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Instrumental Assessment of Scots Pine Trees (*Pinus Sylvestris L.*)

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Abstract

The article presents the results of a study of the quality of stem wood of mature and overripe Scots pine trees (*Pinus sylvestris L*.) using the methods of non-destructive testing of wood with the help of ultrasonic tomography unit Arbotom® and Resistograph 4450. As a result, the integrated use of Arbotom® and Resistograph 4450 devices is necessary in order to obtain a more objective assessment of the state of tree stands and individual trees. As a conclusion, the density of wood at the root crown and at a height of 150 centimeters varies in different trees.

Keywords: Trees, Trunk, Ultrasound Tomograph, Condition.

Evaluación instrumental de pinos escoceses (*Pinus sylvestris l.)*

Resumen

El artículo presenta los resultados de un estudio sobre la calidad de la madera de tallos de pinos maduros y demasiado maduros (Pinus sylvestris L.) utilizando los métodos de prueba no destructiva de la madera

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con la ayuda de la unidad de tomografía ultrasónica Arbotom® y Resistograph 4450. Como resultado, el uso integrado de los dispositivos Arbotom® y Resistograph 4450 es necesario para obtener una evaluación más objetiva del estado de los rodales y de los árboles individuales. Como conclusión, la densidad de la madera en la corona de la raíz y en una altura de 150 centímetros varía en los diferentes árboles.

Palabras clave: árboles, tronco, tomografía ultrasónica, condición.

1. INTRODUCTION

One of the challenges of modern forestry is to assess the quality of stem wood of the main forest-forming species using a non-destructive testing method. Of particular importance is the assessment of the tree condition in mature and overripe stands that enter the dying phase. This phase is accompanied by external signs, such as dieback, a decrease in radial and height growth, the emergence of fruit bodies of wood-destroying fungi, and excessive debris. Many authors evaluated the state of mature or overripe stands using visual methods, as well as enumeration methods by measuring radial and height growth and stand volume. However, visual and measurement are not always helpful in identifying internal rots of various degrees of development, as well as other hidden defects that can only be determined when the trees are cut. Recently, instruments and tools have emerged that help determines the internal state of the trunk by the wood density, as well as by the speed of the sound propagation in the trunk. The goal of the research is to study the state of model pine trees aged 100 years or more using Arbotom® and Resistograph 4450 (RENN TECH, Germany) and the probable direction of the fall of trees with internal and external trunk defects under heavy wind load (Alekseev, 2006).

Place of study: Irkutsk region, Bratsk, residential area Energetik. Geographically, the north of the Irkutsk region is situated in the tableland forest province of southern taiga and subtaiga pine and larch forests near the Angara River. The climate of the study area is sharply continental and is characterized by a long cold winter with little snow and a short summer. The growing season is 120 days. The average annual precipitation per year is 374.3 mm. The prevailing wind direction is westerly and southeasterly. The average wind speed is 2 m/s. The average multiannual temperature per year is 2.4; the absolute temperature of the air is – 43.1 minimum and +31.4 maximum. The last date of frost is July 1. The first date of the autumn frosts is August 1. The average date of river freeze-up is November 10. The average dates of the flood beginning and end are May 10 – June 1. The depth of soil freezing is average – 100 cm, maximum – 200 cm. The depth of the snow cover is 35–50 cm. The average date of formation of a steady snow cover is October 25, the number of snowy days is 180. The average date of the clearance of a steady snow cover is April 15. Adverse climatic include (Bucur, 2003):

-Cold winters with little snow and deep soil freezing (up to 2 m);

-Significant duration of dry periods in summer (up to 20 days);

-Low relative humidity of air;

-Insufficient precipitation;

-The long period of strong winds.

In general, the climate of the region is favorable for the successful growth of cedar, pine, larch, spruce, fir, birch, aspen and shrubs. Assessment of mixed young pine and larch trees was carried out using the data of the Irkutsk region (Isaeva, 1975; Catena, 2003).

