Temperature dependence of the elastic constant of Borassus Flabellifer ‘BF’ material by acoustic response

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Abstract. The homogeneous continuous materials are widely used for many structural applications. Migrations of atoms or molecules are the mechanism of mechanical and kinetic processes in materials for their synthesis processing as well as for their structural evolutions. The elastic constant of solids provides valuable information on their mechanical and dynamical properties. In particular, they provide information on the stability and stiffness of materials. In the present study author investigated relation between elastic constant and temperature in Borassus Flabellifer ‘BF’ wood part. Determination of elastic properties of material is based on the longitudinal wave’s velocities via ultrasonic methods. The resonant frequencies of the specimens were measured by Ultrasonic Interferometer (for solids) dual frequency using longitudinal cubic piezoelectric crystal of quartz of frequency 123.62 KHz. The temperature variations from room temperature were done by PID control unit, Mittal Enterprises, New Delhi, India. Characterization of the samples was done by scanning electron microscope (SEM) Model JEOL JSM5400 at 5.0kx750, 10 μm.

Key words: homogeneous, elastic, ultrasonic, piezoelectric, longitudinal.

1. Introduction
Determination of the elastic properties of homogeneous continuous materials by means of measurements of ultrasonic velocity has a long history for different materials [1.2]. Acoustic methods [3] based on the phenomena accompanying propagation of longitudinal stress waves demonstrate their particular usefulness for such testing. Traditional methods required a long time to perform tests and provide only an approximate evaluation of a large batch of material on the basis of testing of small sample population. Development of non-destructive testing [4] made it possible to use the technique for the purpose of diagnosis and assortmentment of raw material. The longitudinal orientation of tracheids or fires is partially disturbed by medullary rays. The ultrasonic energy injected into a fibrous materials couple several modes on each fibre. The physical properties, shape and size of the fibres affect the transmitted ultrasonic field. Each structural element acts independently as an elementary resonator. The spatial distribution of Ultrasonic velocities and frequencies that matched the frequency of the natural fibres could explain the acoustical behaviour of wood as illustrated by its overall parameters [5]. The interfacial discontinuities, cracks, porosity, or density variations may be detected by non-destructive techniques such as ultrasound. This method can help in the understanding of material behaviour under different environment conditions. It is important to relate the non-destructive measurements to the mechanical properties of wood and wood-based composites’. Ultrasonic techniques are however qualified for non destructive measurement of all the elastic constants of such materials. The elastic modulii Cij identification from the measurement of longitudinal ultrasonic velocity were often deducted from the low-frequency, using piezoelectric ultrasonic interferometer. In the present study the material was taken from District Dhar of Madhya Pradesh. Author used the part of Borassus Flabellifer female and male tree wood because from where the toddy or neera collected in pots around 30 litters per day.
2. Material and method
The preparation of material and measurement of density and ultrasonic velocity was reported by Sushil Phadke et al [6] in their earlier communication at room temperature. In the present study the author measured ultrasonic velocity with temperature variation from room temperature to 400K. The variation was made by proportional integral derivative control unit. Single shell PID controlled hot air oven with digital temperature indicator is complete in all respect ready to use on 230-volt input. It consists of electrically operated heating source, air source, & PID controller, Mittal Enterprises, New Delhi, India. Characterization of the samples was done by scanning electron microscope (SEM) Model JEOL JSM5400 at 5.0kvx750, 10 µm by Diya Lab, Mumbai. The technical specifications and main features of PID control unit used in this study as follows:

### TECHNICAL SPECIFICATION

| Input supply | Temperature controller to control the temperature. |
|--------------|-----------------------------------------------------|
| 230volt & +/-10% stabilizer controlled supply. | Max. 300 deg C Approx. |
| Temperature controller, West – 6100 | Heater is available producing heat in oven. |
| Solid-state relay. | Solid-state relay is available to control the temperature. |
| Air pump. | |
| Heater of 600 watts rings type. | |
| Cell dimension are 150/100mm (app.) | |
| Temperature sensors of PT 100. | |

### SALIENT FEATURE

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3. Theory and calculation
The resonant frequency of the specimen $f_s$ is evaluated using the relation:

$$f_s = f_c + \left[ \frac{m_q}{m_s} \right] (f_c - f_q)$$  \hspace{1cm} (1)

Where $f_q$, $f_c$, $m_q$, $m_s$ are resonant frequency of quartz, composite resonant frequency, mass of the quartz rod and mass of the specimen.

