Original scientific paper
Received:29.06.2023
Accepted:15.10.2023
UDK: 674-412.046

TECHNICAL ANALYSIS OF A METAL CHAMBER FOR DIRECT STEAMING OF BEECH LUMBER (*Fagus sylvatica* L.)

Ana Marija Stamenkoska[1], Branko Rabadziski[1], Goran Zlateski[1]

[1]Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia,
Faculty of Design and Technologies of Furniture and Interior - Skopje
e-mail: stamenkoska@gmail.com, rabadziski@fdtme.ukim.edu.mk,
zlateski@fdtme.ukim.edu.mk

ABSTRACT

The aim of this paper is the technical analysis of a metal chamber for direct steaming of beech (*Fagus sylvatica* L.)-edged lumber with a thickness of 50.0 mm. The paper presents the basic parameters of the chamber and calculates the dimensions of the metal chamber and its capacity. The dimensions of the chamber with sawn lumber, the number of chambers, and the volume of the single lumber stack have been analyzed. The steaming of the wood is an important and complex operation during the processing of sawlogs into sawn lumber. Steaming, in addition to being a technological procedure, is also a thermal procedure. The steaming of the sawn lumber is carried out in the presence of water vapor in steaming chambers according to the following two methods: direct steaming of the sawn lumber and indirect steaming of the sawn lumber. In the method of direct steaming of lumber, the steaming medium is saturated water vapor.

Key words: steaming, metal chamber, technical analysis, sawn lumber, beech, dimensions, capacity

1. INTRODUCTION

The first data regarding the hydrothermal treatment of wood dates back to the 1930s. This data concerns the treatment of lumber with water vapor under normal barometric pressure on masonry-constructed objects. Later, these masonry objects were called "wood steaming chambers." The beginnings of this wood treatment in the world during this period were registered in the Scandinavian countries, Russia, Canada, and China. The first attempts to treat wood with heat and vapor were carried out in pits by the method of soaking, for which pure thermal waters were used.

The wood steaming process is a complex technological process during which the use of heat treatment weakens the bond between lignin and cellulose in the middle lamella of the wood cell wall. The wood hydrothermal treatment is reduced to the fact that the solid libriform fibers are placed in the adjacent porous spaces during deformation so that they do not break. Reducing internal friction during deformation increases the plastic properties of the wood. Internal friction is reduced by increasing the humidity and temperature in the internal parts of the cross-section of the wood.

Steaming and soaking, worldwide, as technological processes, are the most widely used methods for wood hydrothermal modification. Saturated water vapor and hot water are used as mediums for hydrothermal modification. The steaming of sawn lumber implies a technological and thermal procedure where the assortments in a closed system, that is, space, are exposed to the influence of saturated water vapor at a certain temperature and pressure. The purpose of steaming refers to the change of color, improvement of the properties of the wood, sterilization, and the removal of some errors that occurred during the drying process.

The steaming process of the sawn lumber is carried out in the presence of water vapor in steaming facilities by one of these two methods: direct steaming of the sawn lumber or indirect steaming of the sawn lumber. In the method of direct steaming of the sawn lumber, the wood modification medium is saturated with water vapor. The saturated water vapor in the chamber is brought to the boiler plant by a system of pipelines. The tubes through which the water vapor is sprayed into the steaming chamber may have different locations. The location may be central, along the length of the chamber, or the pipes may be slightly raised above the floor or laterally attached along the walls of the chamber. They have a diameter in limits, d = 60.0 ÷ 70.0 (mm), perforated with spirally arranged holes with a diameter, d = 5.0 (mm), at a distance, r = 14.0 ÷ 15.0 (cm). They are made of non-rusting materials, usually copper or aluminum. It is of particular importance for the direct steaming method to know that steaming is done with saturated water vapor, and under no circumstances is overheated steam used. Overheated steam intensively dries the surface of the assortments, and a difference in humidity occurs between the surface and internal layers of the wood. That difference in humidity causes internal stresses and the appearance of errors in the steamed assortments.

The purpose of steaming as a heat procedure is to heat the wood, mitigate or remove errors (collapse, stiffness, etc.) in the sawn assortments caused by improper artificial drying, a procedure known as reconditioning and steaming the wood for obtaining rotary cut veneer sheets or sliced veneer sheets, in which the cutting resistance is reduced in the peeling and cutting technique, the tool is used for a longer time, and the veneers are of better quality (non-fibrous, without cracks and waviness). The heat treatment (steaming) causes the color of the wood to change. The change or equalization of color is of special interest for beech-sawn lumber, which also contains heartwood.