2. METHODOLOGY

The research was carried out on model trees of the Scots pine (Pinus sylvestris L.) of natural origin, included in the urban environment during the construction of Bratsk in 1955. At present, the average age of the Scots pine is more than 100 years. 20 model trees were studied; for each model tree, the diameter of the trunk at the base and at 1.5 m was determined; using a clinometer, the height of each tree and the crown length were measured; the age was determined by the cores sampled at the base of the trunks. A passport was created for each tree, indicating its number, measurements and visible trunk defects. The next step was to obtain an ultrasonic tomogram of trees at a height of 1.5 m using Arbotom®. The research was carried out at heights 50 cm and 1.5 m. The obtained data were processed in the specialized computer program DECOM. For more reliable information, the model trees were examined using the Resist graph 4450. Resist grams were obtained for a height of 1.5 m (Bokshchanin, 1962).

3. RESULTS

As a result of the study of model trees, the measurements for each model tree were obtained, as well as the results of their assessment. Table 1 shows the measurements of the three most typical trees for the study area.

Table 1 – Measurements of the model trees

No. of a model tree	D_{base} cm	$D_{1,3}$ cm	$H_{tree,}$ m	$H_{crown\ base,}$ m	Age, years	Visible trunk defects
6	38	32	21	15	100	Fire scars, trunk lean
7	44	38	23	17	115	Fire scars, trunk lean
8	52	44	23.5	18.5	121	Fire scars, trunk lean

Table 1 indicates that the model trees are mature and overripe, with visible defects of the trunk in the form of scars, extending from 30 to 50 cm mainly in the lower part of the trunk. The trees represented in the table have a trunk slope. As an example, the results of the study of three Scots pine trees (number 7, 8, 6) are given. Measurements were taken at the root crown (45 – 55 cm) and at a height of 150 cm. Figure 1 shows a photograph of the Arbotom® sensors arrangement (the number of sensors is 10). The measurements were taken without duplicating impacts on the instrument sensors (Vikhrov, 1963; Rust & Gocke, 2000).

Figure 1 – The arrangement of the Arbotom® sensors on the tree no. 7.

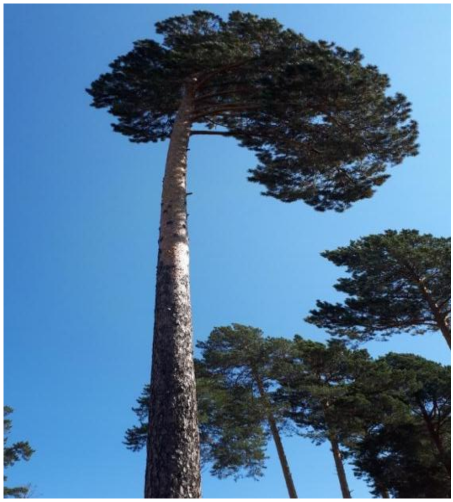

Figure 2 – Model tree no. 6

There is no standardized (fixed) graduation scale. An automatic (floating) graduation scale is used, which proportionally distributes the values obtained from one measurement from the minimum to the maximum. Table 2 shows the mean values of the Arbotom® measurements for some model trees (Liang & Fu, 2012; Lonsdale, 1999).

Table 3 – Analysis of the range of ultrasound propagation velocities for the studied trees

Measurement	The most frequent range of velocities, m/s	Relative frequency, %
Tree 7	657-982	65
Tree 8	610-928	45
Tree 6	540-753	63

Figures 3-8 show the tomograms of the model trees under study at 40-50 centimeters and 150 centimeters height from the tree base. The green color on the tomograms represents the high speed of ultrasound propagation, the yellow color corresponds to the average speed, and the red color shows the low speed of ultrasound propagation through the wood. As follows from the tomograms obtained, the quality and strength properties of the studied trees are higher at the trunk basis than at a height of 150 centimeters. The average speed of ultrasound propagation at the trunk basis is 1.53-1.59 times higher than that at a height of 150 centimeters (Zhukov, 1931)

