Investigation of damage risk on cultural heritage items in the climate chamber with non-destructive testing methods

Keywords: *climate fluctuations — cultural heritage — climate chamber — structured light scanning — damage risk*

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Abstract

Climatic fluctuations may have a different impact on artworks depending on their material properties and thickness. Artworks such as panel paintings usually consist of different materials and layers (e.g., priming, several colour layers, coating), and each one reacts differently regarding swelling and shrinking. The divergent behaviour of each layer can cause stress inside the composite material [Mecklenburg 2010, Michalski 2011]. Both short- and long-term fluctuations of temperature and relative humidity have an impact on artworks: Short-term fluctuations, which occur on an approximately daily cycle, will affect the surface more, especially when there is already damage present. Fluctuations, which occur over a longer period, will also affect the inner layers and the support. Therefore, depending on the frequency and amplitude, climatic changes can cause a variety of damage, such as deformation, cracking of the support or loosenings on the pictorial layer. Thus, the question of which climate fluctuations are still safe for the exposed objects can be very complex.

In various research projects, cultural heritage items housed in historic buildings have been examined in situ with opto-technical methods to investigate their reaction to climatic fluctuations [Drewello et al. 2011, Holl et al. 2021]. As climate data were only analysed after the measurements, it is hard to examine the climatic situations which are most harmful to cultural heritage items. For further investigations, test samples are being examined in a climate chamber using climate fluctuations which were measured on-site. For the monitoring a structured light scanner (SLS) is used as well as a balance to record the change in weight.

SLS is a combination of optical triangulation technology (optical distance measurement by angular measurement inside triangles) and interferometry (interaction of waves). The big advantage of this optical method is the fast recording of surfaces at a high resolution [Eipper 2004].

The measurements have been conducted with a COMET L3D 5M structured light scanner by Steinbichler Optotechnik (now Carl Zeiss Optotechnik). With this method, an area of 260 x 215 x 140 mm is scanned, using the 250 mm lens with a point distance of 100 µm. With the

software Comet Plus 9.63, several scans are combined into a single data file. The scans are carried out in rows with a vertical and horizontal overlap of about 50 % between every single scan. This redundant data reduces the matching errors between the individual scans and guarantees a higher geometrical accuracy for each monitoring area [Drewello et al. 2011].

The used climate test chamber ClimeEvent C/340/40/3/M from Weiss Umwelttechnik GmbH can vary the temperature between -42 °C and +180 °C as well as the relative humidity between 10 and 98 % RH. To be able to conduct optical measurements like the SLS while the chamber is running, it was necessary to install an additional glass panel between the chamber and the door (Fig. 1). With this configuration, the climate inside the chamber stays stable during scanning and opening the door of the chamber and does not affect the experiments.

Fig. 1. Climate test chamber ClimeEvent C/340/40/3/M from Weiss Umwelttechnik GmbH with the wood veneer inside. (© Anne Karl, KDWT University of Bamberg).

The period when an artwork reacts to changes in temperature or relative humidity depends on its material and its thickness. This can be seen in an experiment on a wood veneer with a thickness of 0.5 mm (150 mm width, 100 mm height). Coming from a stable climate condition at 20 °C and 50 % RH, the relative humidity dropped down to 40 % RH.

The reaction of the veneer was measured after 1, 3, 7, 8, and 25 hours. Fig. 2 shows the comparison of the first SLS scan with the other times. To examine the SLS data, two scans of the same surface are compared using the software GOM Inspect Suite 2020. After a manual orientation, the software registers the scans to each other and calculates a “best-fit orientation” (by specifying an error between 0.05 and 0.1 mm). Afterwards, a comparison of the surfaces is carried out. To demonstrate how much the two scans deviate from each other, the software creates a colour-coded image illustrating the deviation. The scale of the false-colour illustration is selected automatically according to the maximum deviation but can be adjusted manually. In this case, a green area means no change; areas, which are coloured yellow (minimum) to red (maximum) indicate a movement to the front, while dark green to blue areas show a warping to the back [Drewello et al. 2011, Holl et al. 2017].

