Technique and Technology of Creating Wooden Panels in the 17th Century in the Netherlands

The use of ancient carpentry techniques to make a panel painting for a technological replica

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1. Abstract

A 17th-century panel painting is a complex work consisting of many layers, each of which affects its durability and reaction to climatic conditions. This paper focuses on the technology and technique of creating wooden panels in the Netherlands in the 17th century. During this period, wood, especially oak, played a key role in the production of panels, frames, and stretchers.

The analysis of the production history of panels reveals changes in the dominant painting medium - from wood to canvas. Despite the popularity of canvas, wooden panels were still common, especially in still-life paintings. Craftsmen specializing in the production of panels collaborated with artists to create high-quality bases for paintings. Craft guilds controlled production, introducing regulations aimed at maintaining high standards.

Oak, as the dominant raw material, was subjected to a process of felling, sawing, and seasoning. The import of oak wood, especially from Gdańsk, played a key role in the production of panels. The characteristic properties of oak wood, such as annual rings, affected its durability and stability.

The seasoning process was crucial for maintaining the wood's properties, eliminating excess moisture, and increasing its durability. This work analyzes the complexity of the process of creating wooden panels in the 17th century, bringing closer the relationship between artists and craftsmen, as well as the impact of the type of wood and technological processes on the final product.

2. Technique and technology of painters in the 17th century.

2.1 Use and production of oak panels in the 17th century

A panel painting consists of many technological layers (board, canvas, layers of ground, imprimatura, paint layers, and varnish). Each of these layers and their interactions affect the condition of the object. All this influences the sensitivity of the painting to changing climatic conditions and its durability.

Until the 16th century, wood was the dominant medium in easel painting. However, in the 16th and 17th centuries, especially in Northern Europe, there was a stylistic development, and canvas became the preferred medium for paintings. Canvas allowed for the use of larger panel sizes and facilitated the transport of works. However, most still lifes painted in the 17th century in the Netherlands were still created on wood. Typically, the format of these still lifes was small compared to other painting genres.

Wood played an essential role in art as a material for making panels, stretchers, and for making frames. In the 17th century, craftsmen who also made frames for paintings were involved in the production of panels. During this period, more sophisticated profiles and elaborate carvings on frames were introduced, emphasizing their artistic character. The production of wooden panels was usually entrusted to a specialized craftsman. This craftsman was independent of the artist but made panels according to the artist's or the commissioner's instructions. In the case of smaller wooden panels, a carpenter could act directly, without the need for consultation with the artist. However, for more complex panels, cooperation between the carpenter and the painter was essential to achieve the desired effect.

In the 17th century in the Netherlands, many artists often bought ready-made primed panels for painting. The type of ground on these panels varied depending on workshop practices. Typically, the first layer applied by the artist was the imprimatura. Such panels were available in large quantities and were even sold by artist dealers. Before the 17th century, it was mainly art material dealers and craft workshops that applied grounds to panels. The existence of such workshops has been documented in countries such as the Netherlands, Italy, and England.

Craft guilds controlled the production of wooden panels. Guilds were organizations that brought together representatives of various professions related to artistic production, such as lace makers, painters, carpenters, instrument makers, and others. Operating within the guilds, craftsmen were subject to specific regulations and quality standards, aimed at ensuring high-quality products and maintaining a certain standard. In the event of delivering a poor-quality product, the craftsman faced consequences, which were intended to prevent the production of low-quality panels. An example of this was the threat of a fine if the panel maker did not cut out the sapwood.

Cooperation among various craftsmen within the guilds also allowed for the exchange of knowledge and skills, contributing to the development of art and craft. Guild rules and the relationships between different crafts could vary depending on the city or region. Each guild could have its unique regulations and requirements regarding production, thereby applying local and specific approaches to quality control and craft standards.

2.1.1 Oak wood

In the Netherlands, oak was the dominant wood species used for creating painting panels. Oak was readily available in that region, but due to overexploitation, it began to run out. In the 17th century, the construction of an average-sized merchant ship required about 4,000 oaks, leading to the necessity of importing wood. In the first half of the 17th century, Dutch artists used oak wood imported mainly through the port in Gdańsk, usually transported in the form of boards or panels. The Second Northern War (1655-1660) hindered the export of oak wood from Gdańsk. As a result, wood from Poland likely does not appear in painting panels made after 1650, replaced by oak boards from forests in western Germany or the Netherlands.

Oaks are long-lived trees, with some specimens even reaching 1000 years old. In Europe, two varieties of oaks are most commonly found: the sessile oak and the pedunculate oak. The sessile oak prefers slightly warmer climates compared to the pedunculate oak. The sessile oak grows in poorer and drier habitats but requires a milder climate. It is most commonly found in mixed forests. The wood of the sessile oak is lighter and softer than that of the pedunculate oak. The pedunculate oak thrives best in fertile, deep soils. It is commonly found almost throughout Europe. In Poland, it is more common than the sessile oak.

2.1.2 Oak wood and its properties

Oak wood is distinctive for its annual rings, which result from the division of pulp cells during seasonal temperature changes. The clear ring pattern is directly related to the wood's morphological structure. The ring-porous structure of oak wood facilitates the differentiation of annual increments, where vessels with a large lumen are found in the rings in the zones of early wood (spring wood).

