A Study on Moisture Content Variation of Malaysian Wood using Microwave Nondestructive Testing at 8 to 12 GHz

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ABSTRACT

Microwave nondestructive testing using free-space microwave measurement system involves measurement of reflection (S_{11}) and transmission (S_{21}) coefficients of Malaysian wood specimens in free-space. From measured S_{21} coefficients in 8 – 12 GHz frequency range, dielectric constants and loss factors were calculated by S_{21} only method for several moisture contents (MC) when electric field was parallel and perpendicular to the grain direction. Measured MC values obtained using the Maxwell Garnett theory are compared with calculated MC values obtained from the weight difference method. For dielectric measurements perpendicular to the grain, there is a good correlation between calculated and measured MC values.

INTRODUCTION

Microwave nondestructive testing (MNDT) of materials is an important science which involve development of sensor and probes, methods and calibration techniques for detection of flaws, cracks, defects, voids and moisture content by means of microwaves [1]. MNDT methods are fast, contactless, accurate and continuous techniques for evaluation of moisture content, slope-of-grain, density of knots and specific gravity of the timber [2-4]. Recently, there has been much interest in applying MNDT to measure the wood physical properties by using the dielectric properties of wood. Free space microwave measurement (FSMM) system is used to measure dielectric constants and loss factors of Malaysian wood in the frequency range of 8 - 12 GHz. The main advantage of FSMM system is that with suitable modifications, it is possible to make precise, accurate and reproducible MNDT measurements on materials under high or low temperature conditions and complex electromagnetic environmental conditions (DC biasing fields, ionizing radiations, etc) due to contactless feature of free-space measurements. Another significant advantage of free-space methods is that the measurements can be made when incident, reflected and transmitted signals are circularly/elliptically polarized electromagnetic waves.

Composite material such as wood causes a linearly polarized electromagnetic wave to become elliptically polarized upon transmission through it. So, free-space methods are specially suited for the evaluation of wood [4]. The physical properties (such as moisture

content, grain angle) of wood and wood products have always been very difficult to measure. Some measurements of useful properties have been destructive, inaccurate and time consuming. So, the MNDT method outlined in this research could provide an alternative method for measuring wood physical properties.

In the past, FSMM system was used by Ghodgaonkar et al [5] to measure reflection coefficients (S_{11}) and transmission coefficients (S_{21}) coefficients in free space. Then, dielectric and magnetic properties are calculated from S_{11} and S_{21}. Also, transmission (S_{21}) only method was used for calculation of dielectric properties by Mohd Aziz Aris et al [6]. In this paper, dielectric constants and loss factors are reported for Punah specie of Malaysian wood at 10 GHz for different moisture contents (MC). Also, measured MC values obtained using the Maxwell Garnett theory are compared with MC values calculated from the weight difference method.

MATERIALS AND METHODS

The wood material obtained from the Forest Research Institute Malaysia (FRIM) has undergone seasoning before being used as specimens. One wood specie was used and its standard local name is Punah (*Tetramerista glabra*) with a density of 674.9 kg/m^3. Specimens of the size 9.5 cm x 9.5 cm and thickness 1 cm were prepared and immersed in water for 7 days to achieve saturated state. The sample is removed from the water and is air-dried at room temperature (25°C). The weight of the sample was recorded and immediately the sample is placed in the sample holder of the FSMM system to measure its dielectric properties. The procedure was repeated if there is any significant change in observed weight as the moisture decreases until there is no significant weight difference. Then, the sample was placed in an oven at 60°C until the sample has achieved an oven-dry state.

The FSMM system consists of a pair of spot-focusing horn lens antennas, mode transitions, coaxial cables and a vector network analyzer (VNA) [5]. For wood specimens, S_{11} and S_{21} are measured using FSMM system after performing free-space LRL (line, reflect, line) calibration technique [5]. Then, dielectric constants and loss factors are calculated using transmission (S_{21}) only method [6]. Maxwell Garnett theory (MGT) [7] is applied to dielectric constant data when the grain direction is perpendicular to the electric field. Then, measured MC values are obtained from MGT formula given in reference [7] and equation (2.11). Calculated values of MC are obtained by the weight difference method. This method gives MC value as the ratio of weight difference of air-dry specimen and oven-dry specimen with respect to the weight of oven-dry specimen.

