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Automatic system for measuring wood moisture using quasi-balanced method of dielectric loss factor measurement

Abstract

The paper presents an automatic system for measuring the moisture content of wood on the basis of loss factor tanδ. The instrument is based on a structure of the non-bridge, quasi – balanced circuit implemented in a program way. The virtual measuring system uses the data acquisition board NI USB-6251 from National Instruments and LabVIEW environment. The preliminary results of experimental studies were compared with the results of the LCR meters Hioki 3522, MOTECH MIC-4090 and meter of wood humidity Powerfix HG00384C.

Keywords: wood moisture, virtual instruments, impedance measurement, quasi – balanced method, dielectric loss factor.

1. Introduction

Wood is a widely used as constructional material and fuel. It is inhomogenous, anisotropic, porous and hygroscopic. Mechanical properties of wood are strongly dependent on its moisture [5]. Wood always contains more or less water which exists as liquid water, as water vapour or as bound water. Wood moisture content can be expressed by the equation:

$$w_C = \frac{m_u - m_0}{m_0} \cdot 100\% \tag{1}$$

with m_0 - mass of oven dried wood sample, m_u - mass of wet wood sample.

Moisture of wood has two limit states: absolute dry (0%) and water-saturated (≈30%). Moisture of wood can be determined by direct physical and chemical methods. The most accurate are direct measuring methods, like thermogravimetric methods or analytical methods. Thermogravimetric methods need determining the wet mass in a wood sample, drying it using oven, infrared, microwaves or freezing, and then determining of dry wood mass [8]. The chemical methods are analytical ones, like calcium carbide method, Karl Fischer titration, distillatory method, gas chromatography methods or mass spectrometry methods. All the testing methods are destructive, and it is their main disadvantage. Indirect measurement methods include electrical methods, radiometric methods, optical methods, thermal methods, hygrometric and acoustic methods. Among them, the greatest practical importance are electrical methods: conductance method and capacitance method.

The principle of operation of conductance method is based on the dependence of electric resistance and wood moisture content. At least two electrodes have to be driven into tested material, so the material and its surface coatings can be damaged. The temperature correction is also required, due to its influence on resistance [3], [7].

Capacitive method is based on the dependence of wood moisture and capacitance or dielectric loss factor. Oven dry wood has ε_r ≈2...3.5 and water has $\varepsilon_r \approx 80$, so electrical constant of wet wood depends on moisture. The main advantages of capacitive method are non-destructive testing and not required temperature correction [4], [6].

Below, the method of wood moisture using quasi – balanced method of loss factor measuring has been presented.

2. Quasi – balanced method

There are many methods for measurement of impedance, electrical loss factor and quality factor of coils, among which there can be distinguished quasi – balanced methods with phase detection. For the circuits there is defined specific condition fulfilled by theirs current or voltage vectors. Usually this is predetermined phase shift between specified vectors (usually it is π/2). A measurement process consists in bringing the system to this state, by changing the setting of a single control element.

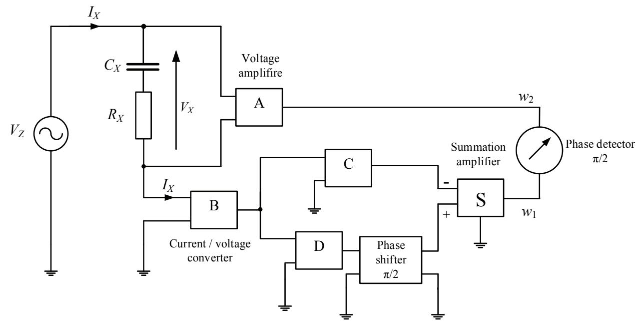

Fig. 1. Block diagram of the quasi – balanced circuit for capacitors loss-factor measurement

The example diagram of the quasi – balanced system for loss-factor tanδ measurement is shown in Fig. 1 [1], [2]. A, C and D blocks denote voltage amplifiers of gains A, C and D. State of quasi – balanced means that phase shift between the signals w_1 and w_2 has the value π/2. Equations signals w_1 and w_2 have the form:

$$\begin{cases} w_1 = BCI_X - \mathrm{j}BDI_X \\ w_2 = AV_X \end{cases}. \tag{2}$$

where: V_X, I_X - voltage and current of tested impedance, A, C, D - voltage gain, B - conversion rate of the current/voltage converter, j - imaginary unit, shifting the signal by π/2.

