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Determination of Variation of Strain Anisotropy of Wood due to change in Relative Humidity

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Abstract- Wood is an anisotropic biological material with a multitude use. The paper describes variation of strain of wood samples due to the change in relative humidity (RH). The strain developed due to change in RH is measured by strain gauge method. In this paper, the strain is measured in longitudinal (L) and tangential (T) direction. For that purpose strain gauge is attached in the prescribed direction and the strain developed due to change in RH is recorded by data acquisition system. The developed data acquisition recorded ambient temperature, RH with temperature compensated and strain of the wood samples in different L and T direction. Strain anisotropies of two wood samples of different thickness are tested at different relative humidity conditions and the results are reported in the paper. Experimental results show that the strain developed in the wood sample is anisotropic.

Keywords- MPLAB-IDE, RISC Processor, Measurement System

1. Introduction

Hygroscopicity is the property of wood to take moisture from the environment and to hold it in the form of liquid water or water vapour. This property originates from the chemical composition of wood. As a result of hygroscopicity, wood always carries moisture. Hygroscopicity is an important property, the moisture contained in the wood affects all other properties[1,2]. The exchange of moisture due to changes in ambient relative humidity and temperature affects the dimension of wood. To use wood to its best advantage and most effectively in engineering applications its specific characteristics or physical properties must be considered. The versatility of wood is demonstrated by a wide variety of products. This variety is a result of a spectrum of desirable physical characteristics among many species of wood [1].

Wood is anisotropic with regard to shrinkage and swelling i.e. shrinkage and swelling is not the same in the different grains directions. The greatest shrinks occurs in a direction tangential to the annual rings. The shrinkage in the radial direction is considerably less than in tangential direction. It shrinks least in the direction of longitudinal, along the grain direction[3].

Considerably less than the tangential shrinkage, while shrinkage along the grain is so slight that it can be neglected [2].

Several research works have been done and are still going on to study wood response with the changes of environmental humidity. Dominique Derome et al. studied the hysteretic swelling and shrinkage for latewood and earlywood by phase contrast X-ray tomography [4].

K.B. Dahl et al. developed video extensometer technique for the measurement of planer strain of wood [5].

Ahmad et al. documented the hygroscopic swelling and shrinkage of the central and the thickest secondary cell wall layer of wood in response to changes in environmental humidity using synchrotron radiation-based phase contrast X-ray tomographic nanoscopy. They found that the volumetric strains at the cell wall level are significantly larger than those observed at cellular tissue [5].

The elastic properties of wood differ in the orthotropic direction –longitudinal, tangential and radial. Stefan et al. determined the elastic properties in the three orientations at different moisture conditions [6].

The data acquisition system employes strain gauge, temperature sensor and humidity sensor to measure strain change of wood, ambient temperature and RH. The outputs of the sensors are sequentially read by 10-bit RISC processor (PIC18F43K22 microcontroller). The system firmware for processor is developed on MPLAB-IDE and suitable codes are written on C-language for handling data in the PC side.

To test the variation of strain of different wood samples with RH, a humidity generator is developed by five different binary saturated salt solutions. The humidity generator is designed by using desiccator and wood samples are kept inside the desiccators. The strain developed due to different humidity conditions are recorded by data acquisition system.

2. System Description

The block diagram of the data acquisition is shown in figure 1.

