Structure, mock-up model and environment-induced deformations of Italian laminated wood parade shields from the 16th century

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STRUCTURE, MOCK-UP MODEL AND ENVIRONMENT-INDUCED DEFORMATIONS OF ITALIAN LAMINATED WOOD PARADE SHIELDS FROM THE 16TH CENTURY

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Abstract

Round shields made of laminated wood were widely used in Italy in 15th – 17th centuries for tournaments, parades and exhibitions. The manufacturing techniques originally used are not known from literature nor from any still living tradition. This paper describes: (a) a structural analysis of the shield on which Caravaggio painted his well known *Medusa* (1598); (b) the recently completed construction of a mock-up shield, manufactured with materials and techniques reproducing as much as possible the supposed original ones; (c) the initial results of monitoring performed both on (i) an original shield exhibited in the Museo Bardini in Florence, and (ii) the above mentioned mock-up shield, placed in climatic chambers at DISTAF.

1. Introduction

The well known *Medusa* (Fig. 1) exhibited at the Uffizi Gallery in Florence, was painted in 1598 by Caravaggio (Michelangelo Merisi, 1571-1610) on a convex round wooden shield, approximately 580 mm in diameter. Shields of this type were widely used in 15th – 17th centuries for tournaments, parades and exhibitions; in some cases they were painted with the same techniques as "flat" panel paintings, in other cases they were covered with paper or sheepskin, and decorated with coats of arms or other kinds of drawings or paintings. The manufacturing techniques originally used are not known from literature nor from any still living tradition, but some realistic hypotheses, possibly not far from truth, can be derived from close examination of the existing shields, and from the present knowledge of wood technology and of woodworking techniques. The actual geometrical shape of most existing original shields is not exactly a spherical segment, as supposedly it was at time of their manufacture, but is distorted so it looks similar to a tortoise shell (see below).

As most wooden artworks exposed to environmental variations, these shields uptake/release moisture, and hence their distortion increases/reduces, possibly influencing negatively the well-being and conservation of the artwork; since with time the painted or decorated layers tend to become more fragile, and can not follow without serious risks of damage the contractions/expansions of the wooden support, environmental variations are now especially dangerous. One of the most efficient conservation practices consists therefore in keeping the environment as stable as possible; however scientific knowledge of the climate/deformation relationships can also be very helpful, in order to allow for an evaluation of most favourable climatic environment, based on objective and reliable data. Understanding and describing, both empirically and mathematically, the climate/deformation relationships for this kind of support is even more complicated than for "flat" panels, because of the complex shape of the shields and their laminated structure. As a first step, the authors are carrying out empirical observations of the environment-related deformational behaviour.

This paper has the following main objectives:

1) to provide information about the structure of the shield on which Caravaggio's *Medusa* was painted;
2) to describe the recently completed construction of a mock-up shield, manufactured with materials and techniques reproducing as much as possible the supposed ones (according to authors' judgement);

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3) to report about the initial results of monitoring being performed both (a) on an original shield exhibited in the Museo Bardini in Florence, and (b) on the above mentioned mock-up shield, placed in climatic chambers at DISTAF.

2. The medusa shield

2.1. The structure of the shield

In 1998, we were asked by the Director of the Uffizi Gallery to analyze the wooden structure of the *Medusa* shield (Fig. 1), at that time under restoration.

Fig. 1 – The Medusa's truncated head, painted by Caravaggio in 1598 on a wooden shield approximately 580 mm in diameter.

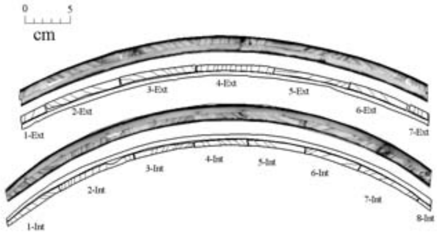


Fig. 2 – Two perpendicular cross-sections of the shield, obtained by Computed Tomography: the upper CT scan is on the smaller ("horizontal") diameter, whereas the lower CT scan is on the larger ("vertical") diameter. Drawings placed under CT scans put into evidence the longitudinal and transversal cross-sections of lamellae, and the random orientation of growth rings.