The system is imported to the state of quasi – balance by changing the setting of the gain of the voltage amplifier C or D. The phase shift between the signals w_1 and w_2 is measured by a phase detector. In the state of quasi – equilibrium the relationship stands:

$$\mathrm{Re}\left(\frac{w_1}{w_2}\right) = \mathrm{Re}\left(\frac{BCI_X}{AU_X}\right) = \mathrm{Re}\left(\frac{BC}{A}\frac{1}{Z_X} - \frac{BD}{A}\mathrm{j}\frac{1}{Z_X}\right) = 0, \tag{3}$$

Equation (3) can then be converted to the form:

$$\mathrm{Re}\left(\frac{BC}{A}\frac{1}{Z_X} - \frac{BD}{A}\mathrm{j}\frac{1}{Z_X}\right) = \frac{BC}{A}\mathrm{Re}\frac{1}{Z_X} - \frac{BD}{A}\mathrm{Im}\frac{1}{Z_X} = 0,. \tag{4}$$

The measurement result is based on the relationship:

$$\tan\delta_X = \frac{\mathrm{Re}(Z_X)}{\mathrm{Im}(Z_X)} = \frac{D_0}{C_0}. \tag{5}$$

where: C_0, D_0 - voltage gains of the amplifiers in the quasi – balance state.

3. The measuring system

The measuring system was implemented in the form of virtual instrument (Fig. 2). Hardware consists of the measuring card NI-USB6251 National Instruments, a PC, and function generator Rigol DG1011 (Fig. 3). The value of the system input resistance is 20 MΩ, and capacitance is 500 pF. The voltage drop across the test object is measured directly by the measuring card, and the current is first converted into a voltage by the current/voltage converter.

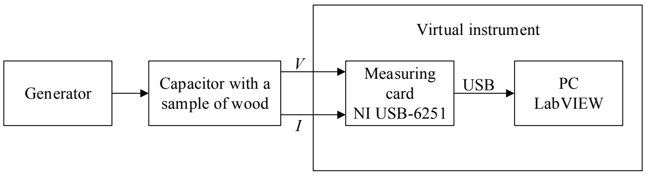

Fig. 2. Block diagram of the virtual measuring system

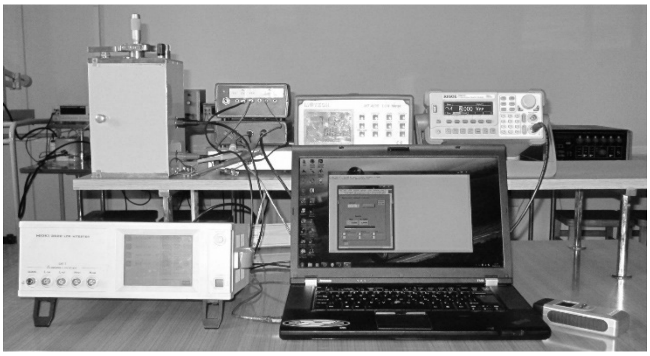

Fig. 3. The measuring position

Signal processing (Fig. 4a) and the virtual front panel (Fig. 4b) were implemented in the software based on the graphical programming environment LabVIEW. The program shows information about the progress of the measurement, the current time and measurement result. MATLAB was used to measure the phase shift angle between the signals.

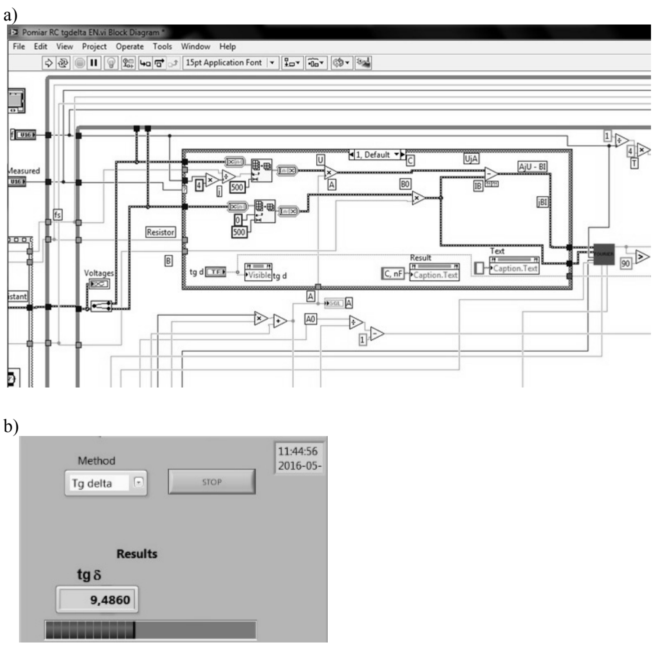

Fig. 4. a) LabVIEW block diagram b) The virtual front panel

4. Results

For measurement tests we used two samples of the following kinds of wood: oak and larch. Before measuring the samples were damp for two days. To measure the moisture content in the wood Powerfix HG00384C was used (Fig. 5a). It is a meter which measures the resistance between the two electrodes. Based on the measured resistance value the humidity is calculated. The meter allows measurement of moisture content in the range of 6% to 44%. Each sample was measured 12 times (six times on each side at different points). The final result of the measurement is the average of all measurements (Tab. 1), (Fig. 6), (Fig. 7).

