DOES MECHANICAL STRESS AFFECT THE DIELECTRIC PROPERTIES OF WOOD?

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ABSTRACT

The effect of mechanical stress on the dielectric properties of wood was studied to assess the possibility of estimating drying stresses from dielectric measurements. The effect was observable for both the mechanical and electric stress parallel to the grain when the wood was at 12% moisture content or greater and at frequencies less than about 10 kHz. For stresses across the grain, the effect was very small, which precludes using this phenomenon for estimating drying stresses.

Keywords: Dielectric properties, dielectric constant, conductance, resistance, mechanical stress, compression, tension.

INTRODUCTION

The major source of drying degrade in lumber is internal stress resulting from moisture gradients. If these stresses could be measured directly, control of kiln-drying schedules could be optimized. This study tested the feasibility of estimating mechanical stress in wood from measurements of the dielectric properties of the wood. This report is a condensation of the results of the study; a more comprehensive report including details of the procedures and data may be obtained from the National Technical Information Service, Springfield, Virginia.

BACKGROUND

The change in permeability of ferromagnetic materials due to mechanical stress, the Villari effect, is well documented, but the analogous change in dielectric constant of polar solids from mechanical stress is relatively obscure. Leading basic texts on dielectric properties of solids (Debye 1945; Smyth 1955; Von Hippel 1954) make no mention of this phenomenon. There is, however, theoretical reason to expect mechanical stress to affect dielectric properties of polar solids due to orientation and change in freedom of motion of molecular dipoles as the material is strained (Braybon 1953; Crawford and Kolsky 1951; Treolar 1947). Also, there is limited experimental evidence that the dielectric properties of at least some polar solids are strain-sensitive (Iida and Fukuyama 1981; Norris et al. 1956; Scott 1935).

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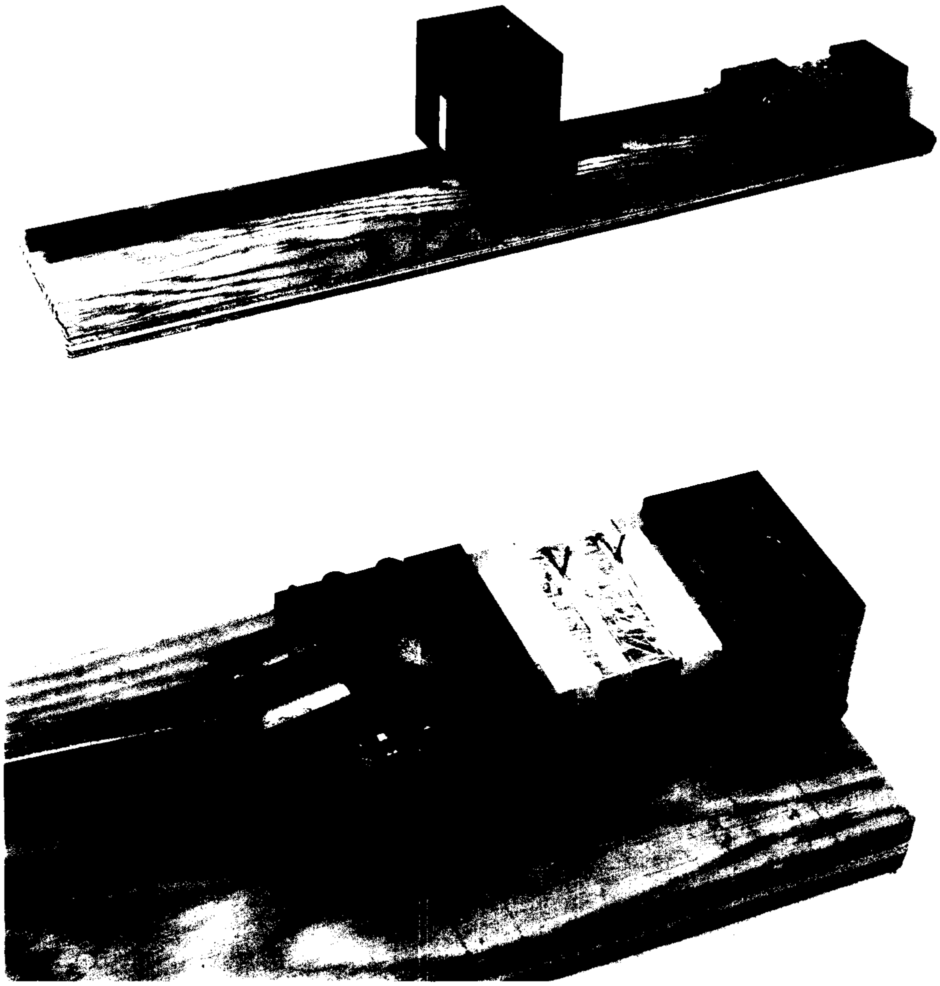

FIG. 1. Two views of the loading vise used to apply either tension or compression stress to the specimens.

