MEASURING THE DIELECTRIC PROPERTIES OF AUSTRALIAN WOOD SPECIES

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ABSTRACT

Through its industrial applications potential (i.e. drying, stress relief, structural modification for impregnation, bending and surface treatments to enhance coating), microwave processing could offer a powerful material-processing tool to wood industry.

In order to scale up a microwave process, the development of the exploratory process to production scale has to be performed. This research basically depends on microwave-material interaction understanding. The main effect of microwave-material interaction is the conversion of microwave energy into heat within the material due to the absorption of the electromagnetic energy through the dielectric properties of the material.

Wood is a very complex material with poor thermal conductivity and permeability. As a result, under the various industrial microwave processes, temperature within wood may range from 100º to 170ºC giving rise to internal wood pressure of up to 7 atm. Variety of methods for measuring the relative complex permittivity has been described in the specialised literature. However, to obtain the dielectric properties of wood which are relevant to microwave heating, measurements at elevated temperatures and pressures have to be performed. Such research has not been undertaken before and requires the design of new equipment.

The aim of this paper is to present a specially made device and the appropriate measuring procedure for measuring the dielectric properties of wood under high temperatures and pressures.

To measure the dielectric permittivity of wood at microwave frequency of 2.45 GHz and under high temperatures and pressures, the short-circuit line measurement technique was selected due to its well suitability for high temperature measurements. The experimental set-up (Figure 1) consists of a VNA (HP 8720C) system connected to a standard waveguide which for high pressure and temperature convenience was extended with a special designed high-pressure cavity. Used as the sample holder, the cavity was manufactured from stainless steel waveguide with build-in pressure applicator and Pyrex pressure window (transparent to microwave and resistant to 150°C and 5 atm.). The cavity is ended with an attachable fixed short-circuit. The sample temperature is progressively increased by means of an electrical heater placed underneath the sample holder. An immersion probe inserted within the sample detects and reads the temperature. As the measurement aim is to simultaneously perform internal wood temperature and pressure of about 150°C and 5 atm. respectively, air pressure is applied inside the cavity and it is controlled by the pressure gauge.

Figure 1: Experimental set-up

For such configuration, when a wood sample of a certain thickness, which perfectly fits the sample holder cross section, is placed to the left of the short-circuit, the VNA system measures the 1-port scattering parameters (which in this case is the reflection coefficient - S_{11}). Since the reflectivity at a point within the transmission line is related to the impedance at that point, the procedure used to determine the wood sample permittivity is based on the impedance change caused by the presence of the wood within the rectangular cavity. To solve the final equation (a transcendental equation in the complex plan) which involves the sample length and reflection coefficient and from which the value of permittivity is extracted, a computer program solver was developed. Through its configuration, the solver gives all solutions in a given domain of the complex plane and each solution is obtained within an accuracy of 10^{-8}. However, since the number of solutions is infinite, one has to make sure that the “right” physical solution for permittivity is one of the numerical solutions obtained. In principle, to peak the physical solution among all the mathematical solutions of the transcendental equation, another sample with a different thickness should be measured. The experience could also point out the physical solution.

The method described above is suitable for measuring the dielectric permittivity of wood as long as the calibration of the measuring device includes elements like pressure windows, pumping air holes, etc. However, a special attention has to be directed to the measuring device calibration. Due to the thermal expansion of the pressure cavity components, the initial calibration precision is changing during the measurement process and will directly affect the results accuracy.

Several measurements were performed on Mountain Ash (*Eucalyptus regnans*) wood samples with oven dry density of 0.75g/cm^3 and different moisture contents (MCs). First results for permittivity (Fig. 2) were obtained in radial direction and for different temperatures and related pressures.

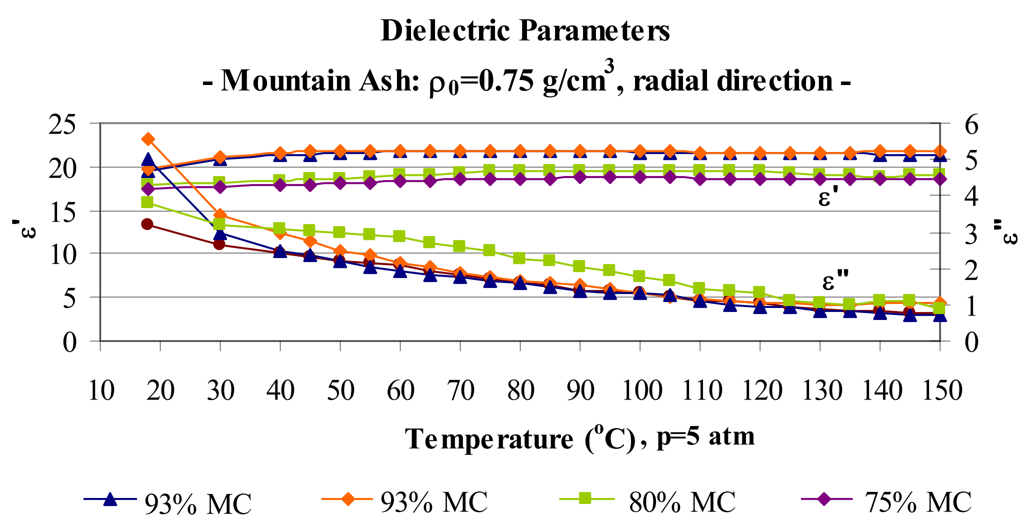

Figure 2: Mountain Ash dielectric parameters at high temperatures and pressures

The results show that with increasing the wood temperature from 20° to 100°C, the value of dielectric constant of moist wood is almost constant while that of loss factor decreases continuously. In the case when the wood internal temperature ranges from 100° to 150°C and the moisture is kept inside by generating high internal pressure, the results reveal unchanged trend for dielectric constant and a continuous decrease for loss factor as low as 0.9. This behaviour is quite understandable since the loss factor of free water, which influences the most the wood microwave energy absorption, reduces from 10.7 at 20°C to about 0.46 at 150°C.

To understand the commercial microwave processing of wood, measurements of the dielectric properties under high temperature and related pressures are crucial. Under this consideration, this paper succinctly described the appropriate technique and method for measuring the wood permittivity which are suitable for experiments at elevated pressures and temperatures. The method is used for mapping the permittivity of Australian and other wood species as a function of moisture content, electric field direction, temperature and pressure. The first obtained results indicate almost no change in dielectric constant but significant change in loss factor as the temperature and related pressure increases up to 150°C and 5 atm., respectively. These data are mainly valuable for designing and optimising generators, applicator systems or other achievable wood microwave processing devices.