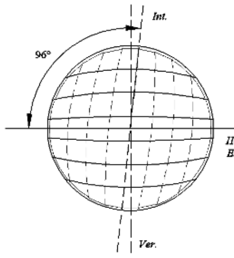


Fig. 3 – The reciprocal orientation of the two approximately perpendicular layers of lamellae.

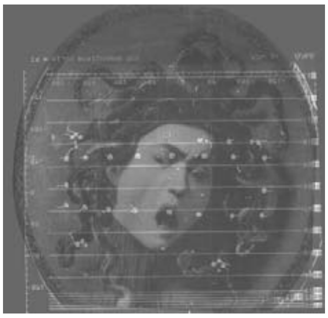


Fig. 4 - The orientation of the painted image, of the strap-holding nails, and of the directions of the lamination's layers. The numbered lines are the traces of the planes along which one series of CT scans was taken.

Fig. 5 – An "exploded" view of the shield's structure.

The growth rings shown are purely fictitious.

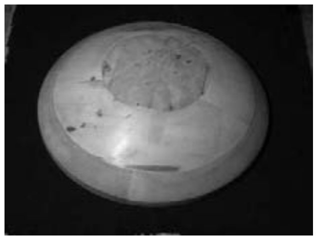


Fig. 6 – The wooden mould shaped (by turning) as a spherical section, to be used for assembling the lamellae.

The following main characteristics of the structure have been derived from direct close observation, from other scientific analyses carried out during restoration, and especially with the support of X-ray Computed Tomography [1] [2] [3] (Fig. 2). The over 80 CT-scan images have been digitally analyzed and reassembled by means of a 3-D CAD software. The resulting "exploded" drawing of the structure is shown in Fig. 5.

- The shield is "tortoise shell" shaped and its perimeter, which is supposed to have been originally circular and laying on a plane, is now slightly elliptical and does not lay on a plane any more; its two perpendicular diameters differ in length (570 mm the larger one, and 550 mm the smaller one); its average radius of curvature is 403 mm, and the dome's height is approximately 115 mm;

- the shield's structure is laminated, made of two layers, glued to each other, of lunule-shaped wooden lamellae (7 in the external layer, 8 in the internal one), approximately 6 mm thick, wide approximately 60 to 92 mm, each layer being approximately perpendicular to the other (Fig. 3, 4)
- the overall thickness of the shield, including the linen and gesso layers, both on the front and on the rear face, is approximately 20 mm, thinned down to approx. 5 mm in the proximity of the perimeter,
- lamellae have straight grain, randomly oriented growth rings, and a constant thickness along both their length and width, indicating that their double curvature derives from a process of deformation, rather than of shaping by means of material removal from a block of thicker wood
- in the normal orientation of the shield, defined both by the painted image, and by the still existing nails which were originally used for fixing the handling straps on the rear, the external layer of the lamellae is oriented "vertically", whereas the internal layer is oriented "horizontally" (Fig. 2, 4)
- anatomical examination carried out by optical microscopy on a wood fragment sampled from the shield during restoration, showed that the lamellae are made of Poplar (*Populus alba* L.) wood ("Gattice" according to Italian standard UNI 2853 [4]).

2.2. Hypotheses about the manufacturing process

We were not able to find in the literature any description of the techniques originally used for manufacturing this kind of shields. Based on the evidence obtained from scans, on present knowledge of wood technology, and on a realistic evaluation of the technical means available at that time, we figured out what the manufacturing process could actually have been. Such hypotheses have been practically implemented, and modified as needed, as described in the following paragraph.