The steaming process is performed in such a way that during a certain time interval, a constant temperature is maintained in the steaming chamber in an interval, t = 95 ÷ 100 (°C) and relative air humidity, φ = 100 (%), and the pressure in the chamber ranges up to 3.0 (bar). When steaming with a steam temperature higher than 100 (°C), the saturated steam passes into overheated steam. At a temperature of 145 to 150 (°C), chemical decomposition of the wood begins. The term steaming of wood refers to the action of saturated water vapor under a certain pressure and temperature, during which convective heat exchange occurs in a controlled, closed environment.

2. MATERIAL AND METHODS

The steaming process takes place in closed facilities called steaming chambers. Steam chambers can be constructed from building materials (masonry) or made from aluminum structural profiles in combination with panel walls, which are made of pure aluminum filled with thermal insulation materials.

A metal steaming facility consists of one or more chambers. Compared to other constructions, they show advantages. The most important advantages stand out, and they are the following: great possibility of maintaining a constant temperature and pressure in the chamber; good heat capacity of the walls; easy manipulation with ordinary or trolleys with a lifting platform; saving heat energy; easy to install and maintain. Their structural parts are made of aluminum grid construction or aluminum profiles. The walls are made of aluminum panel plates with an internal thermal filling of mineral wool or hard polyurethane with a thickness of 120 (mm). The doors of the steam chamber are made of the same materials as the walls, which are: aluminum - thermal insulation - aluminum. The mechanism, which is used to close the door, allows the doors to stick firmly to the wall, which improves the ambience in the chamber. This means that temperature and pressure oscillations are reduced.

The ceiling of the chambers is structurally constructed in the form of a vault in order to avoid the condensate bathing directly on the stack with the sawn lumber. The vaulting of the ceiling in the form of an arch is made of pure aluminum. Condensate, which is created during the steaming process in the chamber, flows from the vaulted ceiling to the walls and flows out through a channel outside the chamber.

For proper management of the wood hydrothermal treatment by steaming, special equipment is installed in the chamber, which provides manual and automatic regulation of the parameters of the steaming process and allows constant control.

The raw material for hydrothermal treatment by steaming, which is the subject of this research in the technical analysis, has the following characteristics:

- wood species: beech (*Fagus sylvatica* L.),
- type of sawn lumber: board, thickness, b = 50.0 (mm),

- level of processing: sawn-edged lumber,
- quality class: 1^{st} quality class,
- initial moisture content of the wood: $W_i > 40.0$ (%),
- minimal width of the sawn lumber: c = 12.0 (cm) and
- minimal length of the sawn lumber: $l_{min} = 1.2$ (m).

Figure 1: *Edged beech lumber with a thickness of 50.0 (mm)*

Figure 2: *Edged beech lumber*

In order to calculate the capacity of the steam chamber, first of all, the amount of lumber and the number of chambers with lumber that are intended to be steamed are calculated.

The following mathematical formulas are applied:

1) Contour volume of the chamber with sawn lumber (V):

$V = s_k \cdot l_k \cdot h_k$ (m^3)

where:

s_k – width of the stack with sawn lumber (m);

l_k – length of the stack with sawn lumber (m);

h_k – height of the stack with sawn lumber (m);

2) Lumber volume in a single stack (V_1):

$V_1 = V \cdot f_k$ (m^3)

where:

V_1 – contour volume of the stack with sawn lumber (m^3);

f_k – factor of occupancy of the stack with sawn lumber (correction factor);

3) Number of stacks with sawn lumber (n):

- the number of stacks with sawn lumber (n) is determined according to the dimensions of the chamber with lumber (length, height, and width);

4) Steam chamber capacity (Q_c):

$Q_c = V_1 \cdot n$ (m^3)

where:

V_1 – lumber volume of a single stack with sawn lumber (m^3);

n – number of stacks with sawn lumber.

3. RESULTS AND DISCUSSION

There are a large number of input parameters that participate in the technical analysis of the steam chamber. In order to calculate the size of the steaming chamber, it is first necessary to analyze the dimensions of a single stack with sawn lumber, the number of stacks with sawn lumber, the volume of the wood mass, as well as the capacity of the steam chamber.