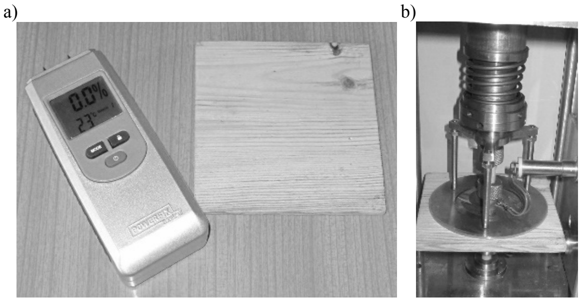

Fig. 5. a) Powerfix HG00384C wood humidity meter and sample of wood, b) Tested capacitor with the sample of wood

Tab. 1. Measurement results

Average moisture, %	Motech MIC-4090	Hioki 3522	Quasi – balanced method
Oak			
23.40	12.34	9.99	13.50
22.15	4.00	3.71	5.60
14.14	4.37	4.34	4.31
12.35	1.26	1.22	1.70
<6.00	0.38	0.37	0.45
Larch			
22.77	15.23	9.99	14.75
22.70	5.18	5.25	5.18
13.95	2.58	3.18	1.94
11.54	1.61	1.63	1.23
<6.00	0.59	0.57	0.78

For the measurement of dielectric loss factory the test sample of wood was used in specially constructed measuring capacitor. The measuring system is shielded against external electric fields (Fig. 5b). During the test of the virtual instrument there was used a sinusoidal signal of amplitude 1 V, frequency 100 Hz. There were made twelve measurements. The tested object was powered from the generator Rigol DG1011. With the help of the measuring card the NI USB-6251 there were collected 2000 signal samples of the current and voltage with sampling rate of 20 kHz. A rectangular window with half-width 600 samples was used in the phase shift measuring algorithm (short-term Fourier transform algorithm). The measurement results obtained from virtual instrument were compared with those of commercial devices: Hioki 3522 and MOTECH MIC-4090 (sinusoidal signal of amplitude 1 V and frequency 100 Hz).

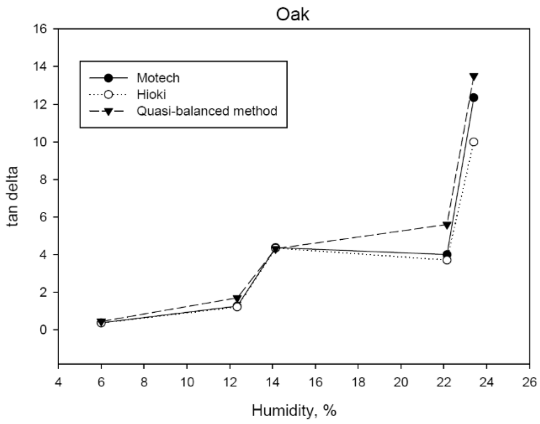

Fig. 6. Characteristics factor tanδ depending on the moisture for oak wood

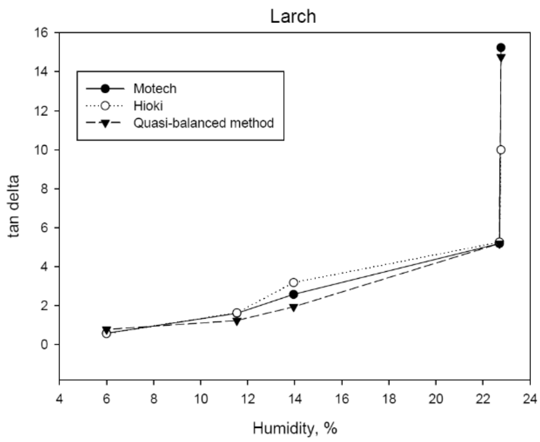

Fig. 7. Characteristics factor tanδ depending on the moisture for larch wood

5. Conclusions

The paper presents the measuring circuit realizing the quasi-balanced method for measuring the loss factor tanδ. Circuit is based on a system in the form of a virtual instrument Algorithm makes possible to simplify the design of the instrument. The processing software makes it possible to investigate different measurement algorithms without necessity to change the hardware part of the system.

Application of a specific measuring card, a current/voltage converter and a measuring circuit has direct impact on the accuracy of the tanδ measurement results.

Results of measurement of the loss factor obtained by various methods were compared mutually, and have been shown to be dependent on the moisture content of tested wood samples. It was shown the loss factor is quite good correlated with the humidity, and the factor can be easy measured by the developed system. The preliminary results were repeatable – this is very beneficial. It was shown the humidity of the wood sample measurement can be changed into the measurement of loss factor tanδ of test sample, and the developed system can be successfully used for the measurement.

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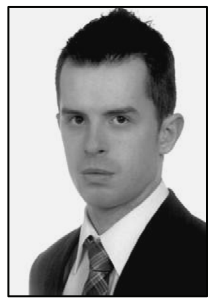

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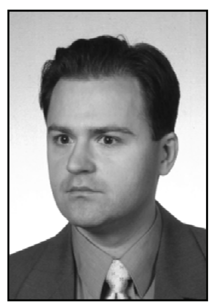

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