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# THE EFFECT OF A SAWING ANGLE ON WOOD TEXTURE

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SYNOPSIS. The mathematical model of log sawing with a fixed angle to the log axis attaining a desired wood was developed. The research revealed that the change of sawing angle relative to axis produced unique pattern of wood texture. The results of theoretical simulation were confirmed by experimental researches and similar character of sawing angle influence on wood texture was revealed in both types of investigations. The database of wood textures of logs sawn with the breakdown method (in parallel with the log axis, in parallel with the log generatrix, with angles of $5 \ldots 15^\circ$ to log axis) was created and furniture design alternatives were proposed.

KEY WORDS: wood texture, sawing angle, log, lumber

## INTRODUCTION

Production from massive wood has been popular for many years because products from construction composite materials possess worse decorative properties and toxicity, which is caused by synthetic glues. Besides massive wood is characterized by some features that practically are impossible to reconstruct in composite materials, such as texture bulk, stability for mechanical properties at temperature drop and moisture, lack of foliating for thinness and unsticking of edge.

There is a constant need in diversification and improving of competitive capacity of furniture from massive wood, which encourages searches for new approach in their production, using the original texture in particular. One of these approaches is lumber production with original texture, which supplied value of wood as decorative material and satisfied furniture producers. Wood texture as natural wood is formed by macroscopic anatomic elements therefore its beauty is defined by complexity of wood structure and aggregates of separate components. Wood texture received at log sawing by traditional methods parallel to axis or generatrix of log is generally known and these limits design possibilities and verifications. But the

change of sawing angle (angle between sawing plane and log axis) as respects axis on 5 ... 15° and more can lead to receiving of beautiful wood texture. Despite the fact that volume recovery is decreased and its cost value is raising but products with such texture meet the consumer requirements.

Investigations of round lumber sawing at fixed angle to axis log are up to date tasks and its decisions will allow satisfying customers of exclusive furniture and our curiosity in search of new wood decorative properties.

Original texture can be also made by irregular pressing, shelling by knife with corrugate edge, shelling of wood under angle to fibre direction, developed in such cases we will deal with products from extruded or glued wood.

The main hypothesis is the possibility of wood texture simulation for lumber depending on the direction and methods of sawing with regard to the log axis, prediction of volume recovery with required texture and creation of wood texture set for production of wood furniture.

Analysis of specialised scientific and technical papers and monographs indicates that nowadays detailed researches of influence of angle log sawing on wood texture were not performed.

## MATERIALS AND METHODS

Experimental log sawing of Amur Corktree (*Phellodendron amurense*) (20 trees) and Scots pine (*Pinus sylvestris* L.) (20 trees) parallel to log axis and under angles of 5°, 10° and 15° were performed for simulation of wood texture and its comparison with theoretical development.

Logs are sawed in band saws with horizontal disposition of task tool (Poland) by breakdown method (parallel to axis which is generatrix of log under angles of 5°, 10° and 15° to log axis). Lumber with thickness 25 mm and in some cases heart plank with thickness 60 mm are received. The drying of lumber to 15-20% of moisture is performed in atmospheric forcing. Conventional drying kiln (Ukraine) provides 6-8% of moisture. Longitudinal and cross-sawing of lumber is performed on universal circular sawing machine (Ukraine). Shaping of internal and external lumber faces is performed on jointer (Ukraine) and planer (Japan) respectively. Preliminary and final marking realised by means of joiner's pencil and special chalk. Photographing of wood texture is performed by digital camera "Penta" (Japan) by macro shooting.

All specimens are numerated. The first Arabic numeral corresponds to log number, second Arabic numeral indicates number of segment (it may correspond to either 0, 1 or 2), third Arabic numeral marks number of specimen (1, 2, 3 ... and $n$) and fourth Arabic numeral labels number of section in specimen (1, 2, 3 ... and $n$).

Creation of wood texture set and simulation of product view is performed by Adobe Photoshop 7.0 and 3d max 6.0 computer programmes respectively.

