FAKOPP Microsecond Timer

USER'S GUIDE

Introduction

FAKOPP equipment is designed for evaluation of living trees. The equipment is able to detect holes, decay, cracks in trees by nondestructive technique. FAKOPP measures the transit time of stress wave between two transducers. Application of FAKOPP is very important in evaluation of old trees determination of the health status of the trees. The equipment helps the forester to determine the optimal date of wood felling. Another important application of the equipment is the determination of residual strength of old timbers and log evaluation. The name FAKOPP is a combination of two Hungarian words: 'fa' and 'kopp'. The meanings are tree and sound.

Fundamental of the tapping test

Testing by tapping is an ancient technique. Woodpecker taps trees and in this way it is able to find insects under the bark. Physicians also examine by tapping the human body. Tapping technique is applicable for testing living trees as well.

Wood material of an intact tree is a good sound guide while a decayed wood is a sound absorber. Velocity of sound in an intact wood material is much higher than in voids or decay. This is the reason why the stress wave (sound impulse) front avoids the defects in the tree.

Two transducers define a line across a tree, stress wave - induced by tapping one of the sensors - travels in a straight line to the opposite sensor (see Fig. 1.). We call start transducer the transducer, which is tapped, and stop transducer, which is opposite to the start transducer. If the line defined by the transducers intersects a defect, stress waves avoid the defect (see Fig. 2.).

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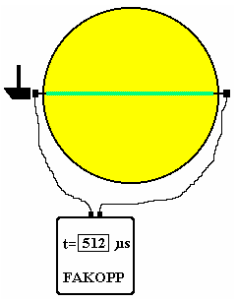

Figure 1. Sound propagation in an intact tree.

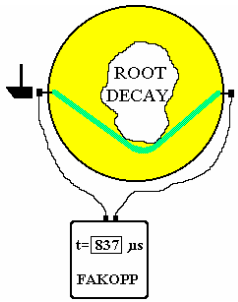

Figure 2. Sound propagation in a decayed tree.

This technique tests the tree only in the line defined by the transducers. If the defect is located not in the centre of the tree, it may happen that existing defects are not detected. To avoid this situation it is necessary to test the tree in two directions, perpendicularly to each other.

The velocity of the stress waves in an intact tree perpendicular to grain direction is between 1100 - 1700 m/s depending on the tree species (see Table 1.).

Tree Species	Radial velocity [m/s]
Birch	**1140**
Spruce	**1310**
Silver fir	**1360**
Japanese fir	**1450**
Scotch pine	**1470**
Black fir	**1480**
Larch	**1490**
Oak	**1620**
Beech	**1670**
Linden	**1690**
Maple	**1690**

Table 1. The velocity of the stress waves in an intact tree in radial direction.

The velocity in radial and in tangential direction is more or less the same. The relative deviation is less then 10 %. The effect of the moisture content is important under the fibre saturation point (30 - 40 % MC). Over the fibre saturation point velocity doesn't change too much because the fibres are responsible for the wave propagation. In the case of living trees' moisture content it is always higher as the fibre saturation point. Temperature is an other parameter which has an influence on velocity. Fortunately this effect isn't important because if temperature increases with 1 °C the velocity decreases about 3 m/s, in the temperature range of 0 - 40 °C.

The radial velocity is the parameter which is sensitive to the internal defects. If the measured velocity is lower than the velocity in an intact tree, it means that the tree contains defect. The deviation between the two velocity data depends on the size of the defect.

The measurement of the stress wave velocity:

How shall we measure the speed of sound in radial direction in wood? According to the formula V=s/t the distance and the transit time must be measured. The distance can be measured with the well-known calliper. For the accurate velocity determination the transit time must be measured with µs accuracy. For the precise measurement of the transit time of the sound the FAKOPP device was developed.

After the evaluation of the trunk the place of investigations must be marked. The investigation must be carried out in a plane perpendicular to the grain. Special care must be taken for the splits and frost checks, because deep splits will be detected as defects by the machine. Trunks with long frost checks must be investigated next to the check in that way that the line indicated by the transducers should not intersected the check.

