Young’s modulus of BF wood material by longitudinal vibration

Sushil Phadke¹, Bhakt Darshan Shrivastava², Ashutosh Mishra³ and N. Dagaonkar⁴
¹Department of Physics Govt. Girls College, Dhar (M.P.), India
²Department of Physics Government P.G. College Biora, (M.P.) India
³School of Physics, Devi Ahilya University Indore (M.P.) India.
⁴Department of Physics Government P.G. College Dhar (M.P.), India
Email: sushilphadke5@gmail.com

Abstract. All engineered structures are designed and built with consideration of resisting the same fundamental forces of tension, compression, shear, bending and torsion. Structural design is a balance of these internal and external forces. So, it is interesting to calculate the Young’s moduli of Borassus Flabellifer BF wood are quite important from the application point of view. The ultrasonic waves are closely related with the elastic and inelastic properties of the materials. In the present study, we measured longitudinal wave ultrasonic velocities in BF wood material by longitudinal vibration method. After measuring ultrasonic velocity in BF wood material, we calculated Young’s modulus of Borassus Flabellifer BF wood material. We used ultrasonic interferometer for measuring longitudinal wave ultrasonic velocity in BF wood material made by Mittal Enterprises, New Delhi, India in our laboratory. Borassus Flabellifer BF wood material was collected from Dhar district of Madhya Pradesh, India.

1. Introduction
Longitudinal waves are broadly used for the purposes of non-destructive evaluation of materials and for generation and sensing of acoustic vibration [1] of surrounding. Many mathematical models describing longitudinal wave propagation in solids have been derived in order to analyse the effects of different materials and geometries on vibration characteristics without the need for costly experimental studies. The increasing use of piezoelectric quartz [2] for the stabilisation of radio frequencies has promoted many investigations of the vibration of the quartz. In the last few years a mass of information has been accumulated disclosing the complexities of vibratory modes and types which may exist simultaneously in one and the same crystal plate or rod. Along with the longitudinal, flexural and tensional oscillations may exist, as well as overtones of any or of all. All engineered structures are designed and built with consideration of resisting the same fundamental forces of tension, compression, shear, bending and torsion. Structural design is a balance of these internal and external forces. At the same time, materials selection, component specification, joining techniques, individual member design and assembly must be also considered. Knowledge of the mechanical properties of materials and how they perform is a must for designers, engineers and architects. It is this knowledge of a material’s performance relative to standardized tests and benchmarks that gives designers greater certainty in the structural integrity of their designs. Determination of the elastic properties of materials by means of measurements of ultrasonic velocity has a long history for different materials [3-4]. Application of Ultrasonic techniques to wood appears to have been pioneered.
by Hearmon [5]. There is direct and continuing application of these analyses to the design and construction of musical instruments [6-7]. The determination of the elastic properties of different wood species is also of importance in the more mundane aspects of their use in the building industry. The ultrasonic bulk wave velocity measurements, require the hypothesis of orthotropic symmetry, are used to determine these properties. The ultrasonic modes considered are longitudinal waves [8], and shears waves with particle motion along the direction of the applied stress. Compressive and tensile stresses are applied in the longitudinal direction of small clear wood specimen, and ultrasonic waves are propagated through the radial direction of the wood specimen. Stress-induced velocity changes of the ultrasonic waves are measured, and acoustoelastic constants are also determined. Additionally, stress distributions in bending of wood beam specimen are estimated by measuring ultrasonic velocity.

2. Material and Method

The longitudinal axis of each specimen coincided with the longitudinal direction of the wood. The test specimens of BF Female and Male tree leaf stem were kept under air-dried condition. Dried samples were cut in desired shape. We used ultrasonic interferometer for measuring longitudinal wave ultrasonic velocity in BF wood material made by Mittal Enterprises, New Delhi, India in our laboratory. *Borassus Flabellifer* BF Female and Male tree leaf stem wood Material was collected from Dhar district of Madhya Pradesh, India. For longitudinal vibration’s the velocity of longitudinal Vibration given by $V_L = \left(\frac{C_{11}}{\rho}\right)^{\frac{1}{2}}$ and $Y=V_L^2 \rho$, Where Young’s modulus $Y= C_{11}$ and $\rho$ density [9].