# RESEARCH RESULTS AND DISCUSSION

## Theoretical researches

Rings are particular macroscopic elements, which characterise wood texture. Originality and wood texture saturation depend on the following main features, such as share in cross-section, width and number per 1 centimetre, difference between early and late zones and equal layers. Rings are appreciable in ring vascular conifers and hardwood of moderate climate. Texture of these species is various on log bend because of such features of rings (Vintoniv et al. 2005, Forest Products Laboratory 1999, Ugolev 2006, Borovikov and Ugolev 1989).

Development of internal log CT-scanning technology allows to predict log rings despite the complexity of its identification caused by density of rings, their small size, eccentricity and available knots which change number of rings on images (Andreu and Rinnhofer 2003).

Wood texture received by log sawing parallel to axis or generatrix is known while this feature under fixed angle to log axis is not studied completely nowadays. Thus, the theoretical and experimental researches of influence of angle sawing of wood texture and its simulation were performed.

It is known that log shape in majority cases depends on different natural factors and on its location in trunk. Log shape is similar cone in upper section, it is similar to cylinder or paraboloid in middle part and it looks like as neuloid in bottom part of log whereas shape of rings resembles to shape of trunk (Nosovskyy et al. 1993, Rykunin et al. 2003).

On first stage of investigation shape of log and rings are considered as circular cylinder. This choice is caused by necessity of simplification of complex mathematical estimation. It does not essentially influence the final result because logs selected for experimental investigations are sawed from central trunk section and their shape is similar to cylinder (rise and log length is insignificant, rise is $0 \ldots 3$ mm/m, length is $1.9 \ldots 2.0$ m).

The cylindrical surface in co-ordinate space with generatrixs parallel to axis $Oy$ is described by equation $F(x,\ z) = 0$ (Korn and Korn 1968). Circle is resulted on cross-section of circle cylinder with generatrixs parallel to axis $Oy$ and its equation looks as:

$$x^2 + z^2 = R^2 \tag{1}$$

where: $R$ – radius of cylinder (log, rings),
$x$, $z$ – variable dimension.

Coefficient $k$ which accounts for distance between rings is introduced in equation (1) for reconstruction rings in log. It is equal $R > k > 0$:

$$x^2 + z^2 = (R - k)^2 \tag{2}$$

Increase of coefficient $k$ results in decrease of expression $(R - k)^2$. Reconstruction of each step in change of coefficient $k$ allows to gain multitude circle cylinders (circles) with generatrixs parallel axis $Oy$, their number are equal to number of rings.

Plane which is crossed log under fixed angle and thereby reconstructs wood texture received after log sawing under fixed angle to its axis is introduced. Overall equation of plane is presented as:

$$Ax + By + Cz + D = 0 \tag{3}$$

Modification of coefficient at constant coefficients $A$, $B$ and $C$ and requirement that point of origin is situated on apical butt-end of log results in parallel displacement of plane (simulation of log cut under angle to its axis in direction from apical to bottom butt-end). If coefficients $A = 0$ and $D = 0$ plane is parallel to axis $Ox$ and passes through point of origin. Thus the equation (3) is presented as:

$$By + Cz = 0 \tag{4}$$

The equation of received curve needs to be found for simulation of crossing multitude of circular cylinders parallel between planes (Fig. 1). For resolution of this task, system of equations for plane and circular cylinder is composed

$$\begin{cases} B \cdot y + C \cdot z = 0 \\ x^2 + z^2 = (R - k)^2 \end{cases} \tag{5}$$

Plane simulating of cut log under fixed angle to its axis is passing through axis $Ox$ and point $M(0,\ m,\ n)$.

Co-ordinate of point $M$ depends on the log sawing. Dependence between two co-ordinates of point $M$ can be shown as:

$$m = n \cdot \operatorname{ctg} \alpha \tag{6}$$

where: $\alpha$ – angle of sawing,
$m$ – co-ordinate of point on axis $y$,
$n$ – co-ordinate of point on axis $z$.