EXPERIMENTAL RESULTS

All measurements are performed in 8 to 12 GHz frequency range. But, only dielectric data measured at 10 GHz are used for results reported in this paper. Also, many species of Malaysian wood were used for dielectric measurements using FSMM system. But, only Punah specie is chosen for results reported in this paper. Fig. 1 and Fig. 2 show variation of

dielectric constants (ε') and loss factors (ε'') with the calculated MC values for the Punah specie of Malaysian wood when electric field is parallel and perpendicular to the grain direction.. Also, the measured and calculated values of MC are plotted in Fig. 3 for the Punah specie of Malaysian wood.

CONCLUSIONS

The values of ε' and ε'' increases with an increasing MC**.** Dielectric constants as well as loss factors are higher when measured with electric field parallel to the grain direction as compared to perpendicular to the grain direction. There is a linear relationship between measured and calculated MC values for Punah specie. The dielectric constant ε' of Malaysian wood can be used to measure its moisture content using Maxwell Garnett theory. The application of MNDT using FSMM system at 10 GHz on wood can give fairly accurate MC values compared to the conventional weight difference method. Measuring MC using FSMM system is an alternative method for nondestructive evaluation of Malaysian wood.

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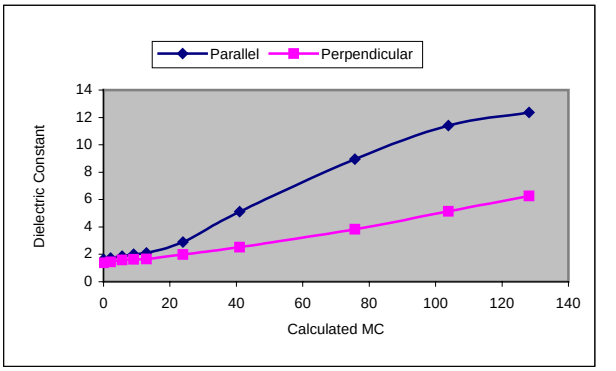

Fig. 1 Plot of measured dielectric constant with calculated MC

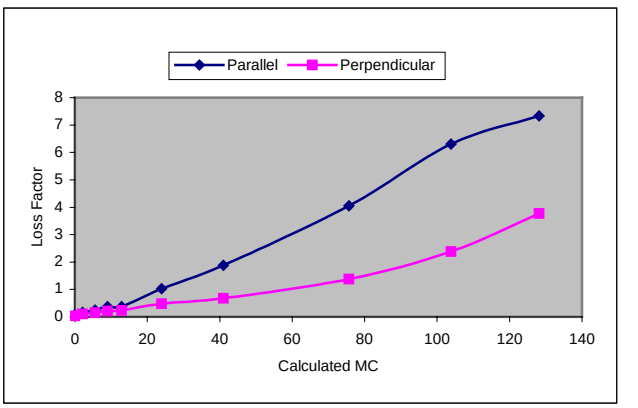

Fig. 2 Plot of measured loss factor with calculated MC

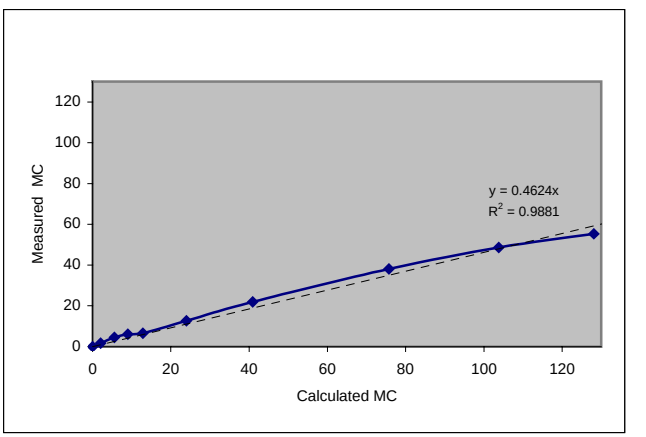

Fig. 3 Plot of measured MC with calculated MC