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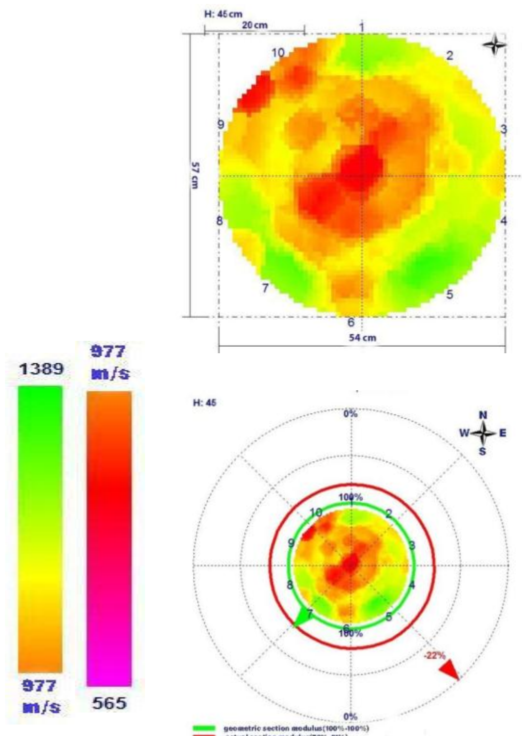