3. The mock-up shield manufactured at DISTAF

Based on the analyses performed, a mock-up of the *Medusa*'s shield has been constructed at DISTAF, reproducing as near as possible its original structure (amount, sizes, location and shape of the original lamellae), overall size and manufacturing techniques. The shape changes of such mock-up model are being monitored by means of electronic callipers with spherical feelers, and of a reference system of "marks" fixed on the shield's surface. Weight changes have also been monitored.

3.1. Manufacturing the mock-up shield

After several tests on the most appropriate procedure, the following practical steps have been chosen, in order to manufacture the mock-shield with simple procedure and equipment.

- individual lamellae, planed at 6 mm thickness from seasoned Poplar (*Populus alba*) modern boards, have been roughly shaped with a band-saw according to drawings made on the basis of the analysis of the original shield
- lamellae have been firstly bent with a "steaming" procedure described below, to a single longitudinal curvature, slightly larger (i.e. with smaller radius) than the final one, to account for a mild post-forming recovery; the mould and counter-mould were easily obtained by sawing a thick wooden board, and then tightened together by means of ordinary carpenter's clamps
- the "steaming" process, carried out on individual lamellae, consisted in (a) soaking the dry lamella in hot water, during approximately 30 minutes, (b) clamping the soaked lamella between mould and counter-mould (Fig. 7), (c) producing quick evaporation of water with a hot air jet (30 minutes at 100 °C was quite effective; in old times, the same result could possibly be obtained by exposing the whole "sandwich" near a fire)
- individual lamellae were then extracted from their "bending" moulds (Fig. 8), and quickly nailed on a wooden "assembling" mould (Fig. 9, 10) turned to the shape of a segment of a sphere, having the "final" desired radius of 403 mm (Fig. 6)
- this nailing process imparted to the lamellae the transverse curvature, needed to fit correctly on to the spherical surface
- the nails (6 for each lamella) were 2 mm in diameter, and were for provisional fixing only, so they were inserted for half of their length, and bent in order to better hold a larger surface of the lamella against the mould (Fig. 10, 11)

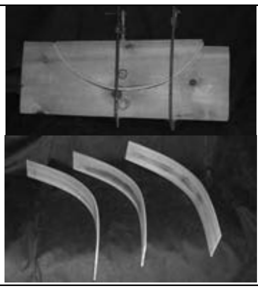


Fig. 7 – A soaked lamella clamped in the "shaping" mould (above) which imparts them a single curvature, and three shaped lamellae (below)

Fig. 8 – After having been shaped with a hand-held smoothing plane, lamellae are successively nailed on the "assembling" mould with provisional 2 mm nails, half-inserted and bent

Fig. 9 – After extraction of nails from first layer, the second layer of lamellae is also provisionally nailed; the hot animal glue is locally applied, so the two layers adhere thoroughly and permanently to each other

Fig. 10 – Shaping and refining by hand the shield, still nailed on the mould.

Fig. 11 – The shield, removed from the mould. The traces of the provisional nails (no more present) are still visible.

Fig. 12 – The rear part of the shield, removed from the mould.

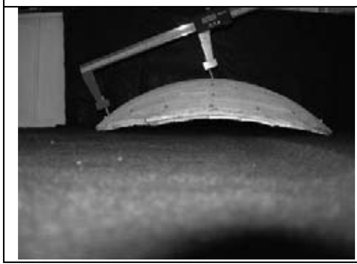


Fig. 13 – Measuring the distance between two reference points, with an electronic calliper (accurate at 0,01 mm)

Fig. 14 – The calliper has been fitted with purpose-made feeler pins, ending with a 3 mm diameter steel sphere

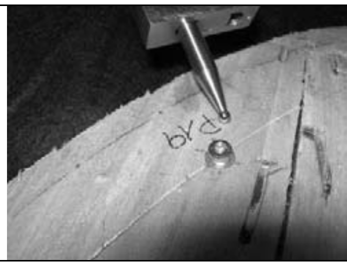


Fig. 15 – The spherical end of the feeler pin fits on top of the hexagonal cavity of the Allen screw, hence identifying a reference point in space, no matter the orientation of the reference screw.