The width of the rings is largely dependent on the average annual temperature, which is an indicator of the length of the growing season. Trees of the same species growing in harsher climatic conditions will have narrower rings than a tree growing in a temperate climate. The width of the rings is also influenced by the availability of light and space for the tree; a well-developed, densely leafed crown allows for the formation of wider rings. Soil fertility also affects the width of the annual rings. Depending on the species and growth conditions of the oak, the width of the rings can vary from 2 mm to 2 cm. The width of the rings changes with the distance from the core to the perimeter. Rings closer to the core will be wider than the outer ones. This is related to the fact that as the tree grows, new rings have a larger diameter, while the surface and thickness of the annual growth remain the same as in the case of older rings. Wider rings occur in the thickening at the base of the tree trunk, as well as in its top part. It is assumed that wood with annual increments narrower than 3 mm is considered narrow-ringed. The physical properties of narrow-ringed wood with a regular pattern are better than those of wide-ringed wood. Such wood is characterized by high strength and hardness.

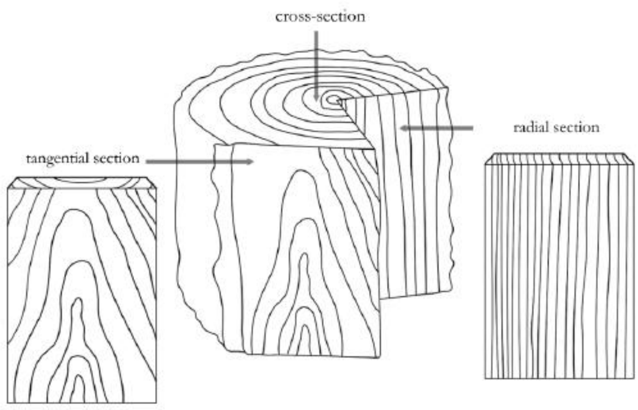

Fig. 1. Diagram of wood cross-sections. Drawing by Marta Hirschfeld.

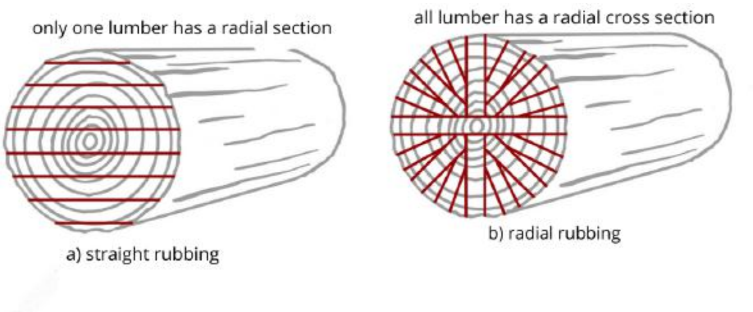

Fig. 2. Types of log cross-sections. Drawing by Marta Hirschfeld.

2.1.3 Tree felling and sawing wood

In the 17th century, trees were most commonly cut down with axes. Splitting wood was a popular method for producing high-quality radial planks, a technique that was common among Dutch and German craftsmen until the 16th century, when the watermill became a more popular tool for cutting large boards. Another way to obtain lumber from a log was by using a saw. The log sawing saw was known in antiquity, later forgotten, and rediscovered in the 14th century.

2.1.4 Seasoning of oak wood

The process of seasoning wood involves drying it to a specific moisture content, suitable for particular applications. This process is especially important for oak wood, which, due to its hardness and density, tends to retain more moisture compared to other species. Seasoning removes excess moisture, resulting in greater durability and stability of the final product. Prolonged seasoning of wood allows for even distribution of moisture and induces chemical changes that fix the internal structure of the wood at the submicroscopic level. The effect of seasoning is the reduction of wood's hygroscopicity and its tendency to swell and warp. Wood obtained from freshly cut trees is saturated with water. Even after the seasoning and drying process, a certain amount of water remains in the wood. How much water is in the wood affects its physical, mechanical, and technological properties. The absolute humidity of wood is a parameter that expresses the percentage of water content in wood relative to its mass in a completely dry state.

In the context of industry and trade, we can divide wood into the following categories:

- **Wet wood** - absolute humidity exceeding 30%.
- **Freshly cut wood** - moisture content from 50%.
- **Air-dried wood** - with moisture content depending on the season and air from 13 to 22%.
- **Seasoned wood** - stored in dry and heated rooms from 4 to 12%.
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For centuries, the practice of air-drying wood under cover has been used, which remains a popular method. During this process, wood is protected from rain and direct sunlight. However, this process is somewhat uncontrolled – in cooler months, wood drying proceeds slowly, while on warm and windy days it accelerates. The drying time of wood from wet to air-dry varies and depends on many factors, such as the species of wood, thickness of the lumber, season, temperature and humidity conditions, exposure to sunlight, and storage methods.

