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M. Kaliske and J. Eberhardsteiner (Eds.)

EUROMECH Colloquium 556
Theoretical, Numerical, and Experimental Analyses in Wood Mechanics

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Chairmen

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Contributions

The Mona Lisa Project: an update on the progress of measurement and monitoring activities

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1 Introduction

Since 2004 an international research group of Wood Technologists has been given by the Louvre Museum the task of analysing the mechanical situation of the wooden panel on which Leonardo da Vinci painted his "Mona Lisa", possibly between 1503 and 15014. The general purpose of such study was to evaluate influences which could possibly derive from environmental fluctuations in the showcase where the painting is exhibited, and any measure which could improve its conservation conditions. In order to acquire data about the mechanical behaviour of the panel, and to feed and calibrate appropriate simulation models, the team has not only set up a continuous monitoring by means of automatic equipment, but has also performed manual measurements on the occasion of the annual openings of the showcase where the masterpiece is conserved and exhibited.
The "Mona Lisa" (Fig. 1) is painted on a panel of Poplar wood (*Populus alba* L.) ~79 x 53 cm, ~ 13 mm thick, is inserted in an Oak frame (*châssis-cadre*), and is slightly forced against it by means of four crossbars, which hold it flatter than it would be if unconstrained. Panel and *châssis-cadre* are inserted in a wooden gilded frame, the only visible by the public.
In 2006 a book was published [1] offering a wealth of scientific studies and researches concerning the "Mona Lisa", including the work performed by the Wood Technology Group. Also in 2006 a detailed report about finite-elements simulation model was presented [2].

2 Development of measurement and monitoring techniques

The panel's shape has been determined through manual measurement of its deflection in several points, by means of a mechanical comparator (0,01 mm) and a reference bar. Although it was improved by adding some facilitating equipment, this technique is slow, and allows surveying only a limited number of points; some optical techniques (including Shadow Moiré Technique, Fringe Pattern Profilometry, and Monitoring Optical Markers) have been developed and tested, and their ability to replace manual measurements and provide numerous geometrical data has been demonstrated [3].
Until 2013 the forces exerted between panel and crossbars have been measured manually; however the results were somewhat uncertain, due to the numerous disturbing factors. Accurate and reliable data were recently obtained thanks to the improvement of monitoring equipment, mentioned hereafter.
The deflection variations along time were initially measured by means of only one deformation transducer, located on a reference aluminum profiled crossbar fixed on the châssis-cadre. A special pivoting lever was designed to gain space (only 15 mm thickness allowed). Two further transducers have been added later, providing records of both (a) transversal deflection at the panel's center with reference to the lateral edges, and (b) longitudinal deflection with reference to the châssis-cadre.

Forces exerted by the crossbars on the rear face of the panel were initially monitored on two locations, at the two ends of the upper crossbar, by means of two sub-miniature load cells incorporated into the crossbar thickness, contacting the panel back face through a Teflon articulated head. Since 2013 four improved sub-miniature load cells replaced the previous ones at the four corners of the panel, providing a more complete, accurate and reliable monitoring. Fig. 3 shows the completed most recent assembly: the panel in the châssis-cadre in the frame, the new 2013 crossbars carrying four load cells, and the aluminium crossbar carrying data-loggers, transducers and instrumentation. Such system also provided opportunities for additional quite significant measurements, including (a) variation of forces on panel during its unhooking or hooking, handling, extracting or inserting in châssis-cadre and frame, (b) transition between exposure to different climatic conditions, at the end of the annual opening day, and (c) measurement of elastic parameters of the panel, by tightening or loosening the crossbar's action. Force monitoring could also be used for warning against excessive load on the Panel.
Contact forces between panel and châssis-cadre have been localized and estimated on the basis of local contact pressures, recorded by tests with a pressure-sensitive foil [4]. The monitoring data are automatically read every 20 minutes, stored in a data-logger, and downloaded on the occasion of the annual openings of the showcase.
The results of the above mentioned measurements are being processed and fed into the simulation software which in turn is being developed to allow for an improved simulation - and validation - of the panel's behavior under environmental fluctuations.

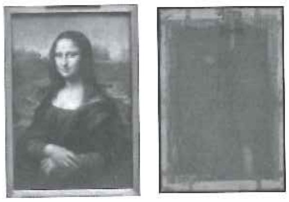

Fig. 1 - The painted face and the back face.

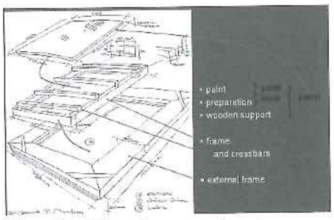

Fig. 2 - Panel, crossbars, châssis-cadre, frame.

Fig. 3 - Completed assembly since 2013 (see text).

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