For this purpose, the following input parameters will be used:

- method of steaming: direct steaming of the wood,
- constructive performance: metal chamber,
- degree of automation: automatic control of the steaming process,
- wood species: beech (*Fagus sylvatica* L.),
- thickness of the sawn lumber: b = 50.0 (mm),
- transport of the sawn lumber (on the entry and exit of the chamber): front-end forklift,
- thickness of wall, ceiling, and chamber door: $b_1 = 12.0$ (cm),
- floor thickness: b = 20.0 (cm) and
- steam chamber capacity: $Q_c = 25.0 \div 30.0$ (m^3).

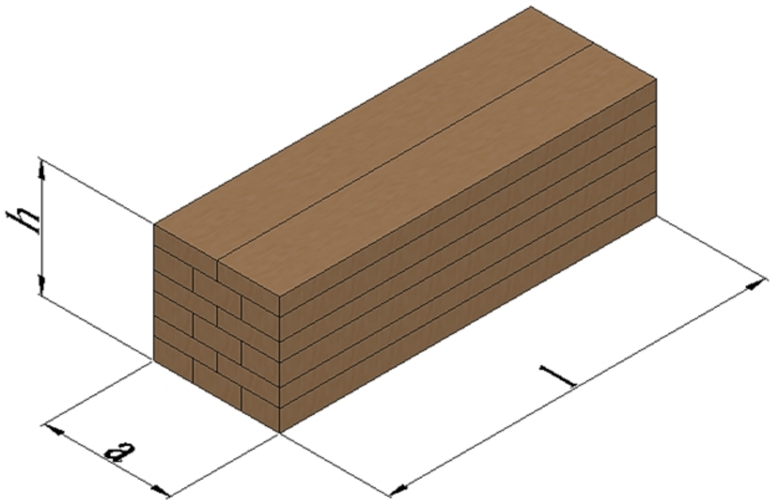

Figure 3: *Single stack with sawn lumber*

Figure 3 shows a model of a single stack with sawn lumber and its parameters.

The dimensions of the stack with the sawn lumber are as follows:

- stack length: $l_k = 4.0$ (m);
- stack height: $h_k = 1.5$ (m);
- stack width: $s_k = 1.4$ (m); and
- factor of occupancy of the chamber with sawn lumber (reduction coefficient): $f_k = 0.85$.

1) Contour volume of the stack with sawn lumber:

$V = s_k \cdot h_k \cdot l_k$ (m^3)

$V = 1{,}4 \cdot 1.5 \cdot 4.0 = 8.4$ (m^3)

$V = 8.4$ (m^3)

2) Lumber volume in a single stack:
$V_1 = V \cdot f_k$ (m^3)
$V_1 = 8.4 \cdot 0.85 = 7.14$ (m^3)
$V_1 = 7.14$ (m^3) ≈ 7.0 (m^3)
3) Number of stacks with sawn lumber:
n = 4 stacks with sawn lumber
4) Steam chamber capacity:
$Q_c = V_1 \cdot n$ (m^3)
$Q_c = 7.0 \cdot 4 = 28.0$ (m^3)
$Q_c = 28.0$ (m^3)

It can be concluded that the contour volume of the chamber with lumber is V = 8.4 (m^3), the lumber volume of a single stack is $V_1 \approx 7.0$ (m^3), the number of stacks with sawn lumber in the steam chamber is n = 4 chambers, and the capacity of the steam chamber is $Q_c = 28.0$ (m^3).

A steam chamber with a longitudinal and a cross-section is shown in Figures 4 and 5, with appropriate calculations for the structural parts of the steam chamber.