Decision of equation system (5) is

$$B \cdot y + C \cdot z = 0$$

or

$$y + \frac{C}{B} \cdot z = 0 \tag{7}$$

If point $M(0,\ m,\ n)$ is related to plane its co-ordinates could be substituted in equation (7) and the result is

$$m + \frac{C}{B} \cdot n = 0 \Rightarrow \frac{C}{B} = -\frac{m}{n}$$

then

$$y - \frac{m}{n} \cdot z = 0$$

The equation of plane is presented as:

$$n \cdot y - m \cdot z = 0 \tag{8}$$

The equation (8) is solved relatively to axis z and it substituted in equation (2)

$$z = \frac{n \cdot y}{m}$$

$$x^2 + \frac{n^2 \cdot y^2}{m^2} = (R-k)^2$$

$$\frac{x^2}{(R-k)^2} + \frac{n^2 \cdot y^2}{(R-k)^2 \cdot m^2} = 1 \tag{9}$$

Thus, unknown curve is ellipse with semi-axis:

$$a = \frac{(R-k) \cdot m}{n} \text{ (larger semi-axis)}$$

$$b = R - k \text{ (smaller semi-axis)}$$

Next equations are received after mathematical transformations:

$$y = \frac{m}{n} \cdot \sqrt{(R-k)^2 - x^2} \tag{10}$$

or

$$y = \operatorname{ctg}\alpha \cdot \sqrt{(R-k)^2 - x^2} \tag{11}$$

Simulation of wood texture is performed by means of programme Excel from packet of application program Microsoft Office according to results of proposed mathematical models (11).

Three mathematical models of wood texture are proposed. The description and theoretical calculation of different sawing variants at various parameters are presented in Table 1.

Table 1. Data for theoretical calculation

| Variants | $d$, mm | $\alpha$, ° | | | $n$, mm |
|---|---|---|---|---|---|
| A | 600 | 5 | 10 | 15 | 300 |
| B | 600 | 5 | 10 | 15 | 450 |
| C | 600 | 5 | 10 | 15 | 600 |

$d$ – diameter of log [mm].

**Variant A** – the plane is crossed through log centre under angle 5°, 10° and 15° to its axis.

**Variant B** – the plane is crossed through log on distance to its centre under angle 5°, 10° and 15° to its axis.

**Variant C** – the plane is crossed through log on maximal distance from its centre under angle 5°, 10° and 15° to its axis.

Graphic images of three variants of crossing of circle cylinders (logs) by planes and theoretical models of wood texture received under various sawing angles are presented in Figure 1.

Analysis of theoretical models of wood texture sawed under angles of 5°, 10° and 15° to log axis (Fig. 1d) indicates that it is practically identical and it does not depend from distance of crossing to log centre or this crossing is passed through