Pierce the transducers into the tree, in that way that the needle penetrate through the bark and reach the wood. The bark of the wood disturbs the investigation, thus the needle of the transducers helps the sound to be propagated through the bark. The other function of the needles is to attach the transducers. The requirement of the accurate measurement is the stable attachment of the transducers. The hammer can be freely used to hit the transducers into the wood, but caution must be taken, that do not hit the plug and the bark of the tree do not hurt the cable of the transducers. Do not mix the start and stop transducers!

Switch on the device. After switching on, press “Reset” button” and hit the start sensor. The FAKOPP device will show the transit time in microseconds. After recording the data, press reset button again and hit again. Record the data. It is worth to calculate the average of 3 taps. Recommended hammer weight 100-200 gram. Automatic reset function is active if reset button is pressed down, while switching on.

If the diameter of the wood investigated is large, than tap larger. The transit time measurement is independent from the strength of the hit in a wide range.

The velocity of sound can be attained that the distance measured by the calliper is divided by the transit time measured by the FAKOPP device. For the calculations use a pocket calculator

The steps of the investigations:

-Determination of the distance between transducers by calliper
-Transit time measurement
The attachment of the transducers
After switching on the machine some reset + tap onto the start sensor
-Determination of the sound velocity
-Evaluation

Evaluation:

The first step of the evaluation is the determination of the reference velocity. The reference velocity can be attained by measurements on the healthy part of the same tree being investigated. Lack of this possibility the data shown in Table 1 can be used.

There is a possibility the effective size of the defect. The measured (V_{mes}) and reference sound velocity (V_{ref}) values are needed. With the following formula the relative decrease of velocity of sound can be attained in %.

$$\text{Relative decrease of sound velocity} = (V_{ref} - V_{es}) / V_{ref} * 100$$

These values are shown in Table 2 in the second column. It can be get back from here. Occasionally in case of really infected trees the measured relative sound velocity decrease can exceed 60%. The reason could be that one of the transducers was pierced into the decayed part of the tree.

The investigation is carried out along a line determined by the sensors. If the decay or hole does not occur in the middle of the tree sometimes the investigation does not detect the defect. To avoid this situation it is worth to measure the tree in two perpendicular directions.

Decayed area ratio given in %	Relative velocity decrease in %
0	0
5	0
10	0
15	0-10
20	10-20
25	10-20
30	20-30
40	20-40
50	30-50
>50	>50

Table 2. The relative velocity decrease as a function of the decayed area ratio.

Determination of the stress wave velocity in fibre direction:

FAKOPP is applicable to measure the stress wave velocity in fibre direction in the case of lumber and tree as well. Strike the transducers into the wood shown in fig. 3.

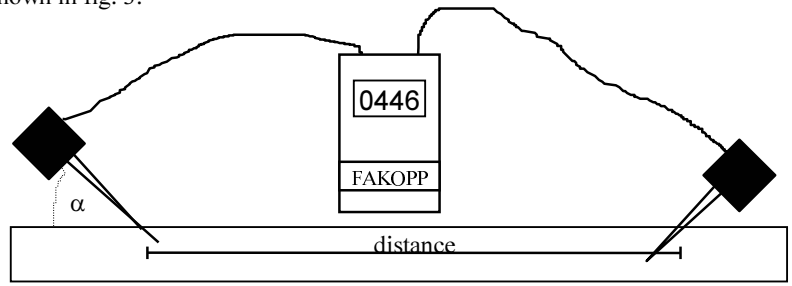

Figure 3. The set-up in velocity measurement in fibre direction.

Angle (α) between the transducer pin and fibre has little effect on transit time, see fig. 4. We recommend 45 degree, but less than 60. Over 60 degree the readout is not reliable.

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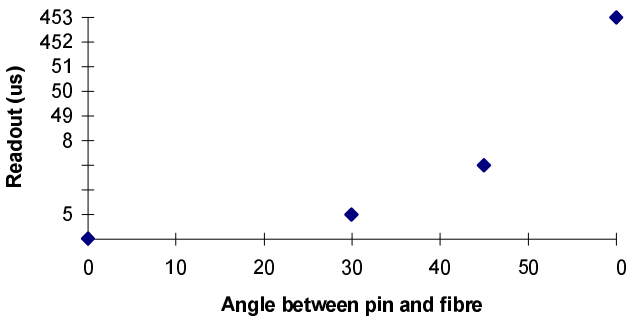

Figure 4. Transit time as a function of pin - fibre angle.