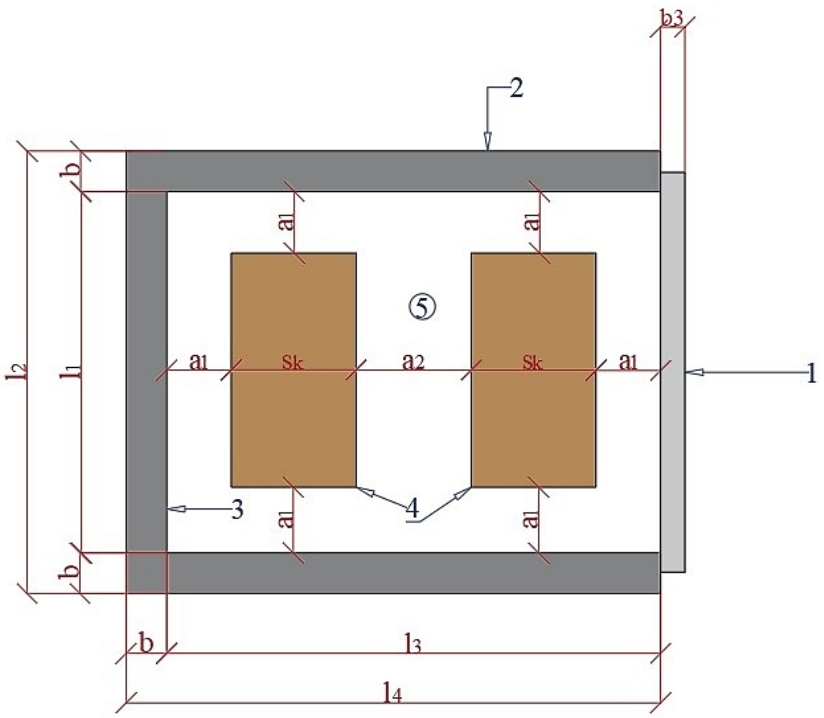

Figure 4: *Longitudinal section of a steam chamber filled with sawn lumber*

Legend:
1) steam chamber door,
2) side wall,
3) front wall,
4) stacks with sawn lumber,
5) floor of the steam chamber,
- b → wall thickness (b = 12.0 cm),
- b_3 → door thickness (b_1 = 10.0 cm),
- a_1 → distance from the sawn lumber stacks to the walls and door of the steam chamber (a_1 = 50.0 cm),
- a_2 → distance between the stacks with sawn lumber (a_2 = 10.0 cm),
- l_1 → internal width of the steam chamber (m),
- l_2 → external width of the steam chamber (m),

- l_3 → internal length of steam chamber (m) and
- l_4 → external length of steam chamber (m).

Mathematically calculated values for:

a) internal width of the steam chamber

$l_1 = l + 2 \cdot a_1$ (m)

$l_1 = 4.0 + 2 \cdot 0.5 = 5.0$ (m)

$l_1 = 5.0$ (m)

b) external width of the steam chamber

$l_2 = l_1 + 2 \cdot b_1$ (m)

$l_2 = 5.0 + 2 \cdot 0.12 = 5.24$ (m)

$l_2 = 5.24$ (m)

c) internal length of the steam chamber

$l_3 = 2 \cdot a1 + 2 \cdot s_k + a_2$ (m)

$l_3 = 2 \cdot 0.5 + 2 \cdot 1.4 + 0.1 = 3.9$ (m)

$l_3 = 3.9$ (m)

d) external length of the steam chamber

$l_4 = l_3 + b_1$ (m)

$l_4 = 3.9 + 0.12 = 4.02$ (m)

$l_4 = 4.02$ (m) ≈ 4.0 (m)

It can be concluded that the internal width of the steam chamber is $l_1 = 5.0$ (m), the external width is $l_2 = 5.24$ (m), the internal length is $l_3 = 3.9$ (m) and the external length is $l_4 = 4.0$ (m).

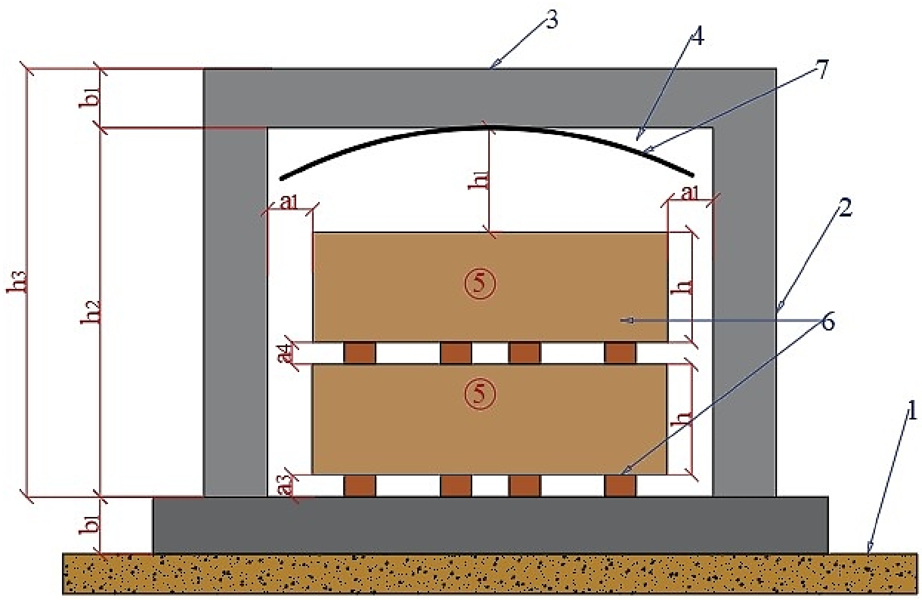

Figure 5: *Cross section of a steam chamber filled with sawn lumber*

Legend:

