Investigation of Factors Affecting Reliability of Fakopp 3D Acoustic Tomograph (Wood Tomograph) Device Used for Determining of Wood Defects in Forestry Industry

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Abstract:
In today’s manufacturing industry, cost, productivity and quality are three important concepts. These concepts are in a relationship with each other. To provide manufacturing quality has a positive influence on cost and productivity. Structure and quality of wood is important in forestry industry. Raw wood material having different features, such as cracks, defects, moisture content, and density, are evaluated in different industrial areas according to these structural characteristics. Therefore, the importance of non-destructive tests methods used for quality control in manufacturing is increasing day after day. In this study, several circular cross-sectional discs in different diameter (30-35 cm) were obtained by cutting down of 20 standing spruce trees. After creating some artificial defects, such as decay, fracture, cavity in those discs, some negativity which may show up in determining of those defects and accuracy rating of the device were tried to detect by applying ultrasonic tomographic technique which is one of nondestructive tests technique. In the literature, it was seen that all characteristics (growth rings, fractures, decay, knot and amount of moisture) in wood or wooden material affected ultrasonic speed of sound in a certain rate. For this reason, effects of moisture contents on ultrasonic measurement were investigated by revealing humidity of the wood via using a moisture meter. In addition, it was tried to determine the relationships between data(diameter alteration of artificial cavity discs and alteration of moisture content in the wood - alteration of ultrasonic velocity) in this study. Thus, it was aimed to contribute to accuracy and reliability of the results obtained by other studies performed by several authors by detecting factors affecting accuracy of measurements on wood and wooden material and degree of influence of those.

Key Terms: Non-destructive test methods, accuracy and reliability, wood materials

Introduction:
One of the main duties of forestry is detection of deficiency and quality assessment in the wood of standing trees. It is vital importance for quality of round wood that if there is cavity inside of standing trees in the forest. Especially, in the early stages of decay, appearances of trees seem to be in good health detection of cavity is not possible by external examination of a tree (Bucur, 2004).

High frequency signals electrically generated by Fakopp 3D Acoustic Tomography device, which is one of non-destructive test devices that will be used in this study, is sent to inside of material as ultrasonic waves by probes that is made from piezoelectric signals. Signals are interpreted by an expert and position of a discontinuity (decay, fracture and cavity) leading to a signal is determined (Kafalı, 2004). Proportion of elasticity versus density normally changes, if there is any decay in anywhere. Thus, the flying time increase and ultrasonic sound velocity decreases (Rahman, 2003; URL-1; Dzbeński ve Wiktorski, 2007).

How to effect relations between proportion of defective disc diameter - alteration of ultrasonic speed and moisture content value in the wood - ultrasonic sound velocity that will be obtained by this study is going to be examined. Also, effect of moisture content in the wood on ultrasonic sound velocity is going to study and thus, it is aimed to contribute the literature by determining correlations between those data.

Materials and Methods:
In this study, measurements were obtained from 20 spruce trees in the field forest sub-district directorate of Madenler of regional directorate of forestry of Artvin. Multiple ultrasonic measurements in the trunk of those trees were obtained approximately on the level of 130 cm from the ground. Wood disc having 30-35 cm diameter and 10 cm thickness were firstly dried in the laboratory. Then, after
making an artificial defect on the disc by a drill having punch set, multiple ultrasonic measurements were performed. While artificial defects by 2 cm diameter were firstly made in the central of trees, 4 cm diameters were secondly made in the central of the wood discs (Figure 1). The main purpose of this is to provide accuracy of the measurements in the standing trees based on determination of artificial defects in the wood disc that obtained by Fakopp 3D Acoustic Tomography device.

![Image](image1.png)

**Figure 1.** The determination of artificial defects in the wood disc by Fakopp 3D Acoustic Tomography device

**Fakopp 3D Acoustic Tomography (Wood Tomography) Device:** Tomography bases on reconstruction of transversal section of an object by some measurement obtained by a device that measures the energy passing through of that object (Lin vd., 2008). Most of the technical tomography studies are applied on timbers and woody structures. Ultrasonic tomography device is applied by some researchers in the timbers, poles and standing trees (Nicolotti vd., 2003). This devices can provide flawless and accurate data in a complete transversal section. This is a surely non-invasive device (Nicolotti ve Miglietta, 1998). Blue regions represent empty and low density regions in the graphic. Decayed area is presented by red and yellow. Light and dark green shows healthy regions (Figure 2).

