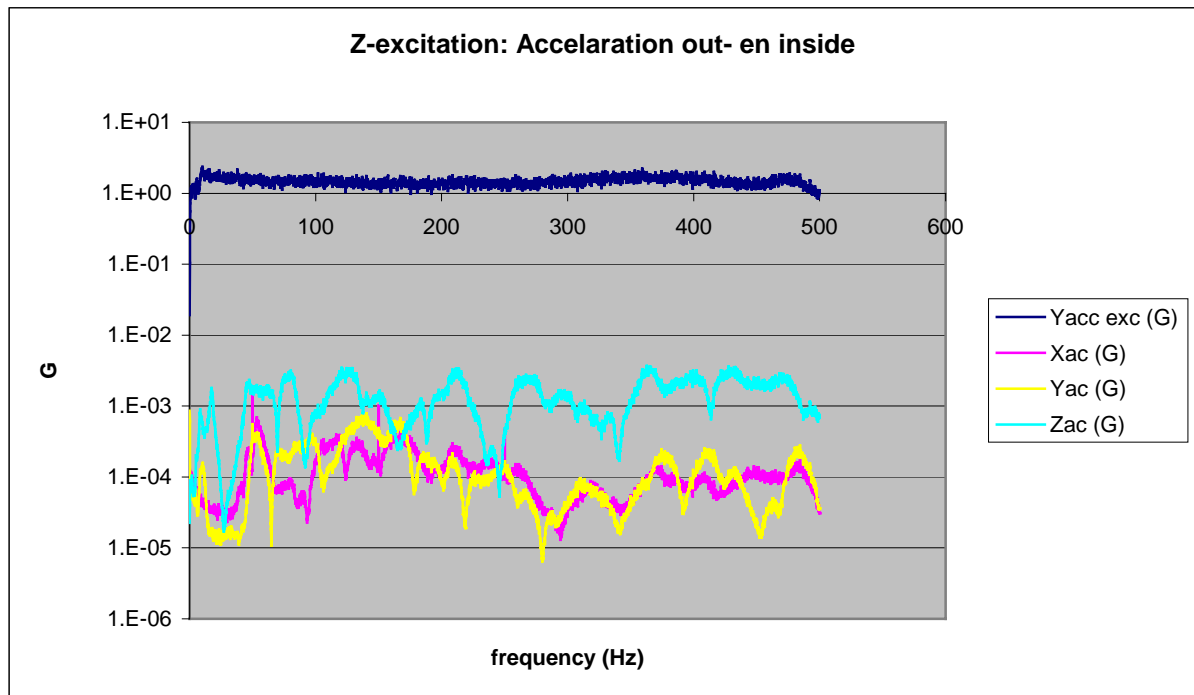


figure 14: Response curve: Excitation in the Z-direction for the frequency range 0-500 Hz

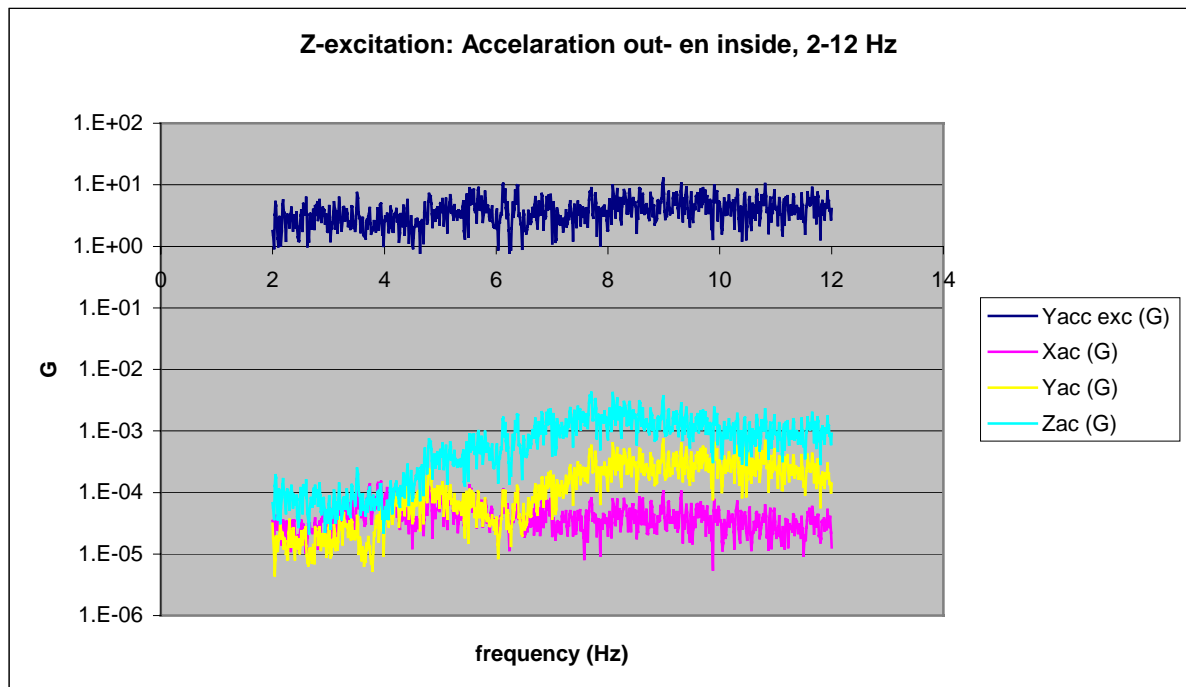


figure 15: Response curve: Excitation in the Z-direction for the frequency range 2-12 Hz

5. Conclusions

On basis of the results of the vibration tests of the Turtle® Case with a thin wooden plate fixed in a frame, the following conclusion can be drawn:

- the measured acceleration inside the case are in all directions a factor 1×10^{-3} to 1×10^{-6} smaller than the incoming acceleration on the outside of the case for both the lower frequency range (2-12 Hz), as for the higher measured frequency range (till 500 Hz).

The following comments should be made:

- the tests were carried out with a thin wooden plate fixed in a frame. Another material and/or size and/or clamping method could alter the results;
- the test were carried out with one type of size of the Turtle® Case. Former mentioned results should not have te be valid for all Turtle ® Case-sizes;
- the accelerometer on the painting (z-direction) was positioned in the middle, investigation on the edge of the plate was not performed. The mentioned damping factors in the canvas-direction should not have to be valid for the whole canvas.
- investigation should be made, which standards there are for vibration-resistance for art, in particular for paintings. If there are no standards on this matter, investigation on other (art) packing cases should be necessary.