

WOOD DRYING BY USING HIGH POWER ULTRASOUND AND INFRARED RADIATION

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ABSTRACT

During the quality control of wood in the sawmills, drying represents the greatest detected problem. In fact, drying by air or in chambers it is an essential step in the wood processing because it is at this stage where more energy is consumed. It means important losses of raw material and expenses for the wood industry.

This work proposes an alternative solution to cracking and rupture of the cellular structure of the wood during the drying process. The proposed technique aims at the use of both, high-power ultrasound and infrared radiation, as non polluting alternative energies for drying wood pieces. The advantages of this system may represent an important economic decision for the lumber manufacturer increasing the production by reducing the drying times but keeping good quality.

INTRODUCTION

Wood drying is the stage where more energy is consumed during wood processing. In general, it is an essential step in which wood quality is decided. An incorrect drying process generates cracking problems, rupture of the cellular structure of the wood, folding in the piece, and in general an inadequate drying stage. These alterations devalue the final product and important losses for the wood industry take place.

This paper deals with an experimental study about the use of both, high-power ultrasound and infrared radiation applied simultaneously as non polluting alternative energies for drying wood pieces. Finally, a discussion on the wood drying process and on the perspectives when both alternative energies are used, will raise.

DEVELOPMENT

At to the present moment, only one paper on ultrasonic drying of wood was found in the literature [1]. The book of V. Bucur "The Acoustics of Wood" [2] which is the most important source of references in the topic doesn't mention the potential use of ultrasound for drying wood. Therefore, this is a new application of high-intensity ultrasound. The referred paper was a preliminary study of the drying of refractory eucalyptus species of 2.5 cm thickness by the application of ultrasonic energy. A commercial 750W Branson generator at 20 kHz was used in the experiments. The results showed that it was able to dry from green up to 20% moisture content in approximately one hour. The temperatures generated within the sample during the ultrasonic treatment were of approximately 150°C. At these high temperatures the wood becomes plastic and the rupture of the cellular structure can be produced.

The experiments of the present work were carried out at the High-Power Ultrasonics Laboratory of the Instituto de Acústica, CSIC, by using an experimental prototype developed for ultrasonic drying of vegetables [3]. The experimental tests mainly consisted in measuring the moisture content of wood samples before and after applying high-power ultrasonic fields at different times. In the ultrasonic drying procedure the ultrasonic vibration is applied in direct contact with the samples and together with a static pressure. The moisture extracted from inside the wood was removed by a suction pump.

The experimental tests were divided in two groups: a) a set of tests at 20 kHz that allow us to verify the ultrasonic effect on pine wood dehydration, and b) a set of tests at 10 kHz with the objective of determining the influence of a lower frequency. In both cases infrared radiation was also applied in combination with ultrasonic energy.

