



HAL
open science

Permanent deformation of wooden panel paintings: what is the contribution of residual drying stresses?

Romain Remond, Patrick Perré

► To cite this version:

Romain Remond, Patrick Perré. Permanent deformation of wooden panel paintings: what is the contribution of residual drying stresses?. Eurodrying'2013, Oct 2013, Paris, France. hal-01804830

HAL Id: hal-01804830

<https://hal.science/hal-01804830>

Submitted on 1 Jun 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Permanent deformation of wooden panel paintings: what is the contribution of residual drying stresses ?

Romain Rémond¹ and Patrick Perré²

¹ Laboratoire d'Etudes et de Recherche sur le Matériau Bois (LERMAB),
Université de Lorraine-ENSTIB,
27 Rue du Philippe Seguin
88026 Epinal, France
romain.remond@univ-lorraine.fr

² Laboratoire de Génie des Procédés et Matériaux (LGPM)
Ecole Centrale Paris
Grande Voie des Vignes
Châtenay-Malabry, France
patrick.perre@ecp.fr

ABSTRACT. This paper analyses the possible effect of residual drying stresses on the permanent deformation of panel paintings. For this purpose, experiments were done, during which samples were submitted to several adsorption-desorption cycles to reproduce what could happen in real climatic conditions. The painted side is regarded in this work as a sealed surface that is mimicked by insulated some faces of the sample with an aluminium sheet. The asymmetry of the moisture content profile generates a global curving of the sample section that is followed over time. Results show that humidity variations in the surrounding, because acting on one single face, reduce the residual drying stress by activating the mechano-sorptive creep. This effect gives rise to a concave cupping towards the non-painted face. This deformation does not disappear as the moisture content becomes uniform across the panel.

KEYWORDS: Panel paintings, wood drying, drying stresses, mechano-sorption, flying wood test.

1 Introduction

Panel paintings are generally compounds products made of a dry wooden support with a coated side that underwent several preparation layers before receiving the painting and final varnish. The painting of Mona Lisa is certainly the most famous example (Mohen 2006). Hence it follows that the painted face depicts a much lower permeability and diffusivity to the moisture flow than the opposite face. Further, as the vapour diffusion through wood is not instantaneous, a moisture gradient occurs within the panel. This gradient induces unsymmetrical dimensional changes (shrinkage/swelling), which turns into internal stresses. It may cause damages such as deformation, cracks in wood, cracks in decorative layers (Lukomski 2012, Colmar 2011, Dionisi *et al.* 2006). Today, some panel paintings depict permanent deformation such as concave cupping (Mohen 2006, Colmar 2011, Lukomski 2012). Some works tried to explain these shapes by using a computational model to simulate the hygromechanical phenomena within the panels over long time. However, they assume that the panel was flat when the decorative layers were applied and that a zero-stress field existed in the initial configuration. The main objective of this work was to analyse the possible effect of the residual drying stress on the permanent deformation of panel paintings.

2 Materials and Methods

2.1 Materials

The vegetal material

Tests were conducted on fresh flatsawn (F) and quartersawn (Q) boards of *Quercus robur* obtained from trees from a natural stand in the Vosges, France. Three specimens were prepared from the same board (Fig.1): (i) sample A is 5 mm thick and had five insulated faces before drying so that the moisture migration occurs in only one direction. These faces were insulated by applying an aluminium sheet coated with an epoxy resin; (ii) sample B is 10 mm thick and only its lateral faces were insulated. This is the reference specimen; (iii) sample C is similar to the reference sample at the initial stage but five faces were insulated at the end of drying to simulate the painting layers. Samples are 150 mm in longitudinal direction and 100mm wide in radial direction (quartersawn) or tangential direction (flatsawn).