If we are testing trees, the transducer's needle need to penetrate the bark. Pin is a wave guide and also fix the transducer. If the transducer is not fixed well the time scatter becomes high.

Measure the transit time given in chapter "The measurement of the stress wave velocity" and measure the distance (see fig.3.) between transducers. Please choose distance 2 m or higher. Velocity is given by the following expression:

V = distance / (transit time - correction)

The origin of the correction is the stress wave travels in the transducers and some electronic delay. The exact value of the correction is given on the last page of this manual. The usual value is 7.

RS232 guide

A built in RS232 port is available in FAKOPP. The aim of the port is to provide an easy method for recording data. In the field we can use paper and pencil, but the users has no free hands, he need to handle transducers and hammer. A frequent interruption of the process slow down the test. The name of the communication software available on the disk is : Fak-PC.exe.

Description

This simple program realizes the communication between FAKOPP and PC. After starting the program you have to select the serial port used by FAKOPP.

If the correct port is selected, and the accelerometer have been hit time data appears on the Readout box.

If Auto store is selected, this data will be automatically stored in the TempData.txt file, if Manual store is selected you have to click Accept button to store data. Hitting A button on the keyboard has the same effect as clicking Accept button.

Clicking the Next tree button adds a new numbered line to the file. Hitting the N button on the keyboard has the same effect as clicking Next tree button.

If you click Save button, the program asks for a file name, in which the TempData.txt will be copied. This is necessary becauseTempData.txt will be overwritten always at starting the program. Storing data temporary in the TempData file is useful if you close the program without clicking Save button. In this case you can find your data inTempData.txt, until you restart the program.

If you click Help button, this help file appears.

Installation

The program needs no installation, you can simply copy it to a destination directory.

File list

- Fak-PC.exe - the program file
- Fak-PC.c - C program source
- Help.txt - help file

Requirements

- Operating system Windows 9x, ME, 2000, XP
- Serial port
- 50 kb free disk space

License conditions

This program is freeware, so it can be freely distributed, the sourcefile can be freely modified, but if you do, please send us your version. The program has been originally compiled with Lcc-Win32.

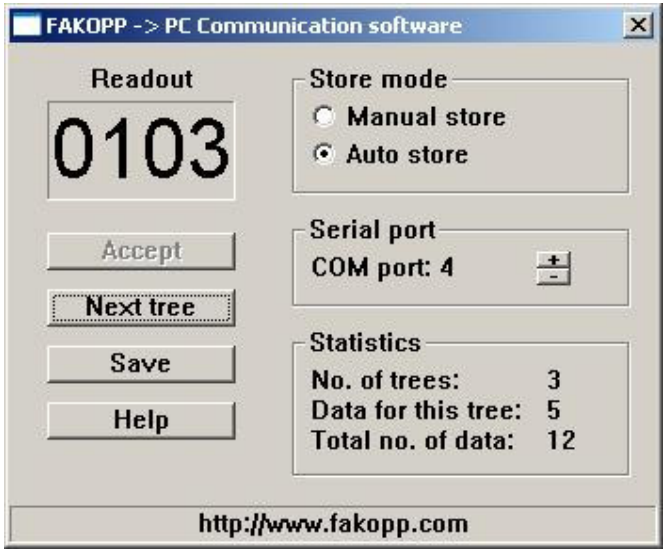

Figure 5. FAKOPP -> PC Communication software screen.

Maintenance:

The battery last long if it is switched out after use. The necessity of the change of the battery indicated by "LO BAT" message.

- Remove the battery compartment cover by knife or small coin.
- Change the 9V block battery.

Field work makes dirty the machine. For cleaning the equipment use soap and watered cotton cloth.

The FAKOPP device and its equipment's:

- FAKOPP apparatus
- Start and stop sensors
- Hammer
- Aluminium bar (44 cm, optional)
- User's manual
- Carrying bag
- RS232 cable and software on disk.