After 3 hours, there is a beginning deformation of about ± 0.6 mm. After 7 hours, the maximum of the deformation is reached, and the veneer moves to the front and to the back. An overall movement of ± 1.0 mm is visible. After 8 hours, the deformation in the middle decreases a bit, but the upper right corner still has a deformation of 0.6 mm. The comparison after 8 and 25 hours is almost identical. This means that a change in humidity of 10 % RH can cause stress / movement within the veneer, which lasts over one day.

The information about the movement of historic (composite) due to changes in temperature and relative humidity is an important step considering the potential of damage caused by fluctuations in climate. But to distinguish between periodic movements and actual damage, further investigation is necessary. One approach could be to expand the measurements with more non-destructive testing methods, such as acoustic emission and time-lapse photography.

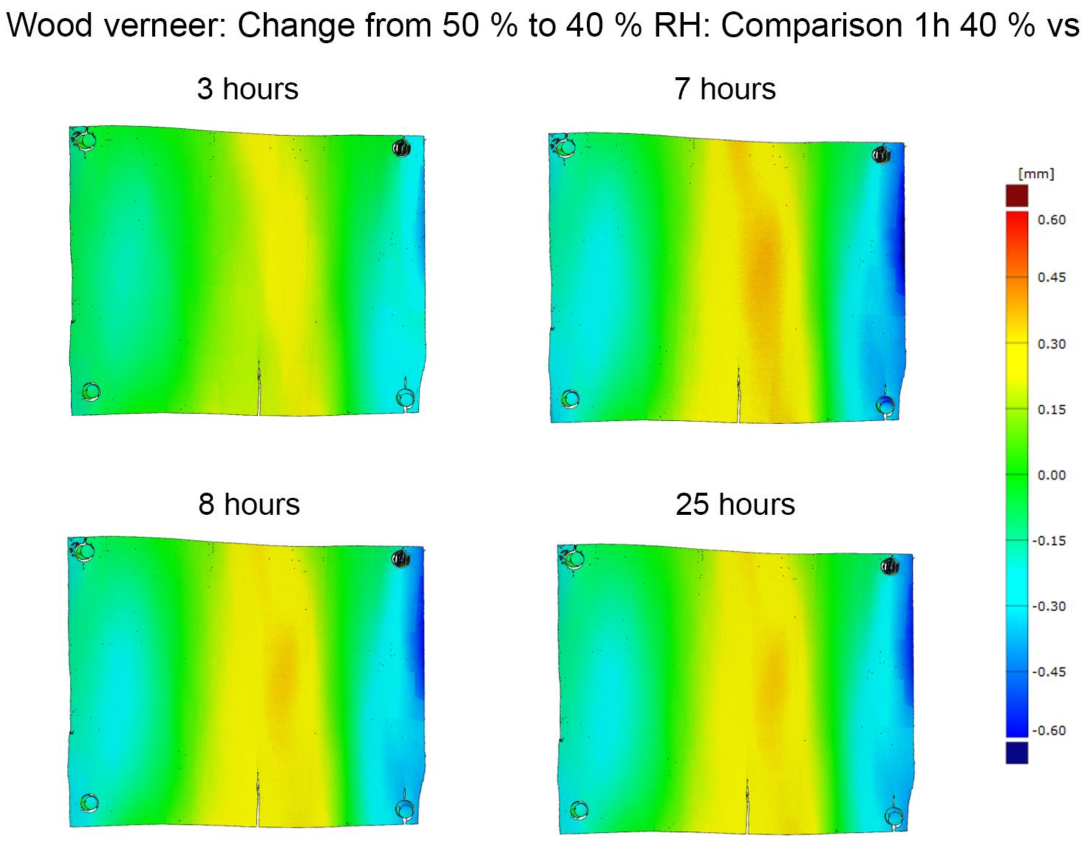

Fig. 2. *Evaluation of the effect of a 10 % climate fluctuation from 50 % to 40 % RH to a wooden veneer. The changes in the surfaces after one hour at 40 % RH are compared with those after 3, 7, 8, and 25 hours. This shows that the highest tension occurs after 7 hours. (© Kristina Holl, KDWT University of Bamberg).*

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Author Contributions

Conceptualization:
Data curation:
Formal Analysis:
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Methodology:
Software:
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Writing – original draft:
Writing – review & editing:

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