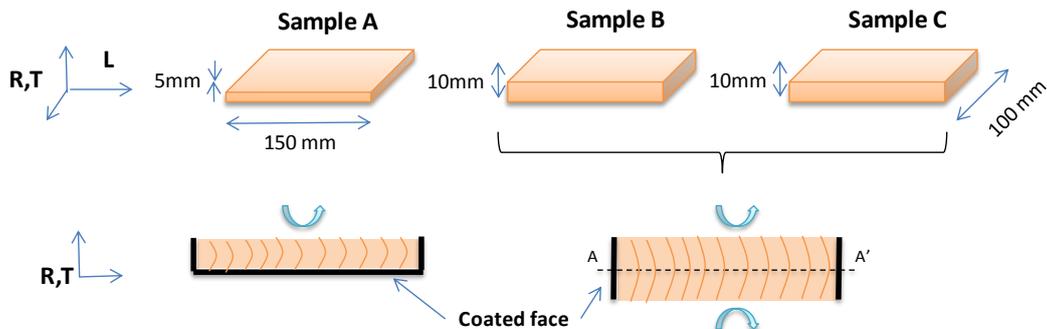


Fig. 1. Sawing pattern and dimensions of samples. The coated surfaces at the initial state are indicated by the thick black lines.

The climatic chamber

The relative humidity in the climatic chamber is controlled through the temperature of a water film, set at the dew point that flows at the bottom of the chamber. Electrical resistances controlled by a PID regulator heat the airflow at the top of the chamber to maintain the desired dry bulb temperature (Zohoun and Perré 1997). A ventilator generates an air circulation between an upper volume where the specimens are placed and a lower volume with a bath containing distilled water.

The measure of the global section curvature

An electrical displacement sensor measures the section curvature. The design required different tricks to ensure permanent contact between the sensor head and the sample face without force. This device was developed by Aguiar and Perré (2000). Additionally, the mass of the sample is measured continuously by a stress gauge glued onto the sample support. In this way, the evolution of the average moisture content can be estimated during the drying test.

2.2 Methods

In a first stage, all fresh wood samples were dried at constant drying conditions with a dry bulb temperature at 25°C and a dew point at 9°C. This results in an equilibrium moisture content value (EMC) of about 6.5%. The dissymmetrical drying of sample A allows one part of drying stresses to be converted into a global section deformation, which is measured continuously with the Aguiar and Perré's device.

At the end of drying, five faces of sample C were insulated to simulate the painting layers at the surface of the panel. Thereafter, several adsorption–desorption cycles were applied to reproduce what could happen in real climatic conditions. The dry bulb temperature is maintained at 25 °C and stepwise variations of the dew point were imposed between approximately 9°C and 18°C with a period of more than one day (EMC variations between 6.5% and 11%).

Figure 2 depicts the climatic conditions applied around the samples during drying and the mass loss of samples A. Noted that the temperature overshoots (red dashed line for wet bulb temperature) at 290 h (Fig.2) are only due to a lack of water in the wet-bulb thermometer.