![Image](image2.png)

**Figure 2.** The tomography image related to standing trees based on determination obtained by Fakopp 3D Acoustic Tomography device

With the aim of accuracy of measurements obtained from planted trees, trees having decay and defection inside were determined and cut, internal section of a tree was compared with the graphics revealed by obtained measurements.

**Wood Moisture Meter Device:** Moisture content value of standing trees was determined by a moisture meter device (GANN Hydrometer HT 85 T) and thus effects of moisture amount on ultrasonic sound velocity was tried to determine. Moisture content
amount in trees or wooden materials effects ultrasonic sound velocity in a certain proportion is known from the literature (Benoit ve Sandoz, 2007). Since a moisture meter cannot detect a decay in a tree and can just use to control conditions leading to decay, this device are secondarily used in studies (Morrell, 1996).

**Data Overarching:**

**Correlation between Wood Moisture Content Value and Ultrasonic Sound Velocity:** Wood moisture content value and ultrasonic measurements of wet and dried wood disc at least in 10 cm diameter were determined. Effects of wood moisture value on ultrasonic sound velocity were tried to reveal.

**Detection of relation between artificial defects in different diameter in wood disk and ultrasonic sound velocity:** 20 wood discs at least in 20-30 cm diameter were firstly dried. Then artificial defects with 2 and 4 cm diameter were generated by a drill having punch set. It was tried to determine how ultrasonic changes according to artificial defects speed in different diameters.

**Findings**

**Findings for accuracy of graphics obtained by Fakopp 3D Acoustic Tomography Device:** To provide accuracy of findings obtained from Fakopp 3D Acoustic Tomography Device in the standing trees examined in this study, standing tree was cut and it was tried to verify if examined transversal section of the trees reflects obtained graphics by the device. After examination, obtained measurement was confirmed this case. To understand accuracy of the measurements obtained from standing tree in the forest, those wood discs with 20-30 cm diameter were transported to the laboratory and artificial defects with 2 and 4 cm diameter generated in the center of that discs by a drill with a punch set were detected by Fakopp 3D Acoustic Tomography Device

**Measurements obtained by Fakopp 3D Acoustic Tomography Device and Wood Moisture Meter Device:** Relations between ultrasonic sound velocity and moisture content value were tried to detect and results were given in the Table 1. The results of relations between artificial defects and ultrasonic sound velocity were also given in the Table 3.

<table>
<thead>
<tr>
<th>Mean (m/s)</th>
<th>Std</th>
<th>Mean (m/s)</th>
<th>Std</th>
<th>Mean (m/s)</th>
<th>Std</th>
<th>Mean (m/s)</th>
<th>Std</th>
</tr>
</thead>
<tbody>
<tr>
<td>1474,85</td>
<td>258,51</td>
<td>1330,35</td>
<td>241,62</td>
<td>1308,40</td>
<td>199,11</td>
<td>1583,30</td>
<td>224,64</td>
</tr>
</tbody>
</table>

**Discussion:**

**Determination of differences in the ultrasonic sound velocity values in terms of wood moisture content values:** It was determined by the statistical analyses that average ultrasonic sound velocity value in dried wood discs (1583,3 m/s) was higher than that in wet discs (1308,4 m/s) and this difference was significant statistically (p<0,01).

The ultrasonic sound velocity measurements obtained wet and dried wood discs were grouped separately in the multiple comparison tests (Figure 3).
Not only speed of sound waves can be changeable in different species, different seasons and different wood moisture contents, but also sometimes it can be changeable in the same tree (URL-2).

**Determination of Differences between ultrasonic sound velocity values in terms of artificial defects in different diameters**: In the analysis of variance, there was a statistically significant difference among ultrasonic sound velocity values in terms of artificial defects in different diameters ($p < 0.01$).