The wood drying process occurs in two stages. Initially, wood is subjected to open-air drying, where it reaches an air-dry state (from 13 to 22%). Once the wood reaches the desired moisture content, it is placed under a roof to protect the lumber from direct precipitation. Cracks in the lumber can occur as a result of uneven shrinkage during seasoning. To prevent this problem, it is important to properly stack the lumber and protect the end parts from excessive sunlight. Drying of the lumber is accompanied by the formation of mainly end cracks. To prevent this, the lumber stacks should be properly arranged.

The trade rules emphasized that wood used for constructing painting panels should be well-seasoned. Based on dendrochronological research, it is known that the seasoning period in the 16th and 17th centuries lasted from 2 to 5 years, while in the 15th century, this process lasted from 8 to 10 years. The properties and behavior of wood were well known to craftsmen who made the panels. Regardless of the wood species, boards that are poorly made, selected, or seasoned can have a detrimental effect on the durability of paintings.

2.1.5 Wood movement

Warping of wood is the process of undesirable deformation, resulting from the influence of moisture changes. When water penetrates between the microfibrils in the cell walls of wood, it causes them to expand and swell. Changes in the dimensions of wood are particularly noticeable in the direction perpendicular to the fibers, where they can reach up to 13% of the original value. Meanwhile, in the radial direction, these changes can be observed to reduce by half, and in the longitudinal direction, they are the smallest, usually below 1%.

When wood remains dry and is only subject to natural fluctuations in air humidity, its dimensional changes are minimal. However, exposing it to more humid air can cause swelling, while the action of dry air can induce wood shrinkage. There is a particular risk of deformation in the case of unevenly distributed moisture in the wood, which can lead to distortions and warping.

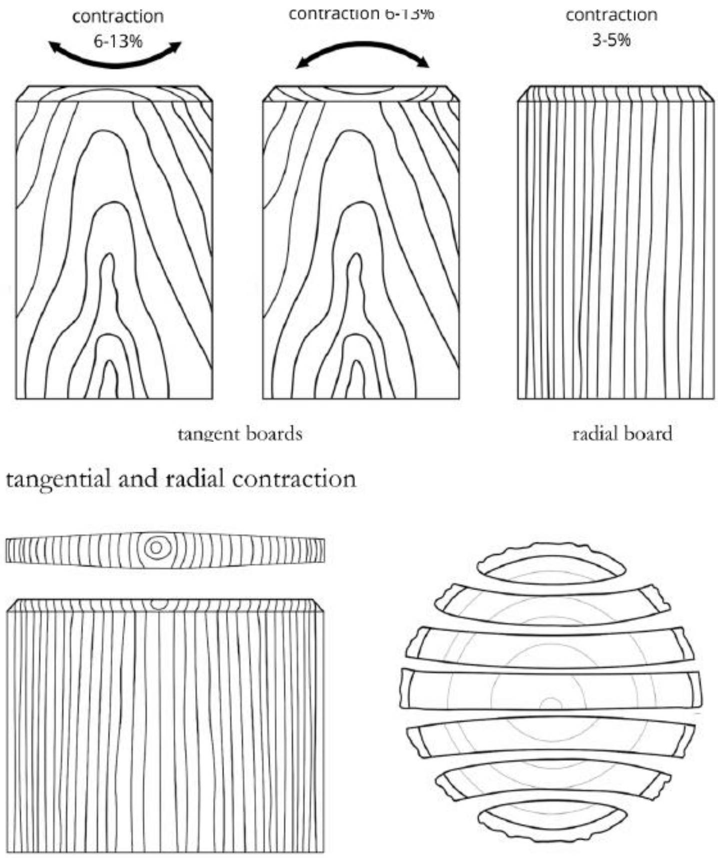

Fig. 3. Wood movement diagram. Drawing by Marta Hirschfeld

Warping of wooden boards is usually the result of two main factors. Firstly, uneven shrinkage in radial, tangential, and longitudinal directions during the drying process can lead to warping.

Secondly, warping can be caused by morphological defects in the wood. Improper or distorted grain patterns and the presence of specific types of wood, such as juvenile or reaction wood, can affect its physical properties. Wood with a heterogeneous structure is more prone to deformation during drying or exposure to varying humidity conditions.

Types of board warping:

a) **A correct board** has all the right angles.

b) **Bulging of the board** appears when one side of the board has higher moisture content than the other side. The expansion of the dimensions of the moist side of the board causes the edges of the fibers to lift. As a result, the board takes on a slight "U" shape. Such a situation can be observed especially when applying mortar or glue to one side of the frame.

c) **Torsion of the board** occurs mainly in the case of boards that contain heartwood and sapwood. The heartwood shrinks less than the sapwood, leading to uneven wood movement.

d) **Bending of the board** into an arc can be a result when one end of the wood curls, twists, or bends relative to the other end. This type of wood deformation can be influenced by drying methods, type of wood, morphological defects, and the way the wood is cut.

e) **Twisting of the board**.

