Research of plywood quality by acoustic methods

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Abstract. Traditionally, for composite materials, glued wood and solid wood are used non-destructive methods of control that take into account the specific features of the object. Plywood is a non-metal anisotropic material of complex structure, so most non-destructive testing methods, such as magnetic and eddy current methods are excluded. For choosing a method, it should also be borne in mind that plywood is a large product and may have significant size defects. The shock method is easier to implement than other non-destructive testing methods, so it can be considered effective for plywood defectoscopy. The existing classical shock method is carried out by the absolute values of the deviations of the characteristics of the oscillatory processes of the plywood. Changing the variable factors of plywood may reduce the accuracy of the device being implemented. Therefore, a technique for improving the shock method by measuring the relative characteristics of the oscillation process was developed. Comparison with the known, most accurate ultrasonic method of control revealed that the highest correlation with ultrasound has such a parameter of the shock sensor as the coefficient of harmonic distortion, which gives reason to recommend the shock method for determining the area defect plywood.

1. Introduction
Plywood has been a common building material in railroad carriages for a long time due to its durability, low weight and resistance to temperature change. The actual problem is improving the quality of products and developing an automated non-destructive method for detecting defects. For defectoscopy of products made from composite materials (for example, polymeric) more usually used acoustic methods and, rather ultrasonics are more effective. The main disadvantage of this method is the necessity to use various lubricating fluids during the control to create conditions for reliable acoustic contact of ultrasonic sensors with the surface of the product. Metal and plastic surfaces are not destroyed. But lubricating fluids cannot be used for plywood. However, seeking the accuracy of measurements, it was decided to check the correlation of the ultrasonic and shock signals to confirm the effectiveness of the selected method.

2. Analysis of recent research and publications
Traditionally, for composite materials, glued wood and solid wood, non-destructive methods of control are used that take into account the specific features of the object. The most popular methods for defecting wood and glued wood are acoustic. This is reflected for the wood in the works by E. Hamma [1], M.
Patton-Mellory [2], R. De Groot [3,4], R. Ross [5,6], P. Niemzs [7], and for glued wood materials in scientific works by I. Bobadilli [8], S. Sanabria [9]. However, at present, there is no effective and inexpensive method to automate this process to improve the quality of flaw detection of the above wood materials.

3. Determine the purpose and objectives of the study
The research aimed to improve the shock-acoustic method of quality control of plywood by identifying the physical and mechanical parameters that have effect on quality for implementation in the technological process of production

To achieve the goal, the following tasks were solved:
- analyzing methods of quality control of plywood;
- investigating the nature of the change of the amplitude of plywood oscillations during impact in the absence and presence of a defect in it.

4. Materials and methods of research
Experimental researches were carried out on the installation (Figure 1) and sample of plywood (6), which includes a shock sensor (5), which through the switching unit (3) is connected to the computer (1), the piezoelectric unit through the same switching unit is connected to the oscilloscope module (2).

Research was conducted using plywood produced from hardwood of Kyiv region, such as birch and alder. Bundle defect was artificially simulated by gluing two plywood samples with planned defect area from $S_1 = 0.0079$ m$^2$ to $S_2 = 0.042$ m$^2$ and depth from 0.004 m to 0.02 m.

Figure 1. General view of the test installation.
5. The main part of the study

For the physical simulation of a defect, a model of a plywood defect was created by gluing two plywood plates of different thickness. The location of the simulated defect was not covered with glue on both plates (Figure 2). Thus, we have obtained one of the most common defects, delamination, which manifests itself with the appearance of an air bubble between adjacent layers of glue and veneer. Veneer, air bubble and glue layers can be imagined as certain elements of the rheological model of plywood, which has its own mass, elasticity and viscosity.

Such a model gives us the possibility to assume that in the case of mechanical action on a material, acoustic oscillations of different shapes will arise, depending on the structure, whether there is or not a defect.

The basis is a classic acoustic method, which is carried out only in absolute value of the deviations of the quality of plywood. This can result in measurements errors when changing such factors of plywood as wood, its moisture, roughness, and others [10].

![Figure 2. Cross-section of the plywood with a defect.](image)

In order to eliminate these deficiencies, an improved plywood quality control (Figure 3) method was developed which is relative to the characteristics of oscillatory processes in plywood.

The main principles of the improved method of plywood quality control using shock method:
- drummer influences on plywood;
- pulse of force of a drummer is transferred to the plywood;
- at the point of impact, there is a displacement of layers of plywood and the oscillating process of the plywood section begins;
- convert mechanical vibrations of a sheet of plywood into electrical (a piezo element was used as a converter);
- analyze the electrical signal from the converter and isolate it from the most informative plot.
- then we measure the electrical signals of the converter and convert it to a digital signal;
- then we store the values of the measured signals in the memory block;
- then we move the drummer for the next measurement at a distance s. If there is no movement repeat item 1;
- then we calculate the relative magnitudes of increasing the fluctuations of the sheet of plywood;
- compare the results of the calculations with the given values of the acceptable level of deviation; which are determined depending on the required accuracy of quality control of plywood;
- in dismissing the comparison results more acceptable decide on sorting sheet of plywood.
Figure 3. Improved method of plywood quality control using shock method.
The initial parameter in the experiments was the speed of sound $v$. The results of the experiment comparing shock and ultrasound methods are shown in Table 1.

**Table 1. Distribution of speed of sound on the plywood area**

| Length, m | Speed of sound v, m/s |   |   |   |   |
|-----------|-----------------------|---|---|---|---|
| 0.04      | 1260                  | 1272 | 1195 | 1139 | 1198 |
| 0.08      | 1206                  | 1195 | 1223 | 1164 | 1250 |
| 0.12      | 1205                  | 501  | 1204 | 1223 | 1165 |
| 0.16      | 1144                  | 911  | 1238 | 1250 | 1261 |
| 0.2       | 1225                  | 1267 | 1228 | 1258 | 1274 |

Width, m 0.06 0.12 0.18 0.24 0.3

Figure 4 showed a visualization of the velocity distribution of sound over the plywood plane. Green and violet is a marked area with a high signal that tells us about a good sanding of plywood, red and blue about the already lower signal, and we can conclude that there is a defect in this area of plywood.

It is possible to observe on visualization of the results of observations that on all surfaces the depression
- the place of the defect (stratification) is clearly visible.

Correlation analysis showed:
- the correlation coefficient between the number of pulsations of the output signal of the shock sensor $n$ and the speed of sound $v$: $K_{n,v} = 0.47$.
-he correlation coefficient between the frequency of free oscillations of the shock sensor signal and the speed of sound: \( K_{fs} = 0.44 \).

6. Conclusions from research and prospects, further development in this direction
As a result of the conducted studies, the efficiency of use of shock and ultrasonic methods for non-destructive testing of plywood was established, in particular:
- among the acoustic methods, ultrasound is considered the most accurate, but for its implementation the surface of the plywood must be treated with a special substance;
- experiments were performed to test the characteristics obtained by the improved shock method on the same samples using ultrasonic flaw detector which showed the same results with the previous ones.

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