- successive lamellae were shaped in-place with a hand-held smoothing plane, in order to give them the exact taper need to fit against the adjacent ones
- after having completed the first layer, the second layer was applied with the same procedure (Fig. 9), the only differences being that before applying the individual lamellae (a) the nails fixing the previous layer are extracted, and (b) the animal glue is locally applied, so that the two layers adhere thoroughly to each other (gluing along the lamellae's edges only would give no strength to the assembly)
- after completing the assembly the shield, still nailed on the mould, was left for approximately on month in a climatic room (20 °C, 65% RH) to reach Equilibrium Moisture Content with the surrounding air; then its periphery was trimmed to a circumference with a hand-held saw, and surface unevenness were smoothed away with a hand-held plane and/or a chisel (Fig. 10)
- (at this point, after removal from the mould, an original shield would have been ready to receive ground-layers and final decorations)

- several stainless steel screws, 3 mm diameter, with cylindrical Allen head, were then applied along “meridians” and “parallels” of the shield, to be used as reference points for successive dimensional monitoring (Fig. 13, 14, 15).
- After approximately one month, the shield was removed from the mould, after having carefully extracted the provisional fixing nails (Fig. 11, 12).

3.2. Monitoring weight and shape variations of the mock-up shield

Monitoring of variations of shape and weight of the mock-up shield was carried out during several months, from June 2008 to September 2008.

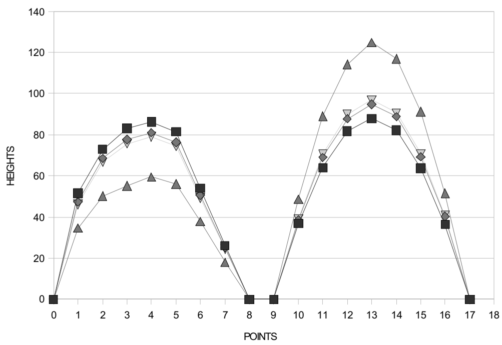
The following significant points in time can be identified:

In climatic chamber “A” (“normal” climate: 20 °C, 65% RH)

- while the shield was still nailed on the mould, and EMC was reached
- immediately after the shield was un-nailed and removed from the mould
- after it reached equilibrium shape
- In climatic chamber “B” (quite “dry” climate: 30 °C, 40% RH)
- when the shield was moved from chamber “A” to chamber “B”
- when it reached equilibrium shape and weight in the new climatic conditions.

Analysis of collected data, here omitted for the sake of brevity, shows that:

- the only significant change in shape during the conservation in chamber “A”, at constant EMC, was observed at removal from mould; the “vertical” diameter (i.e. the one parallel to the external layer of lamellae) increased, whereas the perpendicular diameter decreased → the global shape changed from a spherical segment to a “tortoise shell” shape, also observed in most existing original shields
- a second significant change in shape showed up while reaching EMC in the new climatic conditions: lowering the wood Moisture Content produced an increase of the “vertical” diameter, and a decrease of the “horizontal” diameter (Fig. 16).



nailed on the mould
removed from the mould
stabilized in Chamber “A”
stabilized in chamber “B”

X-axis: standardized diameters
Y-axis: height of the measured points (mm)

Fig. 16 – Schematic profiles of the mock-up shield recorded at selected significant points in time, along the “vertical” (right) and the “horizontal” (left) diameters

4. The monitoring performed on an original shield in “bardini” museum

One of the shields conserved in the Bardini Museum in Florence (inventory n. 408), very similar to *Medusa*’s one, has been monitored during several months by means of a purposely conceived and implemented “deformometric kit”, automatically measuring every 15 minutes the length variations of two perpendicular diameters, and the climatic parameters (temperature and RH) of the surrounding air. The measuring apparatus and some initial results deriving from such monitoring activities are briefly described in Fig. 17, 18, 19, 20. During restoration a very small wooden sample was collected, and the wood species was determined by microscopical examination as Poplar (*Populus alba* L.). The recorded deformations (Fig.21, 22) show significant variations especially of the smaller diameter (the “horizontal” one, according to the terminology used above), whereas the larger diameter (the “vertical” one) varies only by very small amounts.

