Testing Wood Acoustics

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Abstract

Wood acoustics was never specifically studied in the way that would be needed to conduct this experiment. Because of this, we combined the ideas of Francis Bacon's sound acoustics conclusions and Thomas Young's young's modulus of elasticity. The measurements of sound speed were also conducted to help along with the process of the calculations.

This paper will explain how the study of acoustics in wood can help in the experiment conducted. It will also explain how in an experiment conducted in class will help understand the logistics of some unknown wood using Young's Modulus and other observations. There is a step-by-step course of how to set up and find your own data, along with the equations used.

Introduction/Purpose

The objective of the experiment is to figure out what type of wood the unknown wooden billets are made of by having 4 different known billets of wood.

Picture 1: the 6 billets used for this experiment

History

The first known accomplishments relating to acoustics were in the field of sound and light which were studied by Galileo Galilei, Marin Mersenne, Isaac Newton, and Joseph Sauveur[i].

Francis Bacon started a system of his own to study acoustics by not only understanding the production, behavior, and direction of sound, but to also harness the properties in practical ways for communication.[ii] The research then led to looking more into the aspects of the production of the nature of musical sound.[iii]

Galileo and Mersenne worked on the relationship between frequency and pitch of a vibrating string. Which they then came to the conclusion of recognizing that the periodic vibration of an elastic body at a given frequency is responsible for producing a particular musical sound. It was also realized that there was a direct relationship between the periodic motion of a vibrating string and the motion of a pendulum which they used to combine the studies from all forms of motion in bodies, especially harmonic motion.[iv]

Thomas Young studied the elasticity of objects by straining a material beyond the elastic limit. He came to a conclusion of Young's modulus which is the test of a material's stiffness. Young's modulus has been used for so many different materials. It helps understand the mechanical behavior of an object, especially in the flexibility and movement. This helps save builds in the long term by knowing the stability of the materials used before building.[v]

Displayed Equations

First, each billet should be measured to find the volume which can be solved by using

$$V = \pi(\frac{d}{2})^2 h \quad (1)$$

Where d=diameter and h is the height and/or length of the billet.

The main focus of this lab is to find the sound speed which is measured using an ultrasonic transducer to measure the time it takes for sound to travel through an object using echo. Once the time (of how long it takes to cover the entire length) is found, use

$$C = \frac{D}{T} \quad (2)$$

Where c=speed, D=distance, and T=time

This speed can then be used for the Young's modulus formula:

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

Where E= Young's modulus, σ = uniaxial stress, and ε = strain.

This is used to find the measurement of stiffness of an object's material. It is measured by diving the stress by the strain of the object. It is important because it can tell you if an item's material will be destroyed or not depending on the surrounding's effects on the materials. We can then use the information that we know and find this equation to explain young's modulus in a form of sound speed.

$$v = \sqrt{\frac{\gamma}{\rho}} \quad (4)$$

Where v = speed, γ = material, and $\rho = density$

This will then help determine what material something is by comparing it to the data of a known object.

Experimental Process

Each student gets assigned a billet, most of them being known of what type of wood it is, and some are unknown. Each student uses a caliper and meters stick to get the measurements of the billet to be able to measure the volume of each billet. All data of each billet should be shared with the rest of the group.

To start the experiment a V-C-400 V-Meter MK IV machine is needed and needs to be plugged into an outlet and turned on. Then the transducer should be placed on the ground and a wooden billet placed on top (one at a time). Making sure to hold the receiver slightly (to make sure it doesn't fall off) it needs to be placed on top of the wooden billet. Then then time data can be started to be collected. After each pulse, look onto the screen of the machine and read the time it took for the pulse to go through the wooden billet. This data should be shared with the rest of the group. Each billet should collect 6 pieces of data.

Materials:

- Lab notebook
- pen
- V-C-400 V-Meter MK IV machine (ultrasonic transducer system)
- Transducer
- Receiver
- 6 wooden billets
- Caliper
- Meter stick
- Andek-3000I electronic scale

Data[vi]

Billet	Material	Length [cm]	Average diameter [cm]	Mass [g]	Average Time [μs]
4	Hard maple	87.7 ± 0.05	7.06 ± 0.005	2745.3 ± 0.1	179.06
8	Soft maple	87.6 ± 0.05	6.92 ± 0.005	2121.8 ± 0.1	169
2	Ash	87.5 ± 0.05	7.02 ± 0.005	2463.8 ± 0.1	165.34
12	Birch	87.5 ± 0.05	7.01 ± 0.005	2716.6 ± 0.1	167.16
6	Unknown	87.8 ± 0.05	7.03 ± 0.005	2505.8 ± 0.1	160.86
10	unknown	87.8 ± 0.05	7.03 ± 0.005	2496.8 ± 0.1	178.08

On each billet, there was a number and a material written on the top. Two did not have a material written which created those two to be the unknown materials. To find the length, all students used a PASCO Wooden meter stick. A caliper was used to measure the diameter; there were 6 measurements made along the billet and then the average was taken of those six. The Andek-3000I electronic scale was used to measure the mass of each billet. Lastly, the ultrasonic transducer system was used to measure the time. The transducer and receiver, that were connected to the system, worked together to measure the amount of time it took for a pulse to get through the wood. Again, six measurements were taken for each billet and then the average was taken.

Results

Billet	Volume [m^3]	Density [kg/m^3]	Sound speed [m/s]	Young's Modulus [N/m^2]
4	$3.4 \times 10^{-3} \pm 1.5 \times 10^{-5}$	799.7 ± 3.5	4897.8 ± 27.9	$1.9 \times 10^{8} \pm 3.3 \times 10^{6}$
8	$3.3 \times 10^{-3} \pm 4.6 \times 10^{-4}$	644.023 ± 8.990	5183.4 ± 31.2	$1.7 \times 10^{8} \pm 9.7 \times 10^{6}$
2	$3.4 \times 10^{-3} \pm 1.1 \times 10^{-5}$	727.5±2.4	5292.1 ± 32.6	$2.04 \times 10^{8} \pm 5.7 \times 10^{6}$
12	$3.4 \times 10^{-3} \pm 9.9 \times 10^{-6}$	804.4 ± 2.4	5234.5 ±31.9	$2.2 \times 10^{8} \pm 6.0 \times 10^{6}$
6	$3.4 \times 10^{-3} \pm 1.2 \times 10^{-5}$	735.3±2.7	5458.2 ± 34.5	$2.1 \times 10^{8} \pm 6.4 \times 10^{6}$
10	$3.4 \times 10^{-3} \pm 5.9 \times 10^{-6}$	732.6±1.3	4930.4 ± 28.2	$1.7 \times 10^{8} \pm 4.3 \times 10^{6}$

Billet	Unknown or known before	material
4	Known	Hard maple
8	Known	Soft maple
2	Known	Ash
12	Known	Birch
6	Unknown	Birch
10	Unknown	Soft maple

Best estimate using the data collected and calculated

Conclusion

It is not completely clear that Young's Modulus is able to determine the type of wood.

The results were then compared to some of the known data of young's modulus of wood[vii]. The data that it was compared to was in psi which was then compared to the used units of N/m^2. Most of the results does come in the uncertainty of the compared data.

Something to consider is also the observations made throughout the experiment which can help identify the unknown wood, such as: density, how the wood feels and looks. These should be taken into account before making a final conclusion of what type of wood the unknown wood is.

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Contributors: Caitlyn Wishon, Royce Coleman, Nick Cunningham, Neal Conner, Kyle Councell.

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