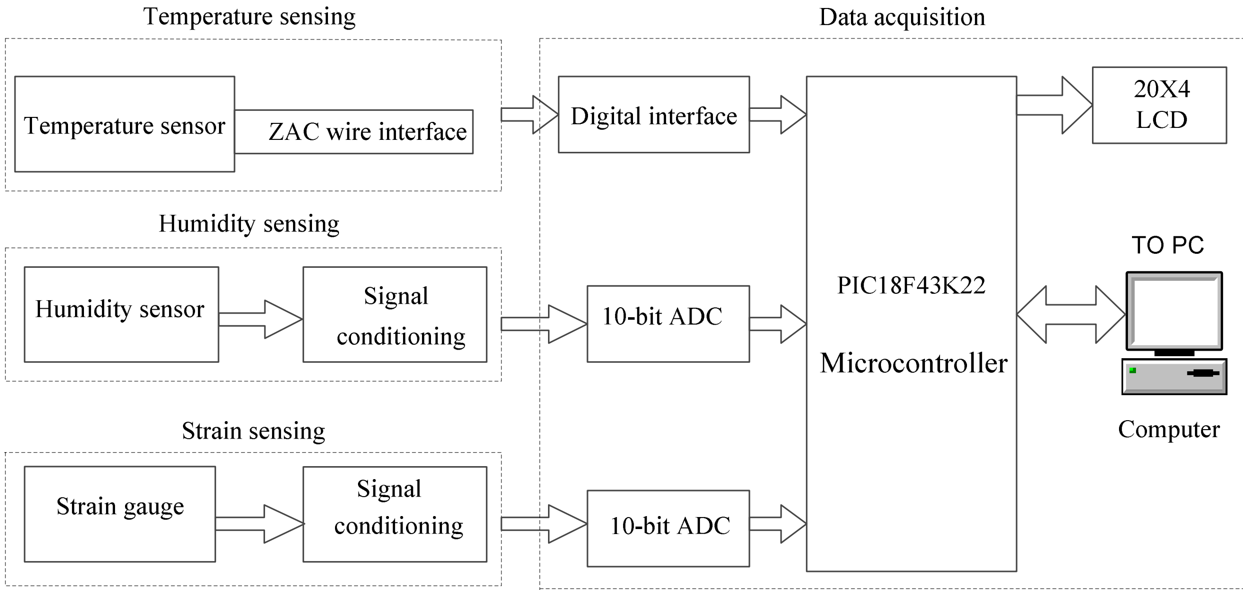


Figure 1. Block diagram of the measurement system

The system includes the sensors along with their individual signal conditioning circuit for the measurement of temperature, relative humidity and strain change of wood sample with relative humidity. TSIC 506F temperature sensor, HIH5030 humidity sensor and CF350-2AA (11) C20 strain gauge are interfaced to PIC18F43K22 microcontroller and connected to PC by RS232 communication. The output of the temperature sensors and strain gauges are fed to the six channels of the 10-bit on chip ADC of the microcontroller through proper signal conditioning circuit. The system features data display on LCD and online data collection on PC using RS-232 communication [7].

2.1. Sensors

TSIC 506F is used for the measurement of temperature which provides digital output with an accuracy of ±0.1K. It is a ZACwire™ interface compatible sensor and a factory calibrated temperature sensor and the digital output (T) of the sensor is given by [8]

$$T = \left[\frac{D}{2047} \times \left(T_H - T_L \right) + T_L \right] \tag{1}$$

Where, D is the 8 bit data from the temperature sensor and (T_H - T_L) being the temperature range of the sensor with T_L= -10 ºC and T_H= 60 ºC.

HIH 5030 is a humidity sensor and used in the system. It is a low voltage humidity sensors operate down to 2.7 V_{dc}. The accuracy of the humidity sensor is ±3%. The output voltage V_{out} and RH is related by the following equation at 25ºC [9]

$$RH = \left[\frac{V_{out}}{0.00636 \times V_{supply}} - 23.82 \right] \% \tag{2}$$

For measurement of strain of wood sample CF350-2AA (11) C20 strain gauge sensor is used which has the nominal resistance 350Ω with gauge factor 2.13 ± 1% [10].

2.2. Signal conditioning of strain gauge

The signal conditioning of strain gauge involves bridge, instrumentation amplifier and peak detector circuit.

A quarter bridges with three fixed resistors and one strain gauge (which is attached to the wood sample) is used for strain measurement. Each of the 350Ω fixed value resistors has tolerance of ±0.1% and temperature co-efficient ± 5ppm/˚C which ensure very low temperature drift. The bridge is excited by 1 KHz, 5V (peak-peak) sinusoidal signal (amplitude accuracy, ±1mVpeak to peak) from the Agilent Function generator (Model no. 33220A). The differential output of the bridge is amplified by an instrumentation amplifier (AD620) and the amplified AC output is converted to DC by using peak detector (Figure 2).

The DC output of the signal conditioning circuit is given by

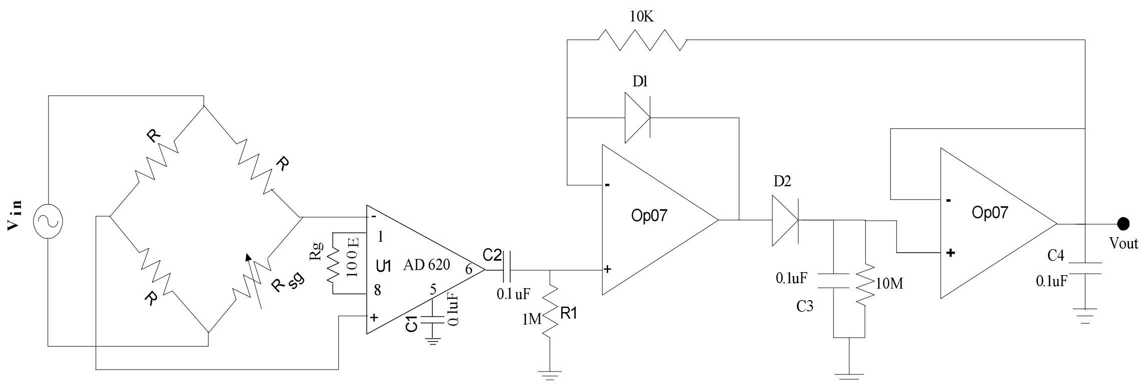


Figure 2. Signal Conditioning Circuit of the strain gauge

$$\frac{V_{out}}{strain} = \left(\frac{49.4\,\mathrm{K}\,\Omega}{Rg} + 1\right) \times \frac{V_{in}}{8} \times \frac{\Delta R}{R} \qquad (3)$$

Where, V_{in} the excitation voltage, ΔR the change in resistance of the sensor and R is the resistance of the sensor in the unstrained condition, R_g is the gain setting resistor[11].

