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Original article

Distorted oil paintings and wax-resin impregnation – A kinetic study of moisture sorption and tension in canvas

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ABSTRACT

Wax-resin impregnation and lining are former widely used conservation methods. It is well-known that these methods slow down moisture diffusion into the canvas and changes the corresponding development of tension. However, the rate at which these processes happen are not well characterized and it is therefore unclear how long treated paintings are protected from high moisture environments. In the present work, moisture sorption characteristics of wax-resin impregnated linen samples were measured using dynamic vapor sorption (DVS) and tensile tests. Samples of untreated linen, wax-resin impregnated linen and Berger's Ethyl Vinyl Alcohol (BEVA) treated linen as well as an aged wax-resin treated lining canvas from 1958 were measured. The samples were in equilibrium at 42% relative humidity at 23 °C in DVS and tensiometer when the relative humidity was stepped to 69% RH while monitoring the development of mass and tension respectively in the canvases. This showed that there is no or little delay from the time moisture is taken up by linen fibers until swelling and the possible tension build up sets in. Both wax-resin impregnated and non-impregnated samples took up moisture when the relative humidity was stepped up, but the wax-resin impregnated samples did so at a much slower pace than the non-impregnated ones. Tension built up in some canvas samples already at 69% relative humidity whereas others stayed unaffected until a relative humidity of 82% was reached. The findings confirmed that a fine weave canvas, tightly spun thread and the presence of wax-resin matrix in the voids between fibers all are factors that characterize a painting at risk of climate related shrinkage damage. It was also demonstrated that BEVA gel treatment had very little effect on the rate of moisture sorption as there was no penetration of the canvas. In the aged lining canvas, moisture was taken up at a rate that was intermediate between untreated and wax-resin impregnated linen, which was ascribed to cracks in the wax-resin coating.

1. Introduction

A wax-resin mixture is virtually non-responsive to changes in relative humidity (RH) and was therefore previously thought of as a suitable material for impregnating or lining canvas paintings that would be exposed to humidity fluctuations. However, the adverse consequences were reported early on [1–4] and many western European conservation studios discontinued the use of the technique in the 1970s and 80s [5]. Apart from colour change, weave interference and flattening of impastos conservators have also seen bulging and delamination in wax-resin treated paintings as a result of fluctuating RH because of contraction in the canvas [6]. Thus, the treatment that was supposed to help valuable paintings withstand poor climate conditions could in fact have an adverse effect. An example is given in Fig. 1 showing buckles in a painting from Master and Fellows of Trinity Hall, Cambridge that had been strip lined with wax-resin along the edges [7].

A large number of highly valued paintings in collections worldwide have received a wax-resin impregnation or lining and are at risk of suffering problems similar to those in Fig. 1 if not kept in strictly controlled environmental conditions.

Previous research has been carried out in order to try to understand the physics behind wax-resin impregnated canvas. Tassinari showed that an unrestrained a wax-resin impregnated hemp canvas can contract at high RH [8]. It was later shown that restrained wax-resin lined canvas paintings sometimes respond to high RH by building up tension [9]. These forces, induced by moisture uptake, will increase the risk of distortion and delamination in wax-resin

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Fig. 1. Gerald Festus Kelly, Lord Chancellor F.H. Maugham PC (1866–1958), circa 1939. Detail on raking light (lit from left) before treatment. By permission of the Master and Fellows of Trinity Hall, Cambridge. ©The Hamilton Kerr Institute. The painting shows bulging as a result of a local wax-resin treatment. In areas without wax-resin there was no bulging.

lined paintings [10]. Whether a painting will be damaged depends on its general propensity to shrinkage as well as the mechanical properties of the wax-resin impregnated painting structure and on weave geometry of the canvas [11]. The reason why wax-resin treated canvas is more at risk of shrinking than untreated canvas is explained by the fact that the wax-resin matrix takes up space in the weave structure and thus enhances the effect of the swelling of the fibers when they adsorb moisture [9]. A study has furthermore shown that tension in wax-resin impregnated canvas over extended periods of time can lead to stress relaxation [12] which will further increase the risk of bulging. The purpose of wax-resin treatment was to protect the painting from the degrading factors such as moisture [6]. Although this was not fully achieved, the treatment will affect the kinetics of moisture sorption. Furthermore, the damage that the developed forces will do depend on the rate at which they are introduced. Forces that are introduced over a longer period of time, for example due to changes in the ambient climate, will often lead to distortion instead of failure in the painting structure [7]. Therefore, it becomes important to understand the kinetics of the processes involved.