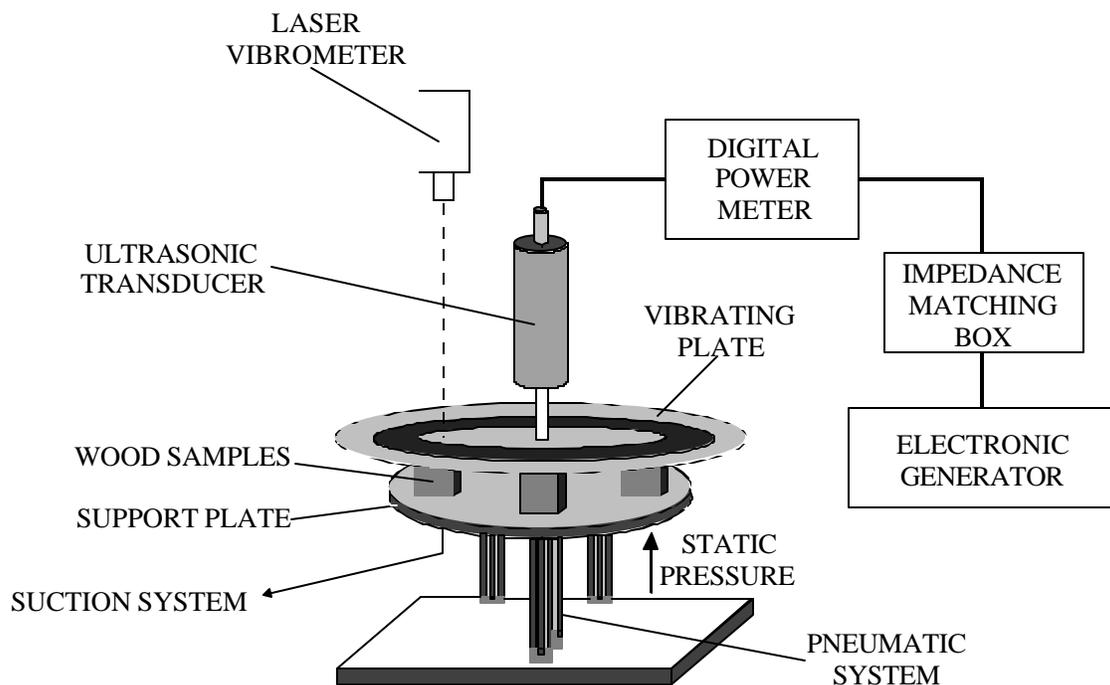


Figure 1. Experimental set-up for wood drying by means of high-power ultrasound under static pressure conditions.

WOOD DRYING BY ULTRASOUND AT 20 kHz AND INFRARED RADIATION. EXPERIMENTAL RESULTS

The experimental set-up for wood drying by applying ultrasonic vibration in direct contact is shown schematically in Figure 1. It mainly consists of the following components: a) a stepped-plate power ultrasonic transducer with the corresponding electronic generator [3]. b) a flat plate parallel to the ultrasonic radiator acting as a sample holder where the suction pump is applied to remove the moisture. c) a static pressure system by means of three pneumatic pistons to get good mechanical coupling between the samples and the vibrating plate of the transducer. The experimental tests were carried out at applied power levels generally lower than 120W. To control the parameters of the driving signal (voltage, current, phase, power applied), a digital power meter was used. An impedance matching box was also used to transfer the maximum electrical energy from the electronic generator to the high-power ultrasonic transducer. The pine wood samples were parallelepipedic pieces of 1.5x2.5x4 cm.

The goal of the experiments was to find an optimum value of the power applied to the ultrasonic drying system to generate the dehydration process of green wood (with a 100% of moisture content). The experimental system operates under a static pressure of 0.5 kg/cm². Infrared radiation to dry the external part of the samples was applied together with the acoustic energy.