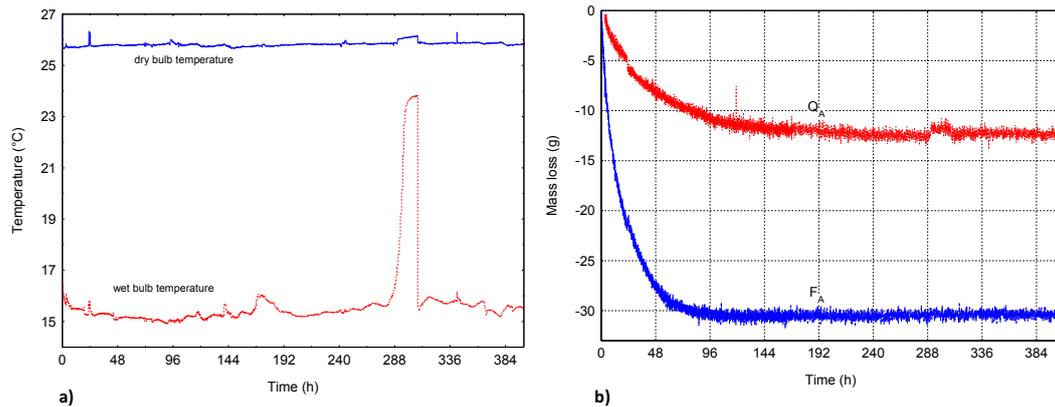
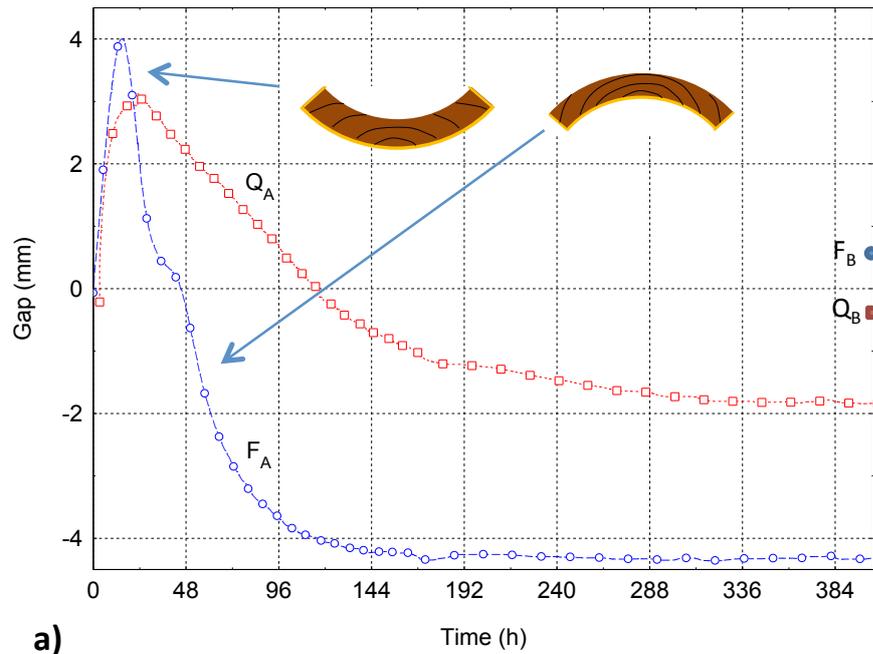


Fig. 2. Climatic conditions inside the chamber during the drying stage (a) and mass loss during drying for samples A (for quartersawn (Q) and flatsawn (F) boards) (b).