Using the value of $f_s$ and the length of specimen $L$, velocity of ultrasonic waves on the specimen can be calculated by the relation:

$$V_i = \frac{2L}{f_s}$$  \hspace{1cm} (2)

We can find the Young’s modulus for the specimen from the relation.

$$E = \frac{V_i^2}{\rho}$$  \hspace{1cm} (3)

Where $\rho$ is the density of the specimen.

4. Result and Discussion
The measured and calculated values of frequency, ultrasonic velocity and elastic constant with temperature for female and male Borassus Flabellifer wood parts were given in the table 1. The relationship and between

![Figure 1 Variation of frequency with temperature for female BF wood part.](image1)

![Figure 2 Variation of elastic constant with frequency for female wood part.](image2)
Table 2-The measured and calculated values of mass, density, ultrasonic velocity and elastic constant.

| S. No. | Mass of specimen mX10^3 | Density ρ | Temperature | Frequency of composite system f_c | Frequency of specimen f_s | Ultrasonic velocity v_l | Elastic constant E x 10^9 |
|--------|--------------------------|-----------|-------------|----------------------------------|--------------------------|-------------------------|----------------------------|
| 1.     | 0.178                    | 783.450704|             |                                  |                          |                         |                            |
|        |                          |           | 730         | 122939.598                      | 119407.625               | 3391.1766               | 9.0097                    |
|        |                          |           | 732         | 122938.31                       | 119399.651               | 3390.9501               | 9.0085                    |
|        |                          |           | 733         | 122936.968                      | 119391.34                | 3390.714                | 9.0073                    |
|        |                          |           | 734         | 122935.568                      | 119382.676               | 3390.468                | 9.0060                    |
|        |                          |           | 735         | 122934.11                       | 119373.645               | 3390.2115               | 9.0046                    |
|        |                          |           | 736         | 122932.589                      | 119364.231               | 3389.9442               | 9.0032                    |
|        |                          |           | 737         | 122931.004                      | 119354.419               | 3389.6655               | 9.0017                    |
|        |                          |           | 738         | 122929.352                      | 119344.191               | 3389.375                | 9.0002                    |
|        |                          |           | 739         | 122927.63                       | 119333.53                | 3389.0722               | 8.9986                    |
|        |                          |           | 740         | 122925.835                      | 119322.417               | 3388.7566               | 8.9969                    |
| 2.     | 0.171                    | 752.640845|             |                                  |                          |                         |                            |
|        |                          |           | 731         | 111642.598                      | 85346.6966               | 2423.8426               | 4.4218                    |
|        |                          |           | 732         | 111641.31                       | 85338.4497               | 2423.612                | 4.4209                    |
|        |                          |           | 733         | 111639.968                      | 85329.8534               | 2423.3678               | 4.4200                    |
|        |                          |           | 734         | 111638.568                      | 85320.8929               | 2423.1134               | 4.4191                    |
|        |                          |           | 735         | 111637.11                       | 85311.5527               | 2422.8481               | 4.4181                    |
|        |                          |           | 736         | 111635.589                      | 85301.8169               | 2422.5716               | 4.4171                    |
|        |                          |           | 737         | 111634.004                      | 85291.6686               | 2422.2834               | 4.4161                    |
|        |                          |           | 738         | 111632.352                      | 85281.0904               | 2421.983                | 4.4150                    |
|        |                          |           | 739         | 111630.63                       | 85270.064                | 2421.6698               | 4.4139                    |
|        |                          |           | 740         | 111628.835                      | 85258.5705               | 2421.3434               | 4.4127                    |
temperature and frequency are shown in figure 1 figure 3 for female and male Borassus Flabellifer wood parts. The figures (1&3) show nearly negative exponential relationship between temperature and frequency. It seems that as frequency increases the structure of the material also change. Figure 2 and figure 4 shows the nearly negative exponential relation between frequency and elastic constant of female and male Borassus Flabellifer wood parts. The figure 5 and figure 6 shows the SEM picture of both the samples at 5.0kv x 750 &10µm.

5. Conclusion
The temperature affect the frequency and elastic constant exponentially were decreasing. As temperature increases the frequency and elastic constant decreases in both the female and male Borassus Flabellifer wood parts because the ultrasonic velocity were increased with temperature in solid material. The SEM picture shows that both the wood parts were highly rough.

6. Acknowledgement
One of the authors (Sushil Phadke) is highly thankful to University Grants Commission, New Delhi for awarding a Minor research Project. Our sincere thanks to Dr. S.N. Mandloi, Principal Govt. Girls College Dhar (MP) India for providing facility to bring samples from Dist. Dhar (M.P.) India. We are very thankful to Mr. Ritusing Kalesh of Dist. Dhar (M.P.) India for providing sample. I also thankful to Devendra Jain of Diya Lab, Mumbai for sending SEM reports in time.

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