Guarantee:

For the FAKOPP device, include the two sensors the guarantee is one year. The guarantee starts at the date displayed on the bill and valid for the following one year. The repair can be asked from the manufacturer. The guarantee does not concern to the break or deliberate damage of the machine.

Technical data:

Size of the machine without sensors:	29 x 80 x 156 mm
Weight:	220 g
Operative apparatus:	reset button and on/off switch
Battery supply:	9V block battery
Power consumption before/after pressing reset button:	14/50 mW
Box of the device:	plastic, not water-resistant
The display of low battery:	"LO BAT" message
Screen:	LCD screen with 4 digits
Standard deviation of time:	± 1 µs
Sensors, start and stop identical:	High sensitive vibration sensor: SD-02
RS232 baud rate is fix:	300 bps
connector type:	DIL 9 , male
Temperature range of the usage and storage:	-10-50°C

SD-02 vibration sensor
technical specification

Mass		
sensor part :	22 gram	
total :	62 gram	
Dimensions		
length:	92 mm	
width in the direction of the cable:	40 mm (+50mm clearing for cable)	
width normal to the cable: 20 mm		
Sensitivity (160 Hz)		
charge sens. sensor part:	1.35 pC / m/s^2 typical	
force sens. total:	23 pC / N	([1])
Resonance frequency		
sensor part:	23kHz typical	
total:	(NA)	([2])
Capacitance		
without cable:	260 pF	±5%
cable only:	100 pF/m	±5%
Polarity:	positive for shock hitting the tip of the spike	
Maximum shock resistance ([3])		
in working direction :	10000 m/s^2	
in transverse direction:	3000 m/s^2	
Temperature range:	–30 ... +70°C	

[1] The force acts on the tip of the spike in the working direction.
[2] It depends heavily on the mechanical coupling between the spike and the wood.
[3] The sensor is intended to endure shocks that occur while the sensor is driven into wood by steel hammer.

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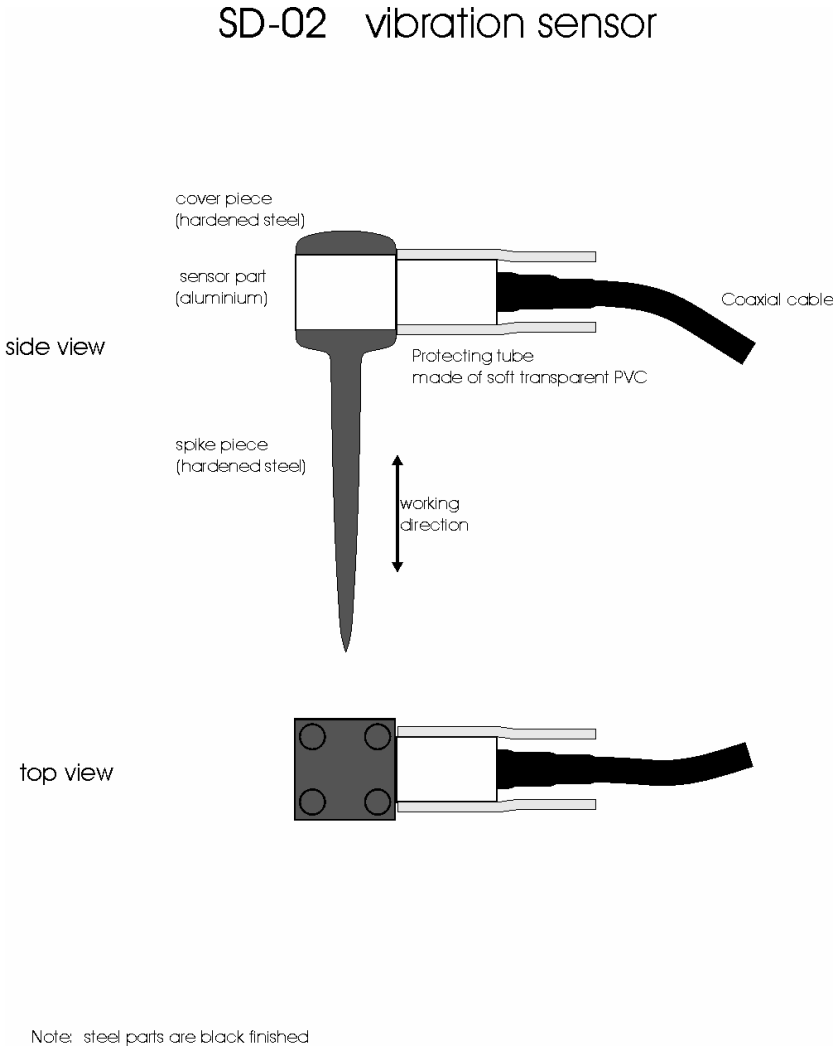