Figure 3 – Tree no. 7 – Tomogram at the root crown

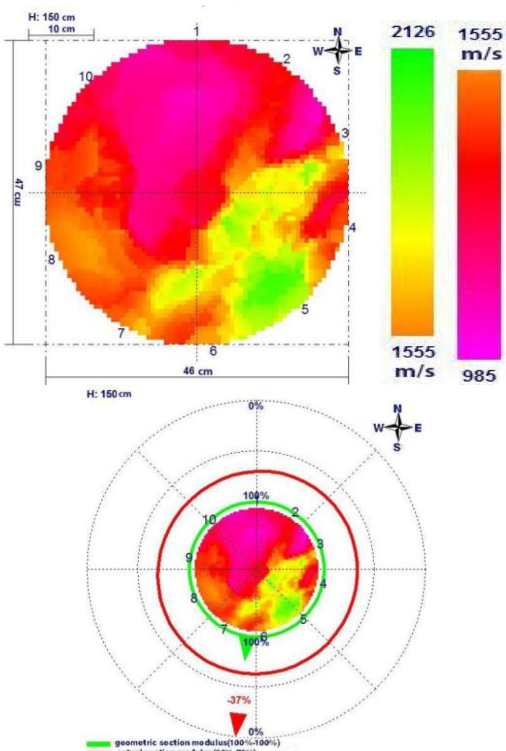

Figure 4 - Tree no. 7 – Tomogram at 1.5 m

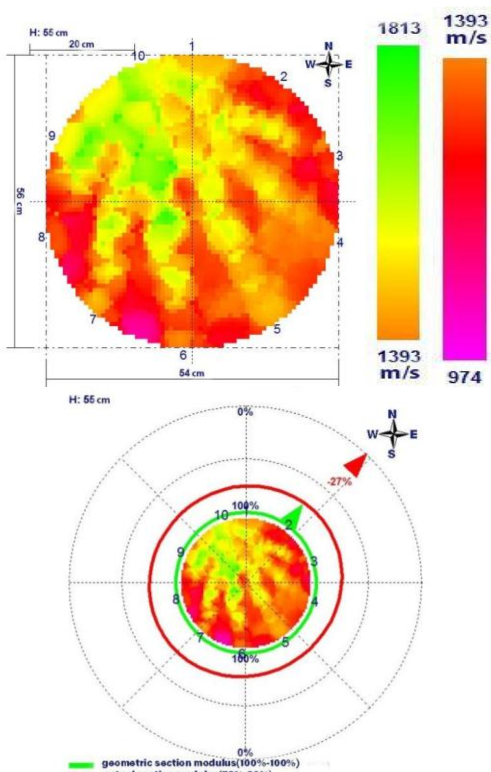

Figure 5 – Tree no. 8 – Tomogram at the root crown

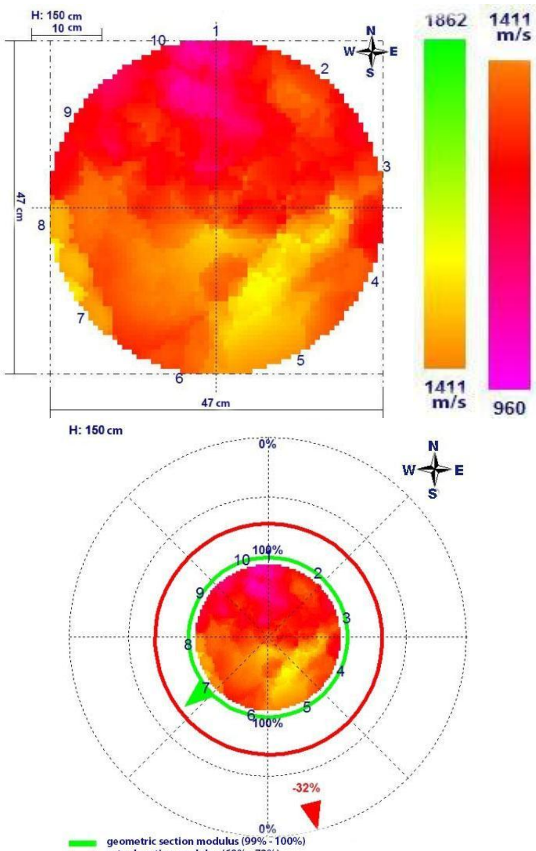

Figure 6 – Tree no. 8 – Tomogram at 1.5 m

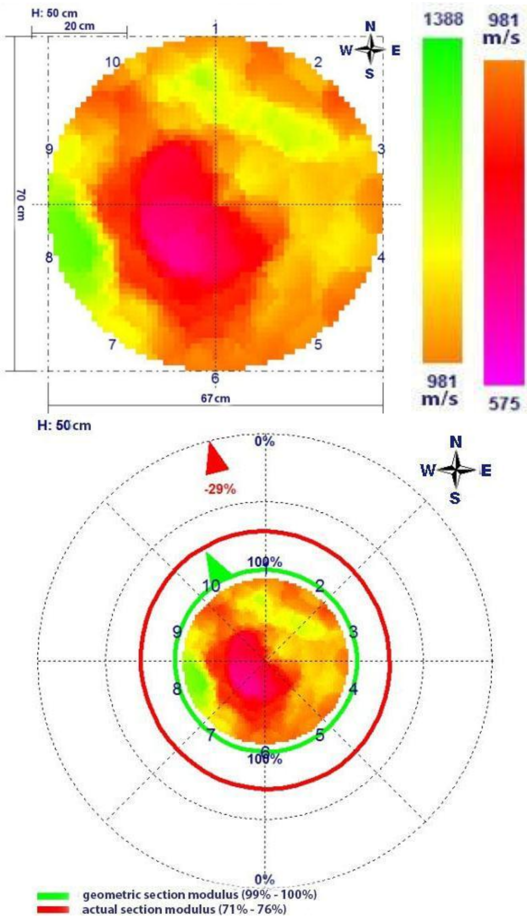

Figure 7 – Tree no 6 – Tomogram at the root crown

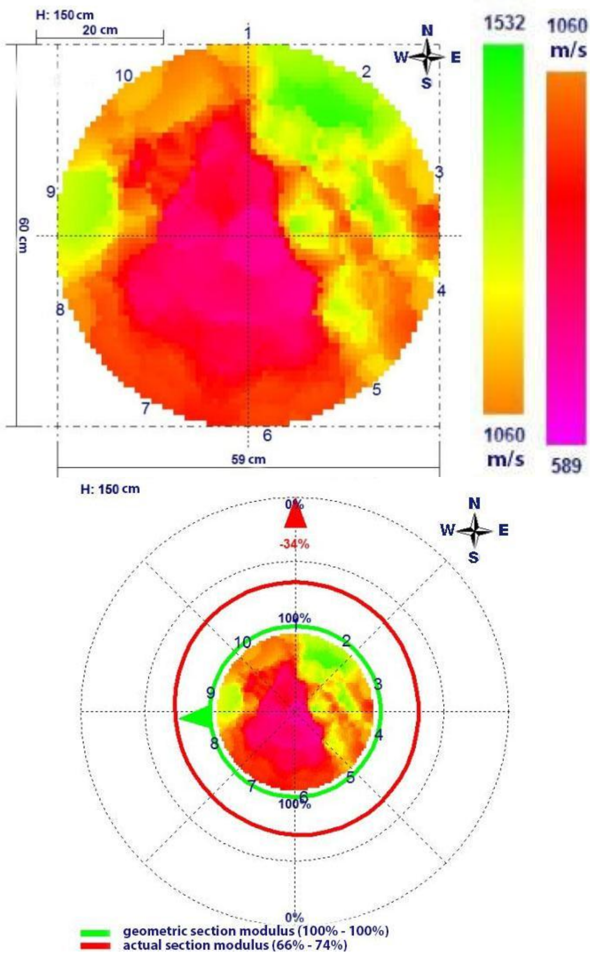

Figure 8 - Tree no. 6 – Tomogram at 1.5 m

The right side of Figures 3-8 shows the geometric section modulus of model tree trunks. The red arrow points to the possible direction of the tree fall under increased wind load. It should be noted that the direction of the possible fall does not depend on the direction of winds prevailing on the study area (the predominant wind direction is westerly and southeasterly, the average speed of the wind is 2 m/s), but on the conventional density of the stem wood. So the tree number 7 can fall in the southern or south-east direction, tree number 8 – in the south-east direction, and tree number 