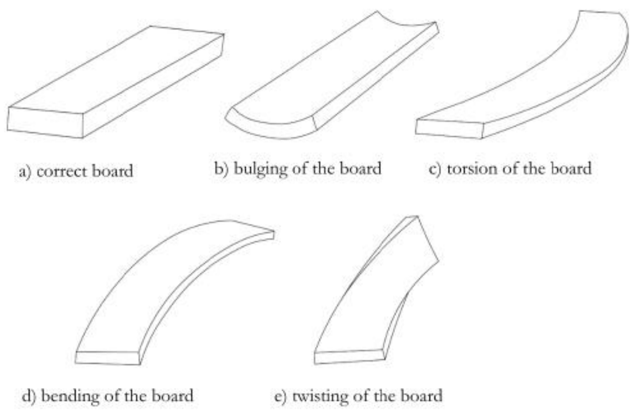

Fig. 4. Types of board warping. Drawn by Marta Hirschfeld.

2.1.6 Wood defects

- **Knots –** are found in places where branches grow. Their presence can affect both the appearance and durability of the wood. Knots disrupt the uniformity of the wood structure for several reasons: their fibers are oriented differently than in the surrounding wood; they are harder; they cause a deviation of fibers in the surrounding wood from the perpendicular direction. All this results in a negative impact on the strength of the wood and can make its proper use more difficult.

- **The core and the oldest annual rings –** are characterized by poorer mechanical properties than the rest of the wood. These parts of the wood are more susceptible to microbiological attacks, as they have a loose and spongy structure, and the core itself is made of thin-walled cells. The presence of the core in a board is considered a defect, as it can negatively affect the durability of the wood.

- **Sapwood –** contains living cells, whereas heartwood consists only of dead cells. Therefore, heartwood is more resistant to microbiological attacks and insect pests. Sapwood is characterized by significantly less durability. Using sapwood to make canvas frames in the 17th century was considered a violation of guild rules. Sometimes, historic canvas frames were made with the involvement of sapwood. In such a case, the boards were properly joined - sapwood to sapwood and heartwood to heartwood. Heartwood and sapwood react to changes in humidity in completely different ways and require a specific arrangement in the frame (Fig. 6).

- **Irregularities in growth rings and grain direction** - wood with irregular arrangements of growth rings and fibers may exhibit different properties in response to changes in humidity and temperature. These differences in reaction can lead to warping and cracking in the wood. A board with such an arrangement of fibers tends to warp, which can cause stress in the frame. These stresses can be the cause of warping, deformation, or cracking of the frame.

2.1.7 Arrangement of boards in frames

The quality of oak wood is visible in the structure of its growth rings. When the rings are thin and arranged parallelly, it indicates radial cutting of the board, which translates into a better quality of the frame. Radially cut boards show significantly less tendency to warp than tangentially cut boards. For this reason, it was believed that obtaining good quality painting frames requires the exclusive use of radially cut boards. The edges of the frame (the so-called board edges) are the most sensitive to changes in humidity, where the wood fibers are cut across.

It is recommended to use an alternating grain pattern in adjacent boards for the construction of frames, which can reduce shape changes during wood warping. Such a connection is crucial to minimize the effects of differences in the shrinking of boards between the core side (so-called right side of the board) and the outer side of the tree trunk (so-called left side). Although radially cut boards also exhibit some anisotropy in shrinking, it is significantly less than in the case of tangentially cut boards. The side of the board from the outer side of the trunk will be more prone to shrinking in the tangential direction compared to the side from the core. To minimize wood movement resulting from differences in shrinkability, it is recommended to glue together boards with an alternating grain pattern.

Boards glued in a unilateral arrangement show a greater tendency to form bulged or concave frames. Frames made from tangentially cut boards, under the influence of humidity changes, will be more susceptible to the intense action of forces than those made from radially cut boards.

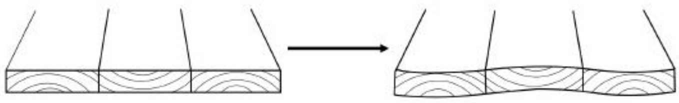

Fig. 5.. Diagram of the work of the boards glued together in an alternating manner (left, right, left). Fig. by Marta Hirschfeld.

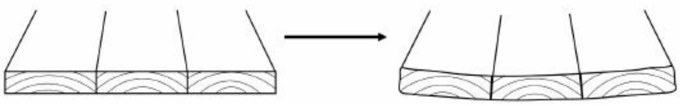

Fig. 6. Diagram of the work of the boards glued together on one side (left, left, left). Drawn by Marta Hirschfeld.

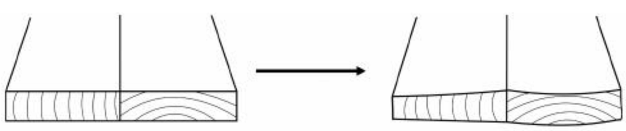

Fig. 7. Schematic of the work of the radial board glued to the tangent board. Drawn by Marta Hirschfeld.

It is necessary to avoid using tangential and radial boards in the same panel simultaneously. These boards exhibit completely different behaviors, and such an arrangement can cause significant stress, as well as lead to weakening or delamination of the boards.

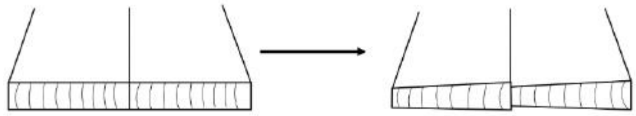

Fig. 8. Diagram showing the possible operation of two glued together boards where the heartwood is glued to the sapwood. Drawn by Marta Hirschfeld.