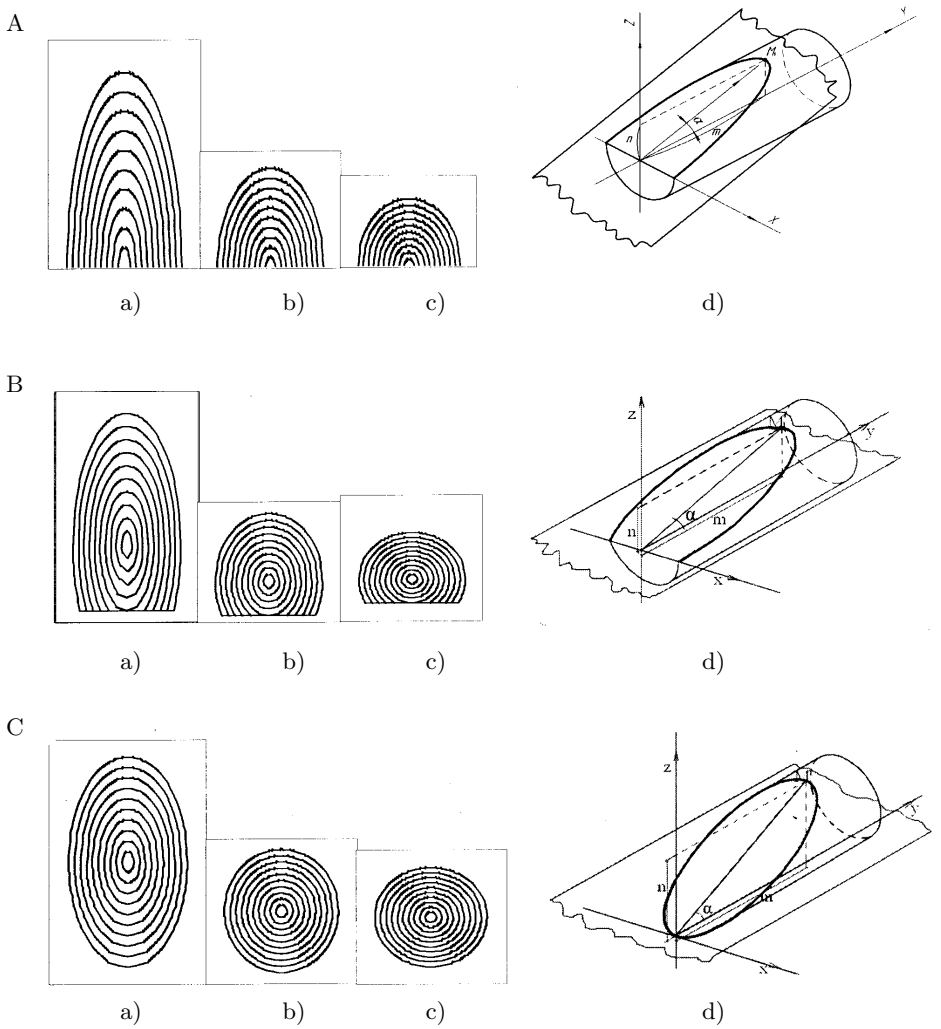


Fig. 1. Images of wood texture which is sawed under angles: a – 5°, b – 10°, c – 15° to log axis, d – crossing circular cylinder by plane which is: A – passing through log centre, B – passing on distance 1/2 from cylinder centre, C – passing on maximal distance from cylinder centre

log centre. Larger semi-axis of ellipse (rings are presented as ellipse or its part in lumber layer, and they form wood texture) is strongly elongated at the log sawing under angle 5° (Fig. 1a) to its axis. Semi-axis of ellipse is decreased in length under log sawing angles 10° and 15°. It is decreased in length under log sawing angles 10° (Fig. 1b) and 15° (Fig. 1c) and their width are not depending. The influence of crossing location for wood texture depends on log length and sawing angle.

Woof textures presented in Figure 1 are received when plane of log sawing under angle to its axis is performed in range from log centre to any point of upper segment (1A) or this plane is performed in range from log centre to any the most

distant point from bottom segment (1B). Wood texture presented in Figure 1C is received when plane is performed in the range from the most distant point of bottom segment (1C).

## Experimental researches

Logs of high quality without surface defects (cracks, rot, crookedness, ellipticity etc) which can essentially influence the location and shape of rings were sawed from central section of trunks. Maximal size of knots (without defects) on log surface is committed to 20 mm, log length to $1.9 \ldots 2.0$ $m$, rise – $0 \ldots 0.3$ cm/m, and log shape is similar to cylinder shape.

The stages of experimental research are included (Fig. 2):

– selection and certification of logs,
– selection of sawing scheme for each log,
– log sawing in segments,
– sawing of segments in unedged lumber (the special equipment for segment fixation at given angle was used),
– preliminary marking,
– drying of lumber,
– longitudinal sawing of lumber,
– cross-cut sawing of lumber (when needed),
– shaping of internal and external lumber faces,
– final marking,
– photographing of wood texture.