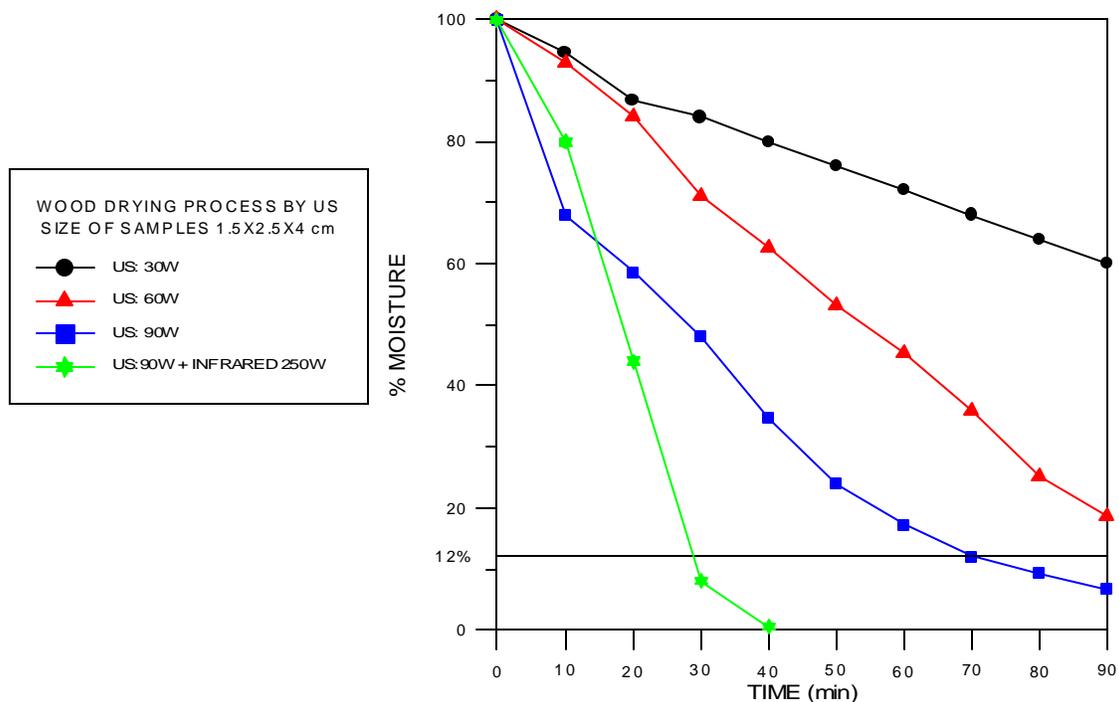


Figure 2. Wood drying of 2.5 cm thickness samples by means of high-power ultrasound (30W, 60W, 90W at 20 kHz) and infrared radiation (250W).

The samples were marked and weighted after sawing. The weight of dried wood was determined by dehydrating four sets of samples in an electric oven at 110°C. The samples were extracted from the main three parts of the pine trunk: albumen, duramen and marrow. Samples were weighted each 10 minutes during the drying process to determine their moisture content. The total time for the drying process was about 1 hour and 30 minutes. The experimental results of the wood drying process obtained by averaging the weight of samples 2.5 cm in thickness (1.5x4 cm in cross section) belonging to the three fundamental parts of pine wood, are shown in Figure 2. In these experiments, the ultrasonic transducer (20kHz) was driven at three different power levels: 30W, 60W and 90W. The use of both, high-power ultrasound at 90W and infrared radiation at 250W, is also presented in the figure. The infrared source was placed transversally to the samples.

In Figure 2 it is clear that the ultrasound power level at a frequency of 20 kHz has an important role in the wood drying process. In addition, the effect of the infrared radiation at 250W combined with ultrasound at 90W accelerates the wood drying process dramatically. The effect of infrared radiation on wood drying is essentially superficial, because this kind of radiation can only penetrate a few millimeters in the material. Instead, the effect of high-power ultrasound on the wood drying is the extraction of the moisture from the interior to the surface of the material. So that the combination of ultrasound with infrared can be complementary.

The following observations have been realized in the wood drying process:

1. Drying begins on the upper part of the sample, which is in contact with the surface of the vibrating plate of the ultrasonic transducer. Moisture then goes down slowly to the lower part of the sample. Therefore it could be said that the radiation pressure could play a role in the process as a force which is moving moisture away from the radiator.
2. Atomization appears on the lateral surfaces of the sample. Therefore the moisture extracted from the interior to the surfaces of the material seems to be atomized by the action of the high intense ultrasonic vibration.
3. Some burned points were detected in areas close to the wood knots when the ultrasound power level was higher than 120W. Therefore, the maximum value of the power applied to the ultrasonic transducer at 20kHz was generally kept at 90W. At this power level the temperature of the wood induced by the ultrasound varies from 35°C to 45°C.
4. The lack of a good contact and coupling between the vibrating plate of the transducer and the samples gives rise to irregular results.