3. Sample Preparation

Six wood samples of Titasopa (*Gmelina arborea*) in different sizes are taken and prepared for experiment. The samples and sizes are mentioned in Table1. The wood samples are cleaned well and sanded with grit size 1500 for smoothing the surface. Prior to the experiments, the samples are oven dried at 90^{o}C and stored in a desiccator. Six strain gauges are attached by cyanoacrylate adhesive on each of the sample, one in longitudinal (L) and other in tangential (T) direction. Finally the connecting leads are soldered and connected to the bridge circuits.

Binary saturated salt solutions are prepared as per OIML R121 [12] in a desiccator at constant temperature and generate fixed level of humidities with uncertainties [12] as shown in Table 2. A desiccator sealed with silicon high vacuum grease is used in the experiment to generate different fixed levels of humidity using the salts shown in Table 2. The samples under test and sensors are placed inside the desiccator as shown in the Figure 3.

Table2 Samples of Titasopa and dimensions

Samples	Dimension of the samples
S1	5cm×1.7cm×0.8cm
S2	5cm×1.7cm×1.3cm
S3	5cm×1.7cm×2.8cm

Table 2 Levels of humidity generated by binary salt solutions at 25^{o}C

Salt Name	RH(%)	RH(%) Uncertainty in RH
Lithium Chloride	11.30	± 0.27
Potassium Acetate	22.51	± 0.32
Magnesium Chloride	32.78	± 0.16
Magnesium nitrate	52.89	± 0.22
Sodium Chloride	75.29	± 0.12

4. Experimental results

During the experiment the samples under test are placed inside the desiccator for different levels of humidity generated by various salt solutions at 25˚C (±1˚C). At the stable level of humidity, data are recorded at an interval of one minute. Variations of strain changes of the samples are observed for different levels of humidity and plotted in figure 4, figure 5 and figure 6.

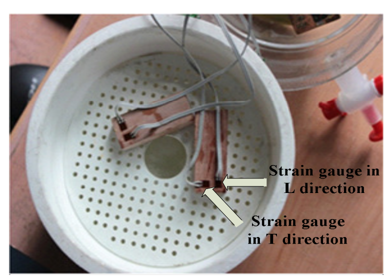
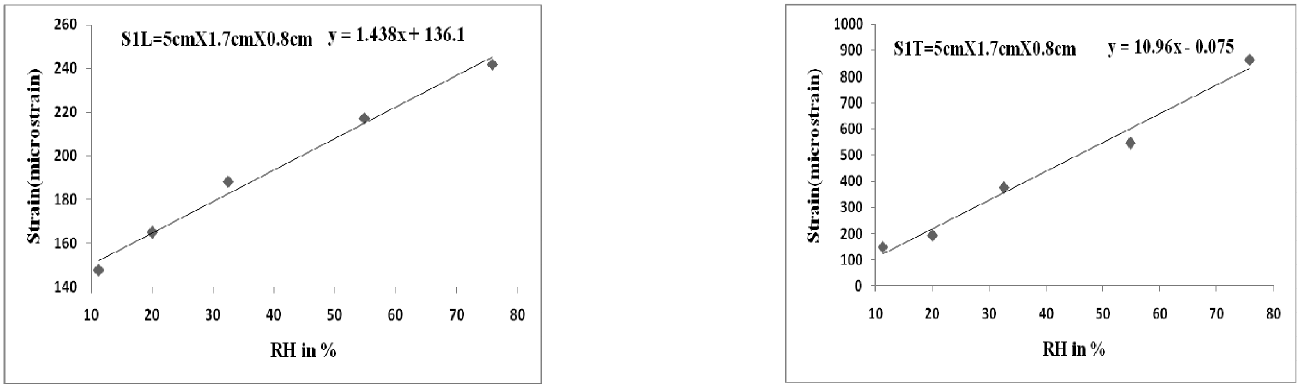
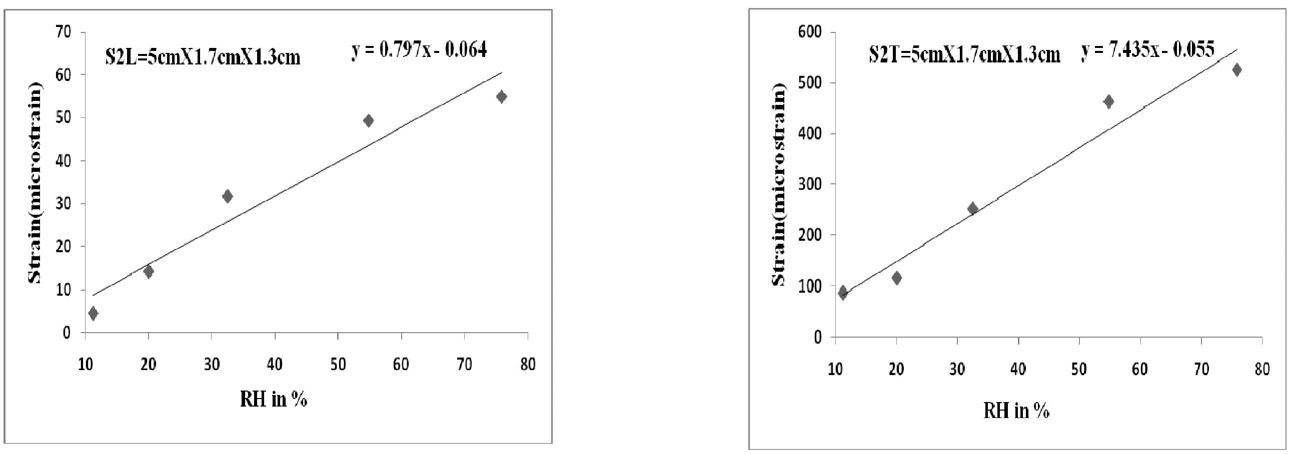