EXPERIMENTAL

The capacitance and equivalent parallel conductance of wood specimens were measured when the specimens were essentially free of external stress, and again while subjected to a single predetermined stress. The loading device with a specimen in place is shown in Fig. 1. Stress levels parallel to the grain were up to 3,600 lb/in.^{2}. Both compression and tension stress were investigated, but tensile stress was limited to a maximum of about 1,400 lb/in.^{2} because of specimen configuration. Measurements were made at frequencies of 0.02, 0.1, 1, 10, and 100 kHz, and on wood conditioned at 30, 65, 80, and 90% relative humidity. Complete data sets were obtained on specimens of Douglas-fir and an unknown species of red oak, and also for stress in each of the three principal directions

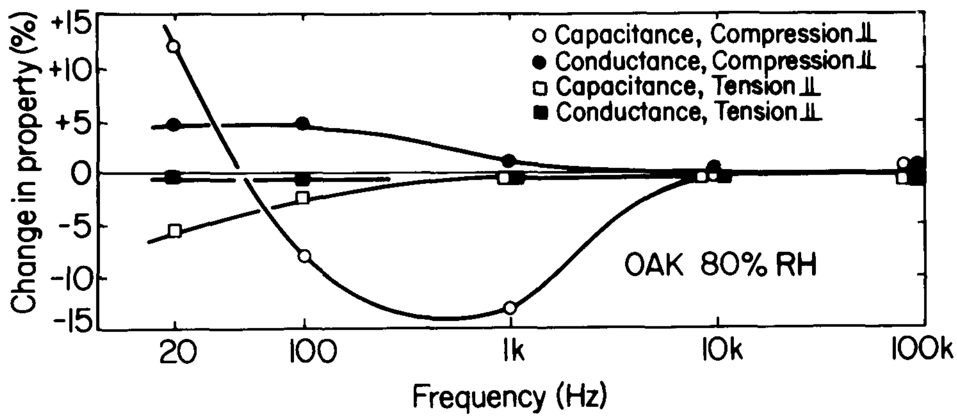

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FIG. 2. Representative plot of data showing the effect of mechanical stress on the dielectric properties of wood. Oak specimen conditioned at 80% RH. Conductance is the equivalent parallel conductance of the specimen treated as a lossy capacitor.

relative to the growth rings of the tree. Stress levels across the grain were reduced in accordance with the lower mechanical properties across the grain.

Most data were taken with the stress in the same direction as the electric field, but a few exploratory measurements were made with the electric field perpendicular to the stress.

RESULTS

The dielectric properties of wood were modified by mechanical stress at some but not all combinations of moisture content and frequency. In general the stress sensitivity of dielectric properties increased as moisture content increased or frequency decreased. There was no detectable effect in wood conditioned at 30% relative humidity (6.5% MC) and no detectable effect at 100 kHz. The effect was significant only for stress and electric field parallel to the grain; for stress across the grain the effect was limited to a very small change in equivalent parallel conductance.

For stress parallel to the grain, compression increased the conductance and tension decreased the conductance; but in magnitude the effect of compression was substantially greater than the effect of tension. By contrast, the dielectric constant (capacitance) was usually decreased by either tension or compression stress, although at low frequencies (generally 100 Hz or less) compression stress sometimes increased the dielectric constant. This is shown in Fig. 2, which also illustrates the typical effect of stress on the dielectric properties of wood at about 15 to 20% MC. Under these conditions, the effect of the stress changed sign as the frequency increased, so at higher frequencies compression decreased the dielectric constant. The frequency at which the effect of stress changed sign was usually about the same as the frequency at which the predominant mechanism of polarization in wood changes from interfacial to molecular dipole (James 1975).

Again, the magnitude of the effect was much greater for compression than for tension.

There was a weak tendency for compression across the grain to reduce the associated conductance, which is opposite to the observation for stress and electric field parallel to the grain. There was no observable effect of stress across the grain on the associated capacitance (or dielectric constant). No consistent effect on either capacitance or conductance was observed for stress parallel to the grain and electric field across the grain.

The dielectric properties of wood measured while the wood was under stress were unstable and drifted with time in the manner of creep. This phenomenon made it necessary to make the measurements quickly and repeatedly in order to establish the effect of mechanical stress apart from the effect of the creep.

CONCLUSIONS

This study showed that the dielectric properties of wood are in fact stress-sensitive at least under some combinations of moisture content, frequency, and grain direction. The effect of mechanical stress is, however, small and somewhat unstable, and particularly is very small for stress across the grain. This latter fact makes dielectric measurements an unlikely way to estimate drying stress in wood.

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