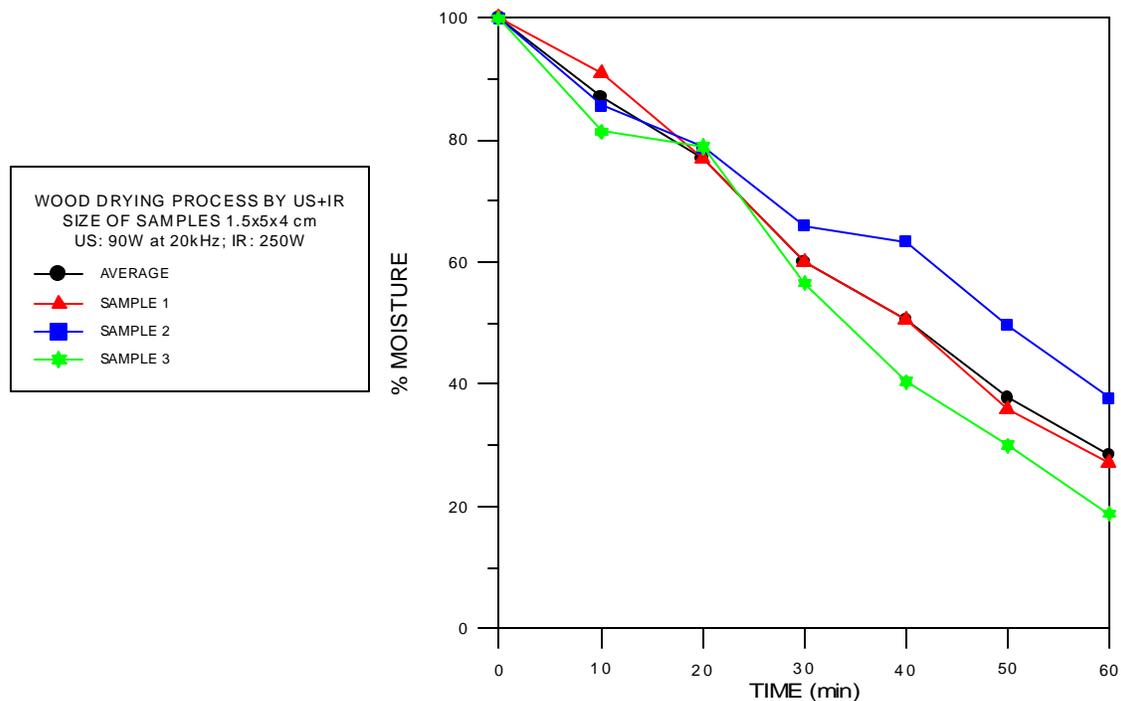


Figure 3. Wood drying of 5 cm thickness samples by means of ultrasound (90W at 20 kHz) and infrared radiation (250W)

To complete the study at 20 kHz, samples 5 cm in thickness were also used. In Figure 3 the results obtained with three different kind of wood samples by applying ultrasound at 90W and infrared radiation at 250W are shown. The graphic with circular dots represents the average value. A final dehydration of the order of the 28% was reached after one hour of treatment when both, high-power ultrasound and infrared radiation were applied simultaneously.

WOOD DRYING BY ULTRASOUND AT 10 kHz AND INFRARED RADIATION. EXPERIMENTAL RESULTS.

A set of dehydration tests with three samples of 5 cm in thickness were done during one hour treatment at 20kHz and at 10 kHz, respectively. The goal was to determine which the influence of the frequency in the wood drying process. At 20 kHz the power applied to the transducer was 60W whereas an “equivalent” power level of 120W was applied to the 10 kHz transducer. It means, that both power levels give rise to the same amplitude of the vibration velocity of the vibrating plate of the 20 kHz and 10 kHz transducers. In both cases the transducer vibrating plate was in contact with the samples. The measurement of the amplitude of the vibration velocity on the surface of the transducer plates was made by means of a laser vibrometer (see Figure 1). The results obtained are:

For the case of 20 kHz.

Time (min.)	Weight (gr.)		
	S1	S2	S3
0	47.95	44.29	47.81
60	41.43	36.92	36.98

For the case of 10 kHz.

Time (min.)	Weight (gr.)		
	S1	S2	S3
0	46.78	44.28	44.64
60	39.77	30.47	28.53

These tests were repeated with 2.5 cm thickness samples. The results obtained are:

For the case of 20 kHz.