2.1.8 Ways of joining boards in 17th century Netherlands

Most panel paintings consist of two or more boards. Only small panels were made from a single board. Oak boards, from which the panels were constructed in the 17th century, could vary in width. Typically, dimensions ranged between 25 and 29 cm. Less commonly, boards with a width of 60–70 cm or even wider can be found. The use of wider boards allows for a reduction in the number of joints required to make a panel.

The thickness of oak wood panels usually ranged from 0.8 to 3.0 cm. In the case of large paintings, efforts were made to minimize the thickness of the board to reduce the weight of the painting. Thicker boards have advantages such as greater durability, rigidity, and dimensional stability. However, as the thickness of the boards increases, there are also disadvantages related to greater weight and difficulty in making such a panel. In a thick board, changes in humidity occur less abruptly. The process of equalizing humidity takes much longer, which can lead to greater damage to the artwork. Paintings made on thinner panels better withstand climate changes. Thinner boards react more flexibly to fluctuations in air humidity.

Panels were created from boards arranged parallel to each other. Typically, in the 17th century Dutch paintings, the wood grains run parallel to the longer side of the panel. In the traditional process of gluing two or more boards together, the principle was that the heartwood is joined to heartwood, and the sapwood to sapwood. Boards were usually joined in such a way that the heartwood was on the outer edges of the panel. On smaller panels, which consisted of two boards glued together, remnants of sapwood could sometimes be observed in the middle of the panel. Unfortunately, remnants of sapwood could cause cracking, as sapwood has inferior physical properties compared to heartwood.

For gluing wood, animal-based adhesives were used. To ensure a precise fit, the surfaces of the boards had to be planed. Sometimes, the edges of the boards were additionally scored with a sharp tool to increase the adhesion of the glue. Less frequently, other methods of joining boards were used, such as lap joints, tongue and groove, dovetail, and wedge joints. These different types of joints were intended to increase the gluing surface area, contributing to the greater strength of the panel board connection. However, such connections could make the gluing process difficult due to the challenge of matching the inner surfaces of the boards and limited access to them. In the case of hide glue, it is important that the joining of the boards is carried out efficiently, as animal glue has a short setting time.

2.1.9 Methods of reinforcing wooden panels

In the 17th century in the Netherlands, additional reinforcements for panels, especially in the case of smaller board formats, were rarely used. Oak panels made from the highest quality wood with a radial cross-section did not require additional reinforcements. This allowed the wood to freely adapt to regular changes in humidity and temperature in Dutch homes.

Artists paid attention to the need to maintain the stability of panels in the 17th century. The curvature of the surface of paintings on a wooden base was reluctantly seen by art buyers. During conservation or restoration works, various types of reinforcements were often added to the panel to prevent or repair cracks, delaminated boards, and deformations on the surface of the painting. Parquetry, wooden strips, butterfly joints, etc., were used. Therefore, on the backs of paintings by Willem Claesz Heda, we can observe various types of reinforcements, added in later centuries.

2.1.9.1 Reinforcement of the panel with canvas

Reinforcing the panel with canvas reached the peak of its popularity in the 15th century, but it was also used in later centuries, especially for large wooden panels. Strips of canvas were often applied not only to the most vulnerable areas, such as the joints between boards and defects in the wood, but also to entire panels. Linen canvas with a plain weave was most commonly used. The canvas was soaked in hide glue and typically applied to the back. It was important to efficiently perform this type of reinforcement, as hide glue quickly gels upon contact with the cold surface of the wood.

2.1.9.2 Reinforcement of the panels with sponges and wooden crossbars

Since the Middle Ages, artists began to extensively use various types of reinforcements on the back of the panel, inspired by techniques used in icon painting. Particularly popular protection against warping of the boards was the installation of movable crossbars, which kept the substrate in a single plane. Maintaining a straight plane was especially important for larger panels, which were more susceptible to stress formation. The reinforcement system also helped distribute the forces acting on the board joints, contributing to the prevention of negative effects of wood movement in variable climate conditions.

A commonly used method for fitting crossbars was the use of the "dovetail" technique. Crossbars could also be nailed down, with particular attention paid to isolating the nail heads. In rare cases, glued crossbars are encountered, but their use is usually avoided due to the significant stress they generate in situations of humidity changes.

2.1.9.3 Reinforcement of the sub-image - "bows"

Wooden reinforcements in the form of butterfly joints (shaped like the letter X) rarely appeared in the original production of panels but gained popularity in later conservation treatments. Their main application was to join adjacent boards, especially in subsequent renovation works. Wooden reinforcements could also take simpler shapes, such as rectangles.

2.1.9.4 Parquet

Parquetry is a construction consisting of wooden slats on the back of a painting. The aim of this process is to maintain a flat surface of the panel and prevent its deformation. In the past, parquetry was widely used as a method of protecting artworks. However, nowadays, parquettes are considered harmful to paintings. It was not until the second half of the 20th century that the effectiveness of this method began to be questioned. It turned out that adding wooden constructions can affect the natural movements of wood under the influence of changes in humidity and temperature. Preventing the wood from moving freely can lead to further deformations and damage to the panel. Additionally, parquetry complicates the examination and analysis of the painting, and also changes its original appearance and artistic value.