Test bar

An aluminium rod is provided for calibration. Dimensions of the solid rod are: length: 440mm, diameter: 20mm. Both ends accommodates a wooden plug (diameter: 13mm, length 28mm) for coupling the transducer nails to aluminium rod. The standard transit time is 89+/-2 µs, when the nails are 12 mm deep inside the wooden plug. The stress wave velocity in the aluminium bar is 5290+/- 20 m/s at room temperature. For the test a small (100 g) hammer is recommended.

After an intensive use of the calibration road, change of wooden plug is necessary. Damage of wooden plug is not covered by the guarantee. Technicians can change it easily.

User can check FAKOPP microsecond timer by using this aluminium test bar.

Trouble shooting guide

Phenomena	**Causes**	**Action**
Screen is blank	Battery low	Change the battery
	Switch is in wrong position	Switch off and on again
	Battery holder problem	Pick up and put back the battery
Time scatter is high	Start and stop transducers are mixed	Connect start transducer to start connector.
	Stop transducer is not fixed well.	Fix it.
	Wrong hammer handling.	Let the hammer spring back. Direction of hit is the direction of nail.
	Too small hit.	Hit stronger
PC communication fails	Other than IBM compatible PC is used	Use IBM compatible PC
	Wrong connection	Check the connectors
	Wrong port number	Select the correct port number.
	Battery low	Change battery

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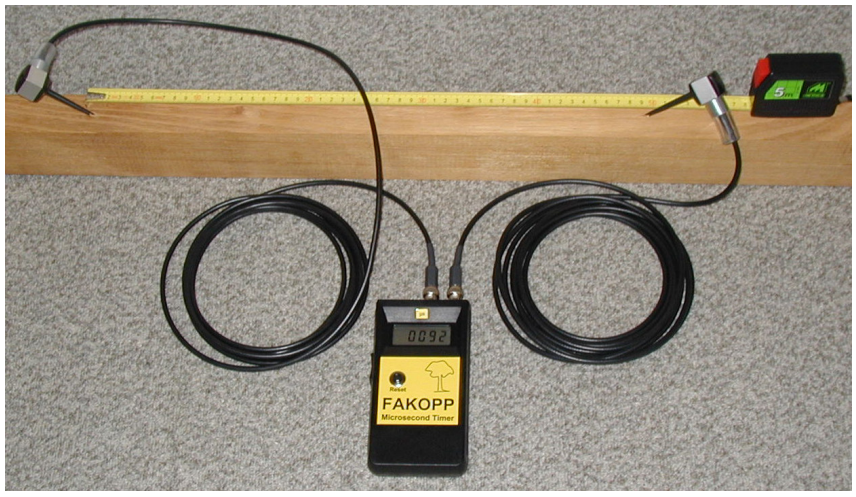
Quick FAKOPP guide

1. Connect the transducers to the timer box.
2. Switch on the timer. Before each hit please press “Reset” button. If you want to use auto reset function, switch on the timer while the “Reset button” is hold down. This case after each hit the actual readout appears on the screen without pressing “Reset”.
3. Transducers are identical. Please select the transducer, connected to the „Start” connector. A colour mark helps you to identify the start transducer. Hit the stat sensor by hammer. Direction of hit is always parallel to the direction of nail. Please let the hammer spring back. Never use heavier hammer the 200g.
4. After use please switch of the unit.



A possible setup.

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