Figure 3. Experimental set up during sample test at different RH level



(a) (b)

Figure 4. Strain variation of S1 vs RH (a) in longitudinal and (b) tangential direction



(a) (b)

Figure 5. Strain variation of S2 vs RH (a) in longitudinal and (b) tangential direction

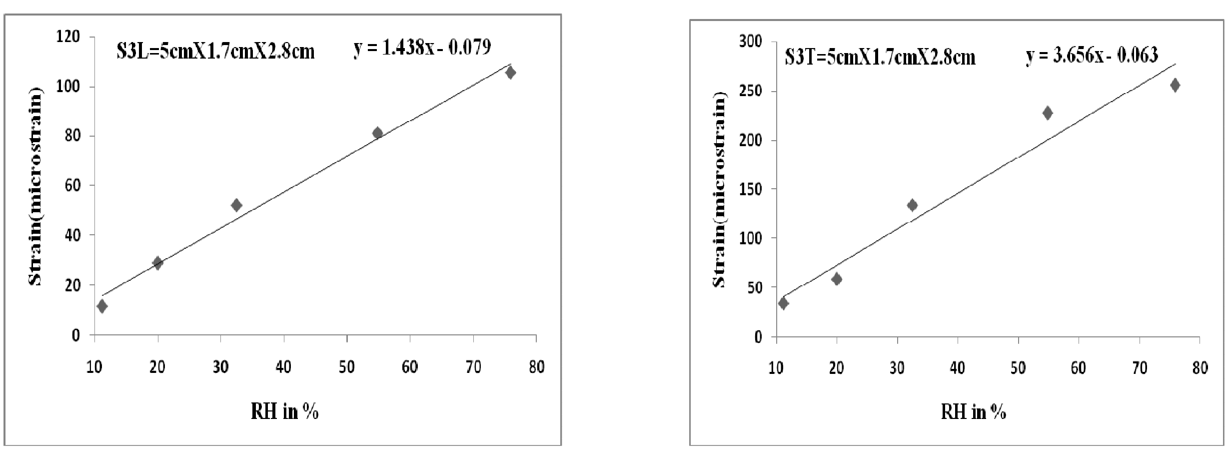


Figure 6. Strain variation of S3 vs RH (a) in longitudinal and (b) tangential direction

The developed data acquisition system is capable of measuring the strain over the surface due to change in ambient relative humidity. The strain developed on the wood samples is found to be linear with the change in RH. From the result, it is observed that the strain variation of different wood samples in different orientation changes with change in relative humidity.

5. Conclusion

A measurement system is successfully developed which can be used to study the effect of RH on wood.

The strain sensitivities of S1 sample in tangential and longitudinal direction are 10.96με /RH, 1.43με/RH. For S2 sample the sensitivities in strain in tangential and longitudinal direction are 7.44 με /RH, 0.79με /RH and for S3 samples the strain sensitivities are 3.65 με /RH and 1.43 με /RH in longitudinal and tangential direction.

The observations agree with the related literature i.e. the difference in sensitivities reveals that the strains are anisotropic within the same sample [1, 2].

6. Acknowledgement

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