1) floor of the steam chamber,
2) side walls,
3) ceiling,
4) front wall,
5) stacks with sawn lumber,
6) wooden separators,
7) vaulting (Al = 99.7%),
8) ground,

- h → height of the stack with sawn lumber (h = 1.5 m),
- h_1 → distance between the stack with sawn lumber and the ceiling ($h_1 = 5.0$ cm),
- a_3 → distance from the floor to the stack with lumber ($a_3 = 10.0$ cm),

- a_4 → distance between two stacks with lumber (a_4 = 10.0 cm) and
- b → floor area (b = 20.0 cm).

Mathematically calculated values for:

a) internal height of the steam chamber

$h_2 = a_3 + 2 \cdot h + a_4 + h_1$ (m)

$h_2 = 0.1 + 2 \cdot 1.5 + 0.1 + 0.5 = 3.7$ (m)

$h_2 = 3.7$ (m)

b) external height of the steam chamber

$h_3 = h2 + b$ (m)

$h_3 = 3.7 + 0.12 = 3.82$ (m)

$h_3 = 3.82$ (m)

It can be concluded that the internal height of the steam chamber is h_2 = 3.7 (m), and the external height is h_3 = 3.82 (m).

4. CONCLUSION

Based on what was presented in the paper, the following conclusions can be drawn:

1) The paper presented the basic parameters of the chamber and calculated the dimensions of the metal chamber and its capacity. The dimensions of the chamber with sawn lumber, the number of stacks, and the volume of the stacks with sawn lumber were analyzed.

2) The hydrothermal treatment of wood is a complex technological process during which the use of heat treatment weakens the bond between lignin and cellulose in the middle lamella of the cell wall.

3) The steaming of sawn lumber implies a technological and thermal procedure where the assortments in a closed system, that is, space, are exposed to the influence of saturated water vapor at a certain temperature and pressure.

4) The steaming of the sawn lumber takes place in a closed environment called a steam chamber. Steam chambers can be built from building materials (masonry) or made from aluminum structural profiles in combination with panel walls, which are made of pure aluminum filled with thermal insulation materials. Metal steam chambers consist of one or more chambers. Compared to other constructions, they show advantages.

5) The raw material for hydrothermal treatment by steaming, which was the subject of this research in the technical analysis, had the following characteristics:

- wood species: beech (*Fagus sylvatica* L.),
- type of sawn lumber: board, thickness, b = 50.0 (mm),
- level of processing: sawn-edged lumber,
- quality class: 1^{st} quality class,
- initial moisture of the wood: $W_i > 40.0$ (%),
- minimal width of the whip timber: c = 12.0 (cm) and
- minimal length of the whip timber: l_{min} = 1.2 (m).

6) We concluded that the contour volume of the chamber with lumber is V = 8.4 (m^3), the lumber volume in a single stack is $V_1 \approx 7.0$ (m^3), the number of stacks with sawn lumber in the steam chamber is n = 4 stacks, and the capacity of the steam chamber is Q_c = 28.0 (m^3).

7) It can be stated that the internal width of the steam chamber is l_1 = 5.0 (m), the external width is l_2 = 5.24 (m), the internal length is l_3 = 3.9 (m) and the external length is l_4 = 4.0 (m).

8) It can be concluded that the internal height of the steam chamber is h_2 = 3.7 (m), and the external height is h_3 = 3.82 (m).

REFERENCES

[1] Hamm, Đ., Lovrič, N. (1971): Parionice za bukovu piljenu građu. Drvna industrija, br. 9 – 10, god. XXIII, Šumarski fakultet, Zagreb.

[2] Hamm, Đ., Lovrič, N. (1971): Parionice za bukovu piljenu građu. Drvna industrija, br. 11– 12, god. XXIII, Šumarski fakultet, Zagreb.

[3] Nikolič, M.: Parionice za drvo, NIGOS, Niš.

[4] Rabadjiski, B. (2019): Parilnici za parenje na bicheni sortimenti. Tehnologii, mashini i energetika vo drvnata industrija. Seminar, Kavadarci.
[5] Rabadjiski, B., Zlateski, G. (2007): Hydrothermal processing of wood, I part. UKIM, Faculty of Forestry, Skopje.
[6] Rabadjiski, B., Zlateski, G. (2015): Hydrothermal processing of wood, II part, Wood Plastification, UKIM, FDTME, Skopje.