Parquetry began to be used at the end of the 18th century, reaching its peak popularity in the 19th century, and was practiced until the mid-20th century. In museum collections around the world, many paintings can be found that were subjected to parquetry in the past. Their current state of preservation varies. The visible effects of parquetry on the panel depend on many factors.

The parquetry treatment was often used preventively. In the past, in the art trade, this construction testified to the authenticity and raised the price of the artwork. Over time, parquetry grew to be considered a fundamental conservation treatment. The procedure for performing parquetry usually consists of several stages. First, straightening of warped boards is carried out, repairing any cracks. Often, the thickness of the panel was also reduced to facilitate its straightening. For this purpose, the wood was thinned, moistened, and then dried under a load. The next step was to glue on longitudinal slats, which run in the direction of the wood fibers of the panel. Longitudinal strips were often placed in areas where cracks in the panel occur. Finally, cross slats are inserted into the slots of the longitudinal slats, thus creating a parquetry structure. As a result of such invasive conservation treatments, information about the original processing of the panel is lost.

2.1.10 Development of the surface of the boards

Planing wood is a processing technique that gained greater popularity after the 14th century. Craftsmen used special planes to precisely remove layers of wood and achieve a straight and even surface of the board. This multi-stage process required skills, experience, and an appropriate workshop setup. In addition to traditional planes, craftsmen also used scrapers and small hatchets. Scrapers helped remove minor irregularities and smooth the wood surface. Small hatchets were used for precisely trimming excess material.

For the preliminary processing of wood, a plane with a semi-circular blade (known as a round plane) is used. It leaves characteristic semi-circular marks in the wood. It is used for the preliminary and rapid leveling of the board surface. After the initial processing, a scraping plane, which has a straight blade, can be used. Skillfully used, it leaves the wood surface without clear marks of processing. During planing, the craftsman had to repeatedly check the surface of the boards with straight measuring tools to ensure that the obtained surface is properly flat and straight. Before gluing the boards together, each of them had to be processed. The most important was to obtain a straight, even, and smooth surface of the face of the panel and perfect edge-to-edge board joints. For the edge-to-edge joints to be durable, the boards had to fit together perfectly. Before gluing, a layout scheme of the boards in the panel was developed, in accordance with the principles of woodwork.

After gluing the boards together, the panel was often further refined with planes. Marks of the plane running across the joints of the boards are frequently visible on the backs of 16th-17th century paintings. The backs were not as meticulously finished as the fronts. This allows conclusions to be drawn about the specific processing technique of the panel.

Panels at that time were beveled to protect them against warping (reducing the end grain surface) and to ensure they were well secured in the frame.

2.1.11 Oak panel for technological copy

The panel is a key element in the process of creating a technological replica, whose main goal is to replicate the original as faithfully as possible. The first step was a thorough analysis of the literature dedicated to wooden panels. During the attempts to make a wooden board, I encountered many difficulties and incoming questions that required careful answers.

Creating such a panel independently requires not only advanced skills but also the possession of high-quality woodworking tools and an appropriate workspace. Therefore, cooperation with experienced specialists, who possess not only knowledge but also the right skills and equipment, proved necessary. Together with Piotr Kusznierczyk, a furniture conservator and an expert in the field of ancient woodworking techniques, we made a panel painting in accordance with the techniques used in the 17th century, using traditional woodworking tools.

2.1.12 Making panels

The boards intended for the creation of a still life copy of Willem Claes Heda were obtained from an oak table top dating back to the early 20th century. I decided to use reclaimed material for the panel. This choice was dictated by several factors. First and foremost, reclaimed wood is well-seasoned and has already undergone a certain process of "working" of the wooden matter. The purchased boards were of high quality and were radially sawn, meaning their grains are arranged parallel to each other. Thanks to the appropriate cross-section of the wood and its prior conditioning, it will be easier to predict any potential movement of the panel that may occur during the creation and subsequent exhibition of the copy.

Currently, the oak wood available for sale is predominantly kiln-dried, and the seasoning time is minimized. It is difficult to find radially sawn oak of adequate quality at building material depots. The trees from which wood is currently harvested are relatively young, which makes it impossible to obtain wide boards. Initially, I made trial panels using oak from wood depots. I abandoned this material because the panels consisted of too many boards, and the quality of the wood was not satisfactory. However, when planning to make a panel in the future, it is worth purchasing contemporary, high-quality planks that have been properly seasoned for a minimum of 5 years outdoors under a roof. After purchasing the planks, it is necessary to dry them in room conditions, which should last at least 2 years. Such a process will allow for the stabilization of the wood and reduce the risk of deformation in the future.

The process of creating a painting panel is a task that requires precision and attention at every stage. The first and extremely important step is the meticulous planning of the entire process. An important aspect of making a panel is the awareness of the principles of woodwork. Wood, as a natural material, undergoes changes depending on the air humidity. Therefore, it is crucial to properly prepare the workspace to avoid future problems related to the wood's behavior, both during the preparatory actions for the panel and its future stability.