2. Research aim

The research questions that are addressed in the present study concerns the interaction between humidity in air and painted canvas and the performance of moisture barrier conservation treatments aimed at stabilizing paintings towards fluctuating climate. The aim is to measure moisture sorption and tension build up in a range of differently treated canvas samples. A procedure for studying moisture sorption kinetic has been developed based on the time resolved mass response of a canvas sample to an instantaneous RH change, using a DVS instrument. This allows the comparison of different moisture barrier conservation treatments, which is useful in the field of paintings conservation. A well-known problem for wax-resin lined paintings that have been exposed to severe climate fluctuations is the deformation of the impregnated paintings. This may be due to changing dimensions of the underlying canvas caused by moisture sorption and desorption over time. This question is explored by measuring tension in different canvas samples as a function of time after an instantaneous RH change.

3. Materials and methods

3.1. Samples

Three kinds of pure linen canvas were chosen for the experiment as shown in Fig. 2 these were open weave (CTS, Italy, piece No. 2297)[1], close weave (Ulster Weavers, quality 3151, piece No. Z4377)[2] and fine weave (Ulster Weavers, quality 1940)[3]. These were impregnated by first applying warm wax-resin mixture to the canvases and then melting the mixture into the fabric using a hot iron. Surplus wax-resin was scraped off from the back of the canvas with a spatula and the canvas was then ironed again on the back. The applied wax-resin mixtures were 70% by weight of bleached pure beeswax from Nidaros Handelshus and 30% by weight of dammar resin from Kremer Pigmente. For the fine canvas, mastic resin from Københavns Farvehandel was used since these early tests were initially done for a different test purpose.

For the Berger's Ethyl Vinyl Alcohol (BEVA) treated samples, three weight parts BEVA gel 371 Hot Sealing Adhesive from CTS 87030 from Kremer was thinned with four weight parts petroleum benzine (boiling point 80–110 °C). The solution was applied to the tensioned open weave canvas with a brush and the solution was ironed at 75 °C in order to smoothen it and allow the mixture to penetrate the canvas structure. The BEVA gel did not penetrate but was distributed as a discrete layer coating the canvas surface.

Two samples, referred to as Ma1 and Ma2, from an aged wax-resin impregnated lining canvas[4] were taken in connection with a relining of a series of wax-resin lined paintings. The paintings selected from Bernstoff Castle, Denmark named "Scenes from the Park" were painted in 1765 by Johan Edvard Mandelberg.

The samples investigated are listed in Table 1. Canvas type, impregnation type and direction of tensiometer measurement is given together with a systematic name for each e.g. UnOpWe is an untreated, openweave canvas tested in the weft direction. This system is used throughout the present paper.

3.2. Instrumentation

Dynamic vapour sorption (DVS) measurements were carried out using an Aquadyne 2 DVS instrument from Quantachrome. Samples were placed on the balances and allowed to equilibrate for 5–15 days in the controlled climate of the DVS sample chamber at a constant 42% RH and 23 °C until constant mass was attained (40% RH and 21 °C in the case of UnCl smp2 and WaCl smp2). The humidity was then switched to 69% RH at 23 °C while logging of the sample mass was continued.

[1] Open weave: 9 warp threads pr cm (thickness: 0.5–0.7 mm); 11 weft threads pr cm (thickness: 0.4–0.6 mm). Cover Factor = 0.73

[2] Close weave: 19 warp threads per cm (thickness: 0.4–0.7 mm); 16 weft threads per cm (thickness: 0.5–0.7 mm). Cover Factor = 0.99

[3] Fine weave: 26 warp threads per cm (thickness: 0.2–0.4 mm); 24 weft threads per cm (thickness: 0.2–0.3 mm). Cover Factor = 0.90

[4] Lining canvas: 11 warp threads per cm (thickness: 0.5–0.8 mm); 8 weft threads per cm (thickness: 0.4–0.7 mm).