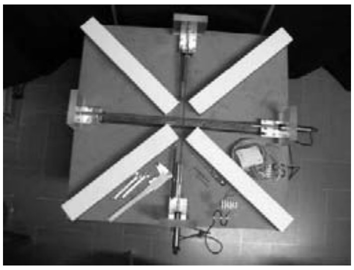


Fig. 17 – The “deformometric kit”, purposely designed and built for monitoring this kind of shields. Four Plexiglas feelers slide freely on perpendicular low friction rails.

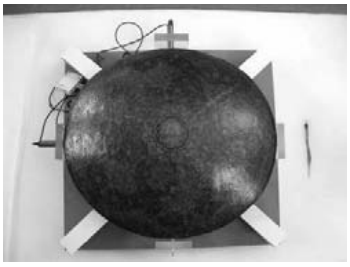


Fig. 18 – The shield 408 mounted on the apparatus, in the Bardini Museum (Florence): top view. Two potentiometric transducers (blue) measure continuously the distance between the opposite feelers.

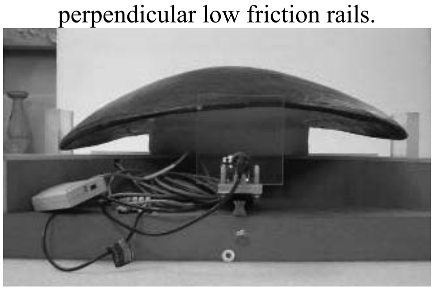


Fig. 19 – The shield 408 mounted on the apparatus: side view, showing the shorter (“horizontal”) diameter. The 4-channel data-logger has self sufficient batteries, which also supply power to the transducers at moment of measurement, which in this case was set every 15 minutes.

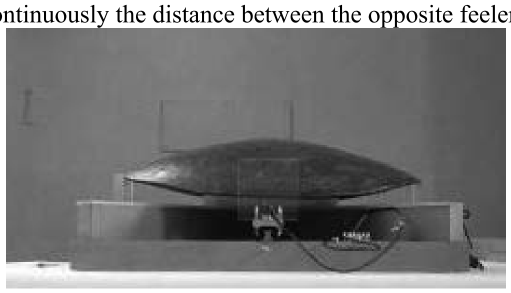


Fig. 20 – The shield 408 mounted on the apparatus: side view, showing the longer (“vertical”) diameter. The shield lays on a plastic soft cushion, the feelers press very gently on its edge. The data logger’s memory, when measuring rate is set at 15 minutes, has a capacity of about 96 days. The battery can last over 1 year.

5. Conclusions

Wood species used for manufacturing the shields

Some art history literature mentions that these shields were made of “Fig” (*Ficus carica* L.?) wood, but no evidence was found to confirm such assumption; on the contrary, the two wood samples positively identified by us showed that the two examined shields (Uffizi’s *Medusa*, and Bardini’s *408*) were both made of Poplar (*Populus alba* L.) wood. In fact, for its technological characteristics Poplar wood appears much more suitable than Fig wood for manufacturing this kind of shields; and experience in manufacturing the mock-up shield confirms this.

Deformations of the shields

Considering the three sets of observations reported above, the following qualitative conclusions may be suggested:

- shield were manufactured on spherical moulds, but subsequent “tortoise-shell” deformation was very likely expected
- shields, as any other wooden artefact, deform (or tend to deform) according to variations of climatic conditions in their environment
- however, due to the peculiar structure, similar to a plywood *ante litteram*, deformations tend to affect more the shape of the whole artefact than the linear dimensions of its surface; this might result in favour of conservation of the paint layers, but further analyses are needed.

