The Use of Ultrasound Energy Propagated in Wood

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ABSTRACT

It is important to detect wood-boring insects at the import or export port for plant quarantine. Chemical pest control is one of the methods, however, we need to consider interference with environmental risk management. In this paper, an ultrasonic vibration was directly supplied from the surface of wood. It was converted to the thermal energy and was propagated in the pallet, then the temperature of the pallet was increased. We found that the temperature distribution clearly showed the shape of the artificially drilled holes. Moreover, when the pallet having the bite mark was flipped and the temperature distribution was measured up to 40°C, the bite mark was found on the distribution. Therefore, it was determined that this system could be very positive as one of the more environmentally friendly pest control methods.

The authors have been developing to produce high intensity airborne ultrasound[1], the levitation is one of the applications[2,3]. The applications are not only for the airbore ultrasound, but also for the applications of vibrational energy in the materials, especially in wood. Fleming et. al[4] used ultrasound at 200 kHz to detect live beetle larvae, but the system didn't obtain good data on that purpose due to the loss of airborne ultrasound energy. In this experiment, a half wavelength step horn was designed at the frequency of 28 kHz and ultrasonic vibration was irradiated in woods. A few amount of ultrasound energy was finally converted to the thermal energy, then the rise in temperature was expected in woods.

PLATE SPECIMEN

Figure 1 shows three types of plate specimen. A is a pallet made of cedar, 30 mm width, 15 mm thick, and 600 mm long, B is a piece of chair in one of imported procesed goods, there are many insect damages on the tail of the board. C is a piece of sliced cedar log having 12mm thich and 85 mm diameter.

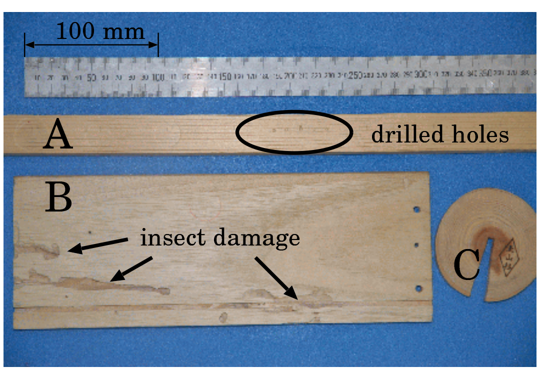

Figure 1: Specimen tested in this experiment.

STEP HORN

Half wavelength resonance step horns, made by Duralumin, were designed in the frequency range between 20 kHz and 40 kHz. Figure 2 shows a sample of 28 kHz step horn driven by a piezoelectric transducers, the vibrational displacement was increased double at the tip of horn. The tip of the horn was set on the surface of wood, the surface of the tip was roughly worked on a lathe, because of increasing the contact force between wood and horn. The vibrational displacement of the tip of horn was obtained up to 2.7 μm at 13 W of electrical input power.

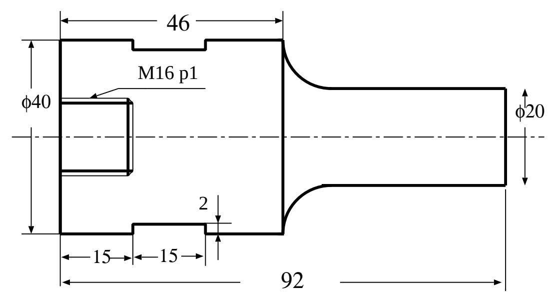

Figure 2: Design of a half wavelength step horn for 28 kHz vibration system.

TEMPERATURE DISTRIBUTION

A pallet of Japanese cedar as shown in Figure 1A was tested. We artificially drilled holes (2 mm diameter) into the pallet and the holes were opened in 3 mm depth from the surface of the pallet. The step horn was connected to the side wall of the pallet and the ultrasound was supplied as shown in Figure 3. The displacement of the tip of horn was measured at 1.9 μm at 4.6 Watts of electric power. The ultrasound was irradiated in 3 minutes and a 10 kg weight was put on the horn to add static pressure while the pallet was tested.

An infrared thermal video system was used to measure the temperature distribution. Radiant thermal energy was converted to the temperature distribution inside the pallet. The thermal energy in 8 to 15 μm was ditected by a microbolometer and minimum thermal resolution was 0.05°C.
Figure 4 shows the visualized temperature distribution. The temperature between 20 to 40°C was converted to the rainbow color as shown as the color table on the left side of the figure. The bottom figure was made by the temperature distribution on the dotted line marked in upper figure. It was found that the ultrasound energy was converted to thermal energy and the temperature of the cedar was increased overall. The rise in

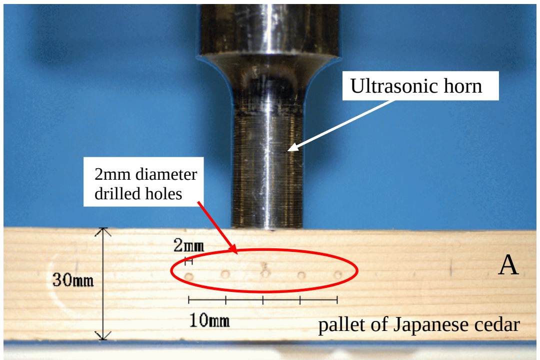

Figure 3: The horn conncted on the side wall.

temperature was especially increased under the tip of horn, the edge of drilled holes was increased about more 4°C while the additional 10 kg of static pressure was put on the pallet.

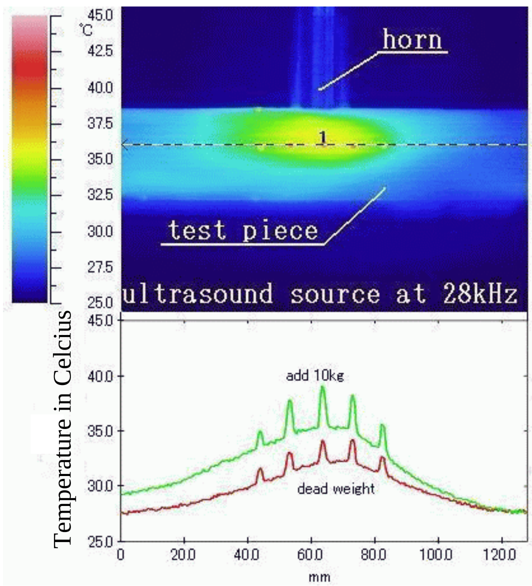