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Sum of Squares</th>
<th>Mean of Squares</th>
<th>F-value</th>
<th>Prob&gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>The artificial defects with 2 and 4 cm diameter generated in the center of that discs by a drill with a punch set</td>
<td>2</td>
<td>644169,0</td>
<td>322085</td>
<td>5,5000</td>
<td>0,0065</td>
</tr>
</tbody>
</table>

Multiple comparison test was revealed that ultrasonic speed measurements obtained from wood discs of standing trees and wood discs having artificial defects (2 and 4 cm diameter) was statistically different and grouped separately.

Figure 3. Relations between Wood Moisture Content Value and Ultrasonic Sound Velocity Value Obtained by Fakopp 3D Acoustic Tomography Device

Figure 4. Ultrasonic sound velocity measurements obtained from wood discs having artificial defects (2 and 4 cm diameter) and wood discs without artificial defects
The higher value of average ultrasonic sound velocity (1583.3 m/s) was measured in the wood discs obtained from planted tree and having no artificial defects (figure 4). This was followed by the average ultrasonic measurement value obtained from dried wood disc in 2 cm diameter (1474.8 m/s). The lowest measurement was observed in the dried wood discs in 4 cm diameter (1330.3 m/s). This case was one to one consistent with the literature. If there is a decay, proportion of elasticity versus density normally changes and thus, flying time increases and speed decreases (Rahman, 2003; URL-1; Dzbeński ve Wiktorski, 2007).

**Determination of correlation between ultrasonic sound velocity measured by Fakopp 3D Acoustic Tomography Device in the planted tree and decayed area:** In the correlation analysis, a negative relation was observed between ultrasonic sound velocity measured by Fakopp 3D Acoustic Tomography Device and decayed area (p<0.05). According to this negative relation, it was determined as it is expected that if amount of decay is higher, ultrasonic sound velocity is lower. If there is a decay, proportion of elasticity versus density normally changes and thus, flying time increases and ultrasonic sound velocity decreases (Rahman, 2003; URL-1; Dzbeński ve Wiktorski, 2007).

<table>
<thead>
<tr>
<th>Multivariate Correlations</th>
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<tbody>
<tr>
<td>Tomography speed</td>
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<tr>
<td>Tomography speed</td>
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<tr>
<td>Tomography decayed area(m2)</td>
</tr>
</tbody>
</table>

**Determination of correlation between ultrasonic sound velocity measured by Fakopp 3D Acoustic Tomography Device in the standing tree and amount of moisture content measured by wood moisture meter device:** In the performed correlation analysis, a negative relation was found between ultrasonic sound velocity measured by Fakopp 3D Acoustic Tomography Device in the standing tree and amount of moisture content measured by wood moisture meter device (p<0.05). It was determined as it is expected that if amount of moisture in the wood is higher, ultrasonic sound velocity is lower; because sound is faster spread in the solid environment.
Results:

All factors affecting ultrasonic sound velocity (wood moisture content, natural defects like snag which develops anatomically) can affect measurement obtained by those devices. Therefore, here, the relation between ultrasonic sound velocity and wood moisture content was tried to reveal statistically. Analysis showed that ultrasonic sound velocity decreased when wood moisture content increased. In that, a negative relation was observed between them. Also, to provide accuracy of measurements obtained by the Fakopp 3D Acoustic Tomography Device, different artificial defects were generated in the central of wood discs obtained from standing trees and it was observed that this device could detect those defects. In addition, it was revealed that ultrasonic sound velocity decreases when diameter of artificial defects increase. Also, it was revealed that if proportion of decayed area increase, ultrasonic sound velocity decreases. Thus presence a negative relation between them was detected.

It was rarely observed in the measurements obtained by the Fakopp 3D Acoustic Tomography Device that similar detections may obtain in a strong tree with certain decay and in a weak tree having no decay. It was thought that this case may occur due to different anatomic structure of each tree (leaf density). Except for those, it was determined that this device can measure some data due to wind which make sound by hitting of wire of the device and placing wrong input information into the device.

Conclusions:

Ultrasonic measurements by this device obtained from standing trees should be calculated again by considering average moisture content value of standing tree...
according to a new formula. Also correct input information should be placed into the device and it should be prefer to study in the weather without rainy and windy.

References


Rahman, A., 2003. Modelling Inground Decay of Wood Poles for Optimal Maintenance Decisions, School of Mechanical, Manufacturing and Medical Engineering, Queensland University of Technology, Australia, 56-69s.