6 – in the northern or northwest direction. The findings are based on the maximum actual section modulus (-27-32%). In addition, the quality of the wood of Scots pine trees was evaluated using the Resistograph 4450. Resistorgrams were obtained by drilling a tree trunk with a thin needle at a height of 150 centimeters. The obtained resistograms showed poor quality of the trunk with the signs of decreasing wood hardness (Lvov, 1971; Ibrahim, 2018).

Figure 9 – Resistogram for Tree no. 6

Green indicates the area of healthy wood, yellow indicates the initial stage of rot, red indicates severe rot. Y-axis shows the relative density of the wood, and X-axis shows the diameter of the tree under study in centimeters of the Resistograph 4450 (Vikhrov, 1949).

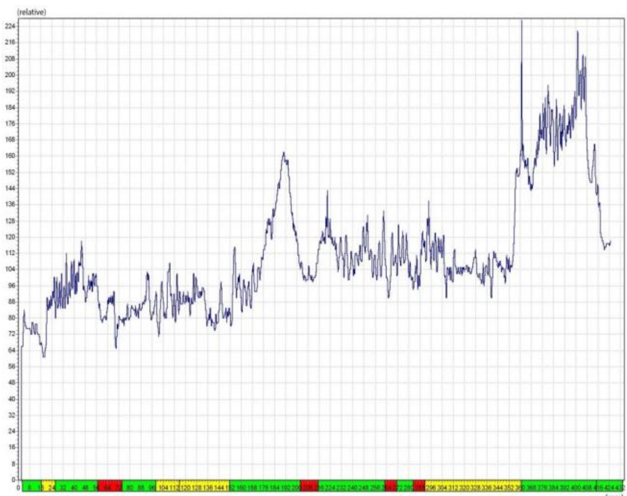

Figure 10 – Resistogram for Tree no. 7

Green indicates the area of healthy wood, yellow indicates the initial stage of rot, red indicates severe rot. Y-axis shows relative density of the wood, and X-axis shows the diameter of the tree under study in centimeters (Deflorio, 2006).