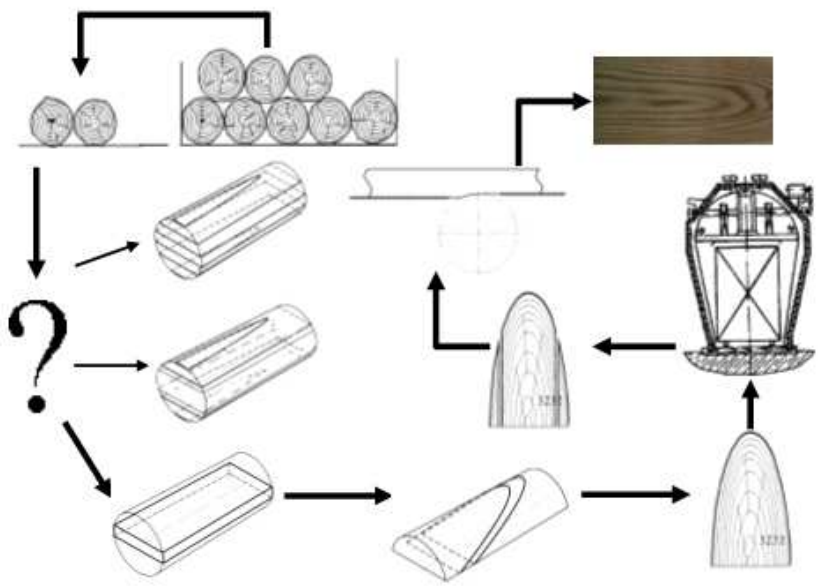

Fig. 2. Scheme of experimental research realization

The results of experimental researches of wood texture are presented in Figure 3.

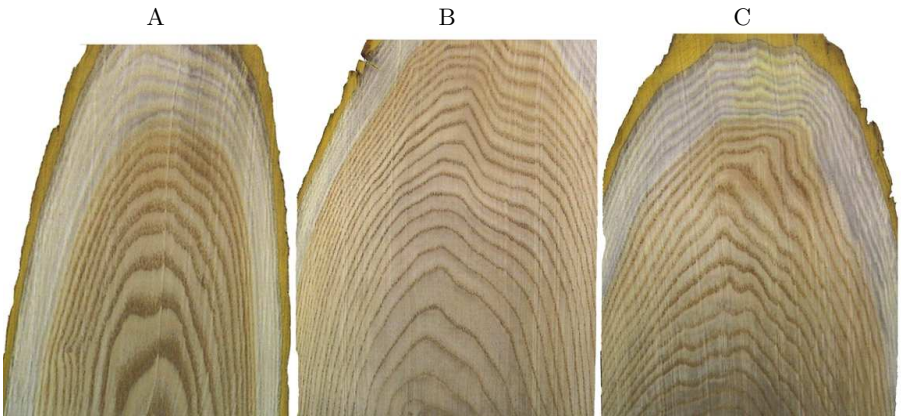


Fig. 3. Images of wood texture sawed under angles: A – 5°, B – 10°, C – 15°

Character of influence of angle sawing on wood texture is identical both in theoretical simulation and experimental investigations (Fig. 4).