2.1.13 Selection and development of boards and their arrangement in the panels

Technical work on the creation of the painting panel began with the disassembly of the oak table top by applying pressure, which caused the old glue joints to crumble. After a thorough selection, the best boards from this top were chosen, paying special attention to their tendency to warp. Ultimately, four boards were selected to serve as the material for the painting panel.

The obtained wood was planned to achieve straight boards of equal thickness. Then, they were cut to the appropriate dimensions. During the planning process, it was essential to obtain a flat surface on the right side of the board, and only then align the remaining surfaces relative to it. It's important that all edges be parallel and perpendicular. The flatness of the board surfaces was regularly checked with straightedges and squares during planning. Any waves, bulges, and irregularities were removed.

Particular attention was paid to the morphological grain of the boards. To ensure stable wood behavior, the heart sides of the boards were arranged alternately (right, left, right side of the board). Before gluing the boards together, a structure was developed that aimed to create an even clamping force on the wood.

2.1.14 Gluing the boards

The boards were glued together using 40% hide glue dissolved in a water bath. To carry out the gluing process, warm hide glue was applied to the surfaces to be glued using a bristle brush. It is important to act efficiently because the glue quickly sets upon contact with the cold and dry surface of the boards. A bristle brush of appropriate size was used to apply the glue. The glue layer should be thin, as this ensures a stronger bond. After applying the glue and fitting the boards together, a clamping system was swiftly applied. The applied force should be maintained until the glue is completely dry (minimum 12 hours).

In the next stage, the face and the back of the glued boards were processed. At this stage, the panel was about 1.5 cm thick, which is quite thick for a panel made of oak wood. Additionally, butterfly joints were made to strengthen the edge-to-edge board joints. The butterfly joints were made from the same material as the painting panel, using a sharp chisel, and then were glued into previously prepared recesses, also in the shape of butterflies. The decision to make butterfly joints was for the sake of learning how to create reinforcements. Since this was my first panel made using traditional methods, I had concerns about the durability of the edge-to-edge glue joints. However, the panel turned out to be very durable. Attempts to separate the glue joints at the edges in the case of later made trial panels ended in failure. Well-executed edge-to-edge gluing is extremely durable. Many of the panels used by Willem Claesz Heda have reinforcements in the shape of butterfly joints, which were likely made in later centuries during conservation and restoration works.

2.1.15 Development of face and reverse surfaces

During the processing of the panel surface, three types of planes were used: a scraper plane, a jack plane, and a smoothing plane. Each of these tools was extremely important, enabling precise woodworking and achieving the desired surface.

- A scraper plane was used to remove unevenness and the top layer of wood. The scraper has a blade with a rounded cutting edge. This tool was essential for processing the back, leaving characteristic marks of wood processing.
- A jack plane was used to level the surface of the panel. The blade of the jack plane has a straight cutting edge, allowing for the achievement of a flat and even wood surface.
- To smooth and remove minor imperfections, a smoothing plane was used, equipped with a chip breaker. It is important to guide the smoothing plane only along the wood grain.

To ensure stability of the boards during planning, it is necessary to use holdfasts or clamps. An extremely important aspect of working with a plane is sharpening the blades properly. Initially, the blade is given the appropriate angle using a diamond sharpening stone. Then, the blade is ground on marble using oil. The next step is to smooth and polish the edges using a piece of natural leather. After sharpening the blade, it is secured in the body of the plane and checked to ensure it is evenly seated relative to the sole of the plane, and properly extended. Then, the wedge is firmly tapped in place using a hammer.

When working with a plane, it is important to remember about proper tool guidance. The plane is pushed away from itself, following the direction of the wood grain. The rear part of the tool is held with the right hand, while the left hand guides the toe. During planing the wood surface, it is important to apply the right pressure on the plane at the entry and exit to prevent the board from chattering at the beginning and excessive planning at the end. The blade of the plane must be properly set to ensure effective and precise work.

Effect of wood processing on its properties:

Water absorption through the wood surface can vary depending on how the board has been processed. Boards that have been processed with traditional, well-sharpened planes have significantly less ability to absorb water compared to boards sanded or planed with power tools. If we place a drop of water on a traditionally planed board, it will remain on the surface until completely evaporated. However, on a sanded board, the water droplet slowly but completely penetrates the wood structure.

2.1.16 Photographic documentation of the process of making a blackboard panel

Photo 34. Oak planks obtained from a table top. The left side of the photo shows the raw surface of the wood, while the right side of the board is covered with polish. Photo by Marta Hirschfeld.

Photo 35. Reverse of oak boards obtained from the table top. The boards have visible losses of wood from nails. The oak table top was 2 cm thick. Four of the best planks from the tabletop were selected to make a sub-image for the technological copy, paying special attention to the planks' tendency to deform and warp. Photo by Marta Hirschfeld.

Photo 36. Selected oak planks for further carpentry. Photo by Marta Hirschfeld.