Time (min.)	Weight (gr.)		
	S1	S2	S3
0	25.58	25.47	24.32
60	16.88	16.61	20.93

For the case of 10 kHz.

Time (min.)	Weight (gr.)		
	S1	S2	S3
0	24.6	24.5	22.87
60	16.73	18.66	19.18

Apparently the best result with 5 cm thickness samples were obtained at 10 kHz whereas with 2.5 cm thickness samples the best results were obtained at 20 kHz. It is important to say that the results of these tests present irregularities and therefore further experiments are needed. If these results were confirmed in a second set of experiments, it could be thought that a correlation exists between the thickness of the samples and the acoustic frequency of the transducer. In addition, the wood drying mechanism could be related with some resonance phenomena of the samples.

All these last experiments were carried out with a new procedure in which the ultrasonic vibration was combined with infrared radiation in a different way. For this purpose the experimental set-up presented in Figure 1 was modified. The samples were placed on the surface of a new supporting flat plate fixed to the top of a metallic cylinder (see Figure 4). The infrared source was located inside the cylinder in

such a way that the radiation goes directly to the lower part of the samples. To facilitate irradiation, rectangular slots were made on the surface of the flat plate just in front of the samples.

CONCLUSIONS

The use of sonic (10 kHz) and ultrasonic vibrations (20 kHz) at moderate power levels accelerates the wood drying process without the appearance of any type of damage in the wood. Wood samples up to 5 cm in thickness were treated satisfactorily.

If high-power ultrasound and infrared radiation are applied simultaneously, both processes complement each other and produce better results.

The mechanisms that seem to be present in the drying process are not well understood. Acoustic radiation pressure and a kind of sponge effect that facilitates the migration of moisture from the interior to the surface of the material seem to be the most important. Some hyperthermia phenomena caused during the ultrasonic treatment which are attributed to the frictional forces within the wood may be also present

A set of early experimental tests seem to point out that a certain correlation could exist between the acoustic frequency and the thickness of the samples. Nevertheless further tests are needed to reach to clear conclusions.

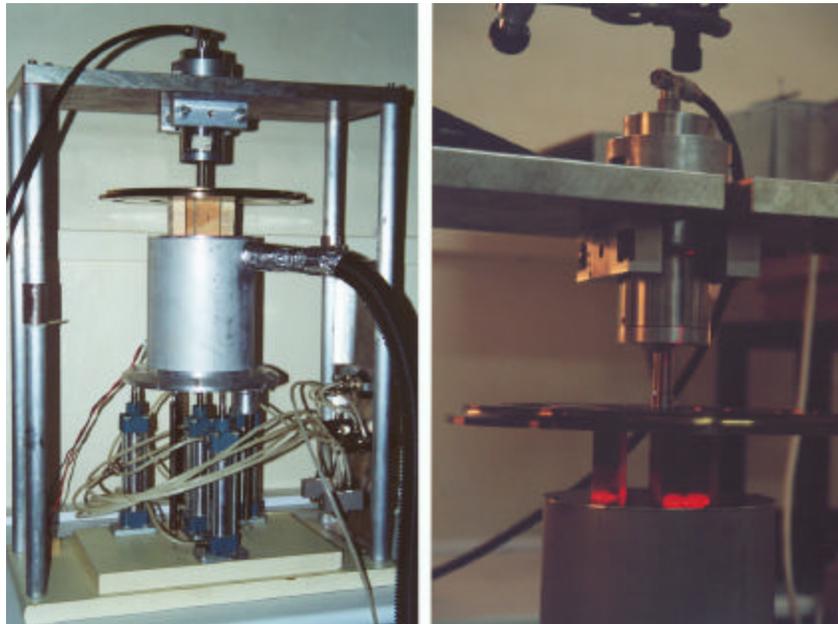


Figure 4. New wood drying system by high-power ultrasound and infrared radiation.

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