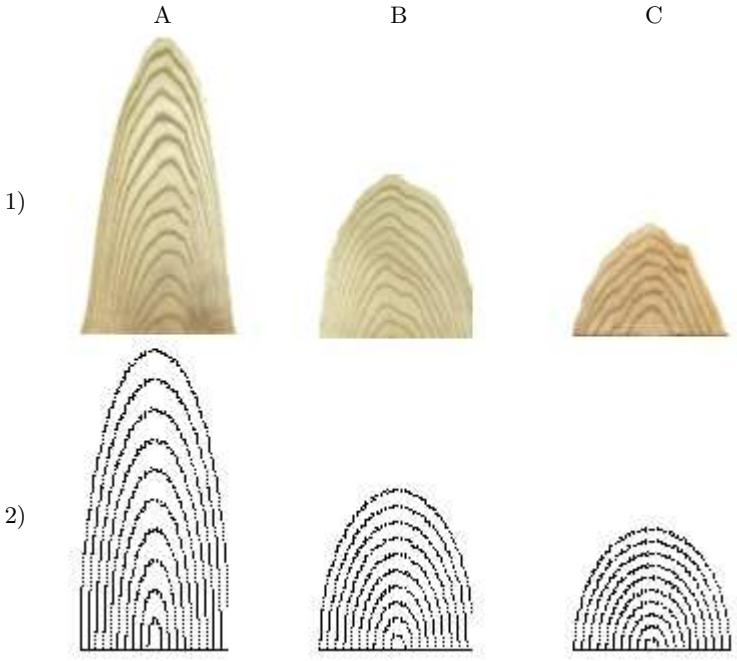


Fig. 4. Images of wood texture sawed under angles: A – 5°, B – 10°, C – 15° in experimental investigations (1) and theoretical simulation (2)

It is difficult to predict both wood texture and final view of wood product from lumber of traditional sawing (parallel to log axis). The use of wood texture sawed under angles of 5°, 10° and 15° to log axis can facilitate this prediction. The examples of wood texture set and use of wood texture in finished furniture sawed under defined angle is presented in Figure 5.

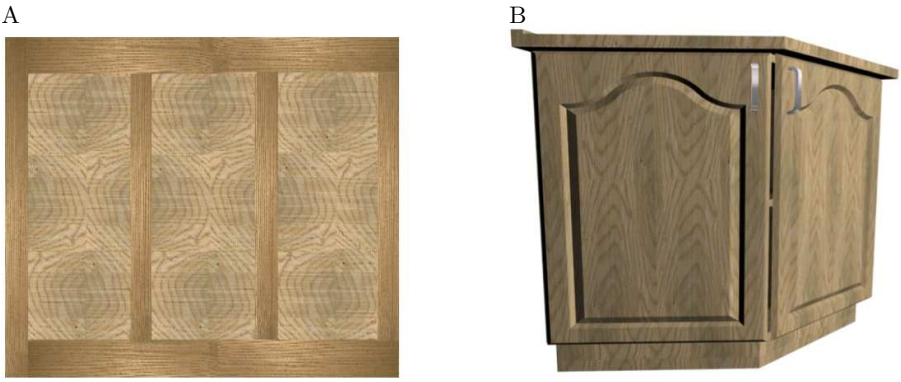


Fig. 5. The use of wood texture sawed under angle 10° to log axis: A – set of wood texture, B – use of wood texture for design of bedside table

Analysis of theoretical results and experimental research of wood texture sawed under angles 5°, 10° and 15° to log axis indicates possibility of theoretical simulation of wood texture and prediction of volume lumber recovery. However, such analysis can be correct under condition of exception of main factors, which can influence the location and shape of rings (cracks, rot, curvature, ellipticity and knots of big size). Other factors ignored in this paper can also result in various variants of wood texture sawed under different angles to log axis and formed by rings. Rings can possess original (curving) unexpected shape and form beautiful texture (Fig. 4 (1)). However, exact prediction of wood texture and volume lumber recovery is practically impossible as a result of natural origin of wood. The investigation of influence of some factors in this prediction is possible for logs with shape similar to cylinder.

## CONCLUSIONS

The theoretical and experimental study of influence of sawing angle on wood texture is performed.

1. Analysis of scientific and technical literature testifies that technology of sawing of round lumber presented in woodworking plants does not foresee original wood texture as criteria of method of round lumber sawing.
2. It is developed the model of log sawing under angle to log axis and it allows to predict of wood texture.

3. The change of sawing angle to axis of 5 ... 15° allows to receive original pattern of wood texture. Volume lumber recovery of course is decreased and its cost price is increased but high art value of products manufactured from that lumber ensures the selling of products.
4. Database of wood texture is developed for different methods of log sawing by breakdown method (parallel to log axis, parallel to log generatrix, under angle of 5° ... 15° to log axis) and variants of furniture design are proposed.
5. Application of technology of round lumber sawing under angle to its axis in production requires specialized equipment.

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