Photo 37. The picture shows an oak plank immobilized in a carpenter's visor and a planar plane. The contact edges of the sub-painting boards had to be brought to a perfectly flat and parallel surface. Perfectly derived (straight and parallel, with right angles) surfaces of the boards guarantee a joint without gaps. For this purpose, a plane planer and measuring tools such as strips, angles and gauges were used. The planer was run parallel to the edge of the joint. Photo by Marta Hirschfeld.

Photo 38. The photo shows the correct fit of two boards before gluing them together. Well-matched edges do not allow even a thin sheet of paper to be inserted between them. Photo by Marta Hirschfeld.

Photo 39 Before gluing, check all the contact edges between the boards, as well as the surface of the face and reverse of the future sub-image. All boards must be of equal thickness. The order of the boards and the points of contact should also be marked. Gluing the boards together should be done efficiently, so it is advisable to use any facilities that will allow you to quickly and accurately adjust the edges of the joints. Photo by Marta Hirschfeld.

Photo 40. The photo shows skin glue prepared in a water bath with a concentration of 40%. In addition, you can see the arrangement of the boards and the wooden structure, which ensure precision and the shortest possible gluing time. The glue was applied to the contact surface of the vertical plank (right side of the photo) and quickly matched it with the plank laid flat. The remaining boards were glued in this way. Photo by Marta Hirschfeld.

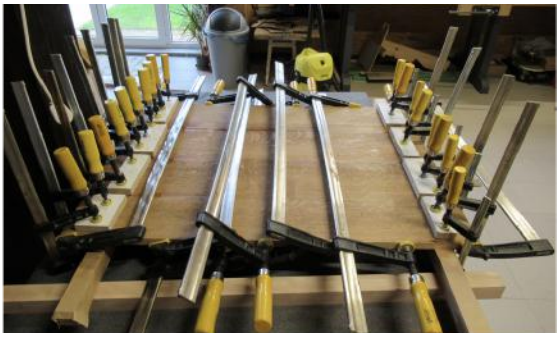

Photo 41. A set up squeeze system on freshly glued boards. Long carpenter's clamps exert the appropriate force needed to achieve thin joints. With them, excess glue and air are removed from the joints. Shorter carpenter's clamps, set vertically, force the sub-image to maintain a flat face and reverse surface during the gluing process. Such a structure should be maintained throughout the glutinous glue curing time. Photo by Marta Hirschfeld.

Photo 42. Reinforcements in the shape of bows. To reinforce the joints of the boards at the joints, bows made of oak wood were used, keeping the arrangement of the fibers in relation to the sub-image. The bows were made using a pattern attached to the board with clamps. The pattern was marked and incised on the oak board using a stitching knife. The material for the bows was chosen from outside the area of the cut pattern. The edges of the bows made in this way were aligned. It should be noted that such reinforcements were not originally used in the 17th century in the Netherlands. They were added to the sub-images during restoration activities. The bowing is not essential and a well glued sub-image does not require their use. There are many other methods of reinforcing the panel, however, additional reinforcements may be necessary for complex and large wooden subpainting

constructions. Photo by Marta Hirschfeld.

Photo 43. The photograph shows a cut hole in the panel in the shape of a bow. While the panel was being worked on, it was stiffened with wooden strips and carpenter's clamps. The bow holes were made using a template attached to the panel with clamps. The pattern was marked and incised on the sub-image using a stitching knife. The material within the cut pattern was selected using a chisel. The bow was then tried on to the hole and smeared with glutinous glue (the same glue used to glue the boards together), fitted into the hole in the sub-image and squeezed using carpenter's clamps. Photo by Marta Hirschfeld.

Photo 44. Sub-image with pasted bows and nail restorations. The cavity restorations were made in a very similar way to the bows. A cavity shape was cut in oak wood, which was then glued into the sub-image. The glued-in pieces protrude above the surface of the panel, and in the next stages they will be stippled with a chisel to create an even reverse plane. Photo by Marta Hirschfeld.

Photo 45. Glued boards from the reverse side, as well as a planer, a honing machine and a stitching knife. Before gluing, the reverse side was pre-treated and excess glue, which flowed out during gluing, was removed. The grader was used to level the surface, while the honing machine was used for planing to level and smooth out irregularities. When planing the boards, it is necessary to immobilize them, and in this case a carpenter's table was used. Photo by Marta Hirschfeld.

Photo 46. Scraper plane. Photo by Marta Hirschfeld.

Photo 47. Finished front of the panel. Photo by Marta Hirschfeld.

Photo 48. Stage of processing the reverse side. The reverse side was processed using a scraper with a semi-circular blade. Traces of the tool and chamfered edges are visible. Chamfered edges help reduce the surface of the wood's cupping and facilitate mounting the panel in the frame. The panel visible in the photograph has a thickness of about 1.5 cm. Photo by Marta Hirschfeld.

Photo 49. The final appearance of the reverse side was achieved by further planing to a thickness of 8 mm using a scraper with a semi-circular blade. Additional planing was decided upon after consultations with panel painting conservators. The reduced thickness of the board will allow for more appropriate wood behavior under varying humidity conditions. Additionally, the four edges of the panel were chamfered again. Photo by Marta Hirschfeld.

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