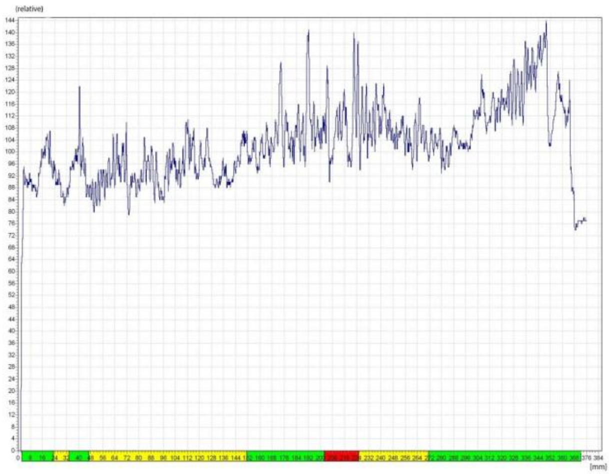

Figure 11 – Resistogram for Tree no. 8

Green indicates the area of healthy wood, yellow indicates the initial stage of rot, red indicates severe rot. Y-axis shows the relative density of the wood, and X-axis shows the diameter of the tree under study in centimeters. Drilling was performed in the direction of the possible tree fall. The resistograms show the difference in the relative density of spring and summer wood of the annual layers. The decrease in relative density indicates the presence of rot in the initial or later stage of development. As 9 – 11 show, all trees have internal rot in a different stage of development: from initial too late. 26.4% of the trunk cross section is affected by rot in the tree number 6, 41.4% – in tree number 7, 53.6% – in tree number 8. Such trees can be considered emergency trees, which may fall under wind loads (Deflorio & Fink, 2008).

4. DISCUSSION

Studies on similar topics have been undertaken by O.N. Tyukavina, M.F. Lavrov, A.E. Mestnikov, I.A. Melnichuk, Y.M. Yassin Soliman, O.A. Cherdantseva and a number of foreign scientists. The studies aimed at developing a methodological approach to the study of wood density distribution across the trunk cross section and height through the example of the wood of the Dahurian larch, which grows in Yakutia, and diagnosis of the internal state of Tilia Cordata Mill trees using the Arbotom® acoustic ultrasonic tomography system. In general, the publications dedicated to this problem are few. No detailed research has been performed. The research presented in this article differs significantly from those of other authors, as it provides a comprehensive analysis of the interaction of two measuring instruments, the results of which substantially complement each other. As a result, a conclusion can be drawn that the integrated use of Arbotom® and Resistograph 4450 devices is necessary in order to obtain a more objective assessment of the state of tree stands and individual trees.

5. CONCLUSION

The research presented in this article suggests the following conclusions:

1. All 100-120-year-old model pine trees of the Scots pine species have external defects of the trunk, which are visible during the visual examination of trees. The study has proved the presence of internal defects in all the trees, which are confirmed by ultrasonic tomograms and resistograms.

2. The density of wood at the root crown and at a height of 150 centimeters varies in different trees.

3. A wide range of the speed of sound impulse propagation suggests an uneven distribution of the wood density across the trunk cross-section.

4. The speed of sound impulse propagation in the Scots pine wood for the Irkutsk region of the Russian Federation is on average from 1,400 to 2,000 m/s.

5. The vector of the priority direction of the trunk fall in samples no. 7 and 6 deviate slightly depending on the altitude. In sample no. 8 a sharp change of direction is

observed. This may be due to the absence of a localized destruction zone in the stem wood.

6. The use of two measuring instruments simultaneously in assessing the quality of the stem wood increases the accuracy of the data and allows the identification of potentially hazardous emergency trees, both in forest stands and in urban environments.

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