3. Result and Discussion

Table 1 shows typical experimental results indicating the relationships between the stress, strain, and the changes in the ultrasonic velocity. The stress-strain relationships are represented by generally recognized curves for longitudinal compression of softwood species.

The ultrasonic velocity was large in male BF wood material then female BF wood material. Longitudinal wave velocity decreased with increasing density of wood material which affects the young’s modulus of the wood material. The elastic constant of male BF wood material was greater then female BF wood material. compressive stress immediately after the natural state, as in figure 1& figure 2.

![Figure 1](image-url)  
*Figure 1* Comparisons of ultrasonic velocity in Female and male wood material.
Figure 2 Comparisons of Young’s modulus of Female and male wood material.

Table 1-The measured and calculated values of mass, density, ultrasonic velocity and elastic constant of BF (in MKS units)

| S. No | Mass of specimen m | length of specimen L | Volume of specimen V | Density ρ | Frequency of composite system fc | Frequency of specimen fs | Ultrasonic velocity V_L | Elastic constant E |
|-------|-------------------|---------------------|---------------------|-----------|-------------------|---------------------|----------------------|-------------------|
| For Female BF |
| 1     | 0.000278          | 0.0224              | 3.58E-07            | 775.67    | 78146             | 76621               | 3432.621             | 9.1E+09           |
| 2     | 0.000483          | 0.0387              | 6.19E-07            | 780.039   | 61995             | 76621               | 3430.291             | 9.2E+09           |
| 3     | 0.000652          | 0.0536              | 8.58E-07            | 760.261   | 55859             | 76621               | 3435.438             | 9E+09             |
| For Male BF |
| 1     | 0.000298          | 0.0224              | 3.58E-07            | 831.473   | 78986             | 78301               | 3507.885             | 1E+10             |
| 2     | 0.000493          | 0.0387              | 6.19E-07            | 796.189   | 62485             | 45299               | 3506.143             | 9.8E+09           |
| 3     | 0.000671          | 0.0536              | 8.58E-07            | 782.416   | 56203             | 32735               | 3509.192             | 9.6E+09           |

4. Conclusion
There exist obvious linear relationships. The changes in the velocities of these materials are small. The changes in the propagation velocities of ultrasonic waves have been accounted for by the changes in the densities and elastic moduli of the materials. As a result of the application of stress to an elastic material, the density and elastic modulus of the material change. This change is considered to lead to a change in the propagation velocity. Such phenomena that density or elastic moduli change due to applied stresses or deformations. In addition to this, the phenomenon obtained for wood is considered to relate to its cellular
structure complexity. This suggests the existence of a relationship between the acoustoelastic phenomena and the anatomical structure of wood. The changes in the velocities of propagation of ultrasonic waves were given as functions of the applied stress. The relationships between the velocity and stress at the initial level, and those between the velocity and strain at the range of large deformation were straight lines.

Acknowledgement
One of the authors Sushil Phadke is highly thankful to University Grants Commission, New Delhi for awarding a Project. Our sincere thanks to Dr. S. Alawa Principal Govt. P.G. College, Dhar (MP) and Dr. S. N. Mandloi Principal Govt. Girls College, Dhar (MP) for providing lab facility and maximum cooperation.

References
[1] Fedotov I. A., Polyanin A. D. and Shatalov M.Yu. 2007 Doklady Physics 52 607.
[2] Boyle R W and Sproule D O Nature 123 13
[3] Hearmon R. F. S. 1961 An introduction to applied anisotropic elasticity (Oxford University Press, Oxford).
[4] Musgrave M. J. P. 1970 Crystal acoustics. (San Francisco: Holden Day).
[5] Hearmon R. F. S. 1948 The elasticity of wood and plywood. (London: His Majesty’s Stationery Office).
[6] Schelleng J. C. 1969 Catgut Acoust. Soc. Newsletter 11 18.
[7] Schumacher R. T. 1988 J. Acoust. Soc. Amer. 84 1223.
[8] Yasutoshi Sasaki and Kosei Ando 1999 Acoustoelastic Phenomena of Wood NDT.net 4 11.
[9] Shrivastava B. D., Mishra A and Phadke Sushil 2012 Defect and Diffusion Forum 326-328 105