More detailed conclusions will hopefully be obtained by structural analysis of the artefacts, carried out by FEM method.

Acknowledgements

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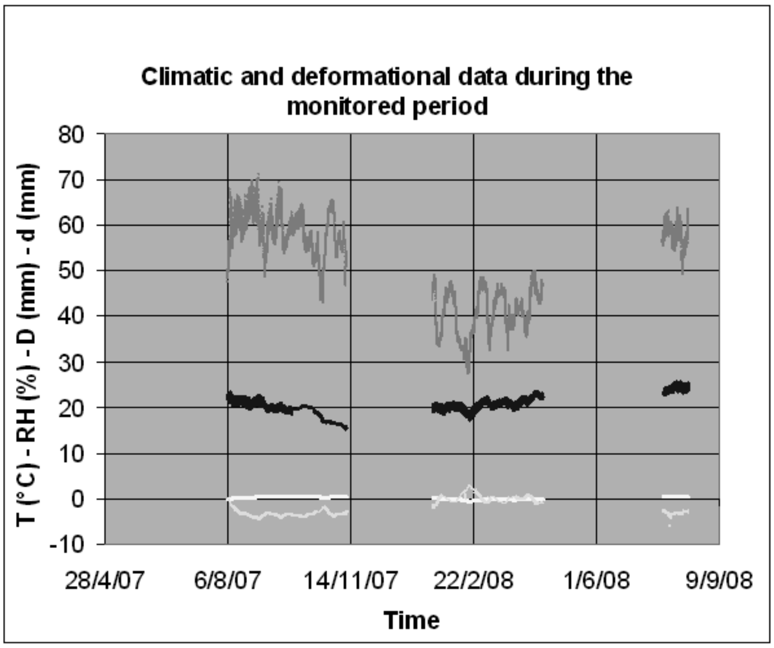

Fig. 21 – Shield 408 in Bardini Museum (Florence) – Climatic and deformational data recorded by means of the "deformometric kit" from June 2007 to September 2008.
Violet = RH (%); Blue = Temperature (°C);
Yellow (D) = Variations of "vertical" diameter (mm);
Blue (d) = Variations of "horizontal" diameter (mm)

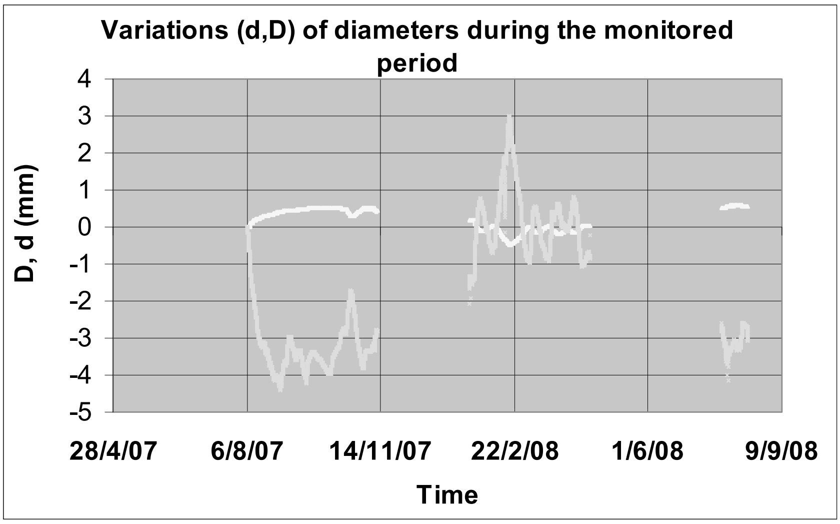

Fig. 22 – Same diagram as Fig. 21, but only diameter variations shown (vertical scale magnified).
"Horizontal" diameter shows larger variations (d): it increases when air RH decreases, and vice-versa.
"Vertical" diameter shows opposite variations (D), but quite smaller.
(Unfortunately, due to technical malfunctions, data from two time intervals were not recorded)

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