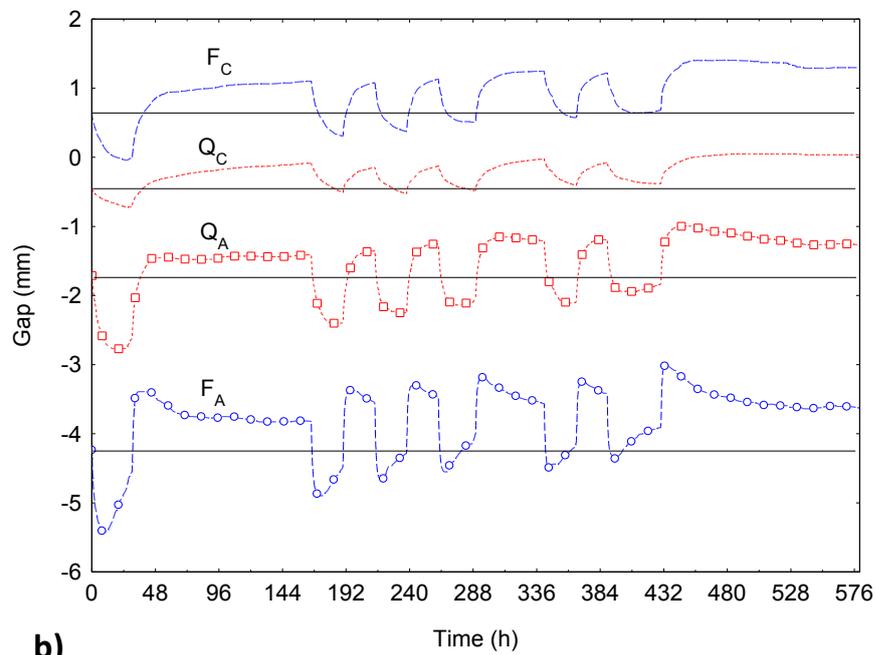
3 Results and discussion

Figure 3 depicts the global curvature of sample A as a function of time. During the drying stage (Fig. 3a), bound water is removed near the exchange surface: the drying rate reduces and, due to shrinkage, the curvature becomes positive. The curvature increases to a maximum curvature. Notice that the maximum curvature reached by the flatsawn board is greater than the quartersawn board, which can be easily explained by the higher shrinkage value in the tangential direction. When shrinkage occurs near the impervious face, the sample comes back to a flat shape and finally acquires a negative curvature that is a consequence of the well-known phenomenon of stress reversal due to viscoelastic and mechano-sorptive creeps. At the end of drying, the negative curvature of sample A is the consequence of residual drying stress and creep strain within the specimen. Consistently, almost no curvature occurs for sample B, which has undergone symmetrical drying conditions (Table 1).

During the post-drying stage, the variations of humidity in the surrounding air change the moisture content of the sample near the exchange surface. These moisture variations activated the mechano-sorptive creep, which reduces the residual drying stress (Table 1). For samples A, the global curvatures decrease. For samples C, this local stress relaxation induced non-symmetrical stress profile through the thickness, which explains the gradual increase of the global curvature along the cycles (Fig3.b). It is important to notice that this deformation does not disappear once the moisture content is uniform across the panel. This "permanent deformation" was observed whatever the sawing pattern.



a)



b)

Fig. 3 a) Evolution of the gap at the half-width of sample A section (Flatsawn (F), quartersawn (Q)) during drying with constant conditions ($T=25^{\circ}\text{C}$, $\text{EMC}=6.5\%$). b) Evolution of the gap of samples A and C during adsorption-desorption cycles ($T=25^{\circ}\text{C}$, $\text{EMC} = 6.5\%-11\%$)(b).

Table 1. Evolution of the transversal section of boards for the different configurations.

	Sample A (5mm)	Sample B (10mm)	Sample C (10mm)
Convective drying	Initial State and 1st drying period 		
	2 nd drying period with tensile stress close to the exchange surface 		
	End of drying Stress reversal 		
Adsorption /desorption cycles	State after several cycles 		

4 Conclusions

In the present work, the possible effect of the residual drying stress on the permanent deformation of panel paintings were studied by experimental investigations. Results show that moisture variations on one single face of the panel reduce the residual drying stress by activating the mechano-sorptive creep which turns into concave cupping (towards the non-painted face).

Obviously, the permanent deformation of wooden panel paintings results of the history of moisture variations, the modifications of the material properties over decades or centuries, etc. Some confrontations with theoretical results will be made to validate a computational model capable to explore the behavior of panels over a longer time.

5 References

- Aguiar O., Perré P. 2000 – The "flying wood" test used to study the variability of drying behaviour of oak, 2nd Workshop of COST Action E15, "Quality Drying of Hardwood", Sopron, Hungary.
- Brandao A., Perré P., 1996 – The Flying Wood - A quick test to characterize the drying behaviour of tropical woods, 5th International IUFRO Wood Drying Conference, Québec.
- Colmar J., 2011 – Hygromécanique du matériau bois appliquée à la conservation du patrimoine culturel : Etude sur la courbure des panneaux peints. PhD thesis, Université Montpellier 2.

Dionisi Vici P., Mazzanti P., Uzielli L., 2006 – Mechanical response of wooden boards subjected to humidity step variations: climatic chamber measurements and fitted mathematical models, *Journal of Cultural Heritage* 7: 37–48.

Lukowski M., 2012 – Painted wood. What makes the paint crack? *Journal of Cultural Heritage* 13s: S90–S93.

Mohen J., Menu M., Mottin B., 2006 – *Mona Lisa: Inside the Painting*, Abrams New York.

Zohoun S., Perré P., 1997 – Mesure en régime permanent de la diffusivité massique du bois dans le domaine hygroscopique: présentation du système “PVC-CHA”. *Les cahiers scientifiques du bois-Instrumentation. ar.bo.lor. Nancy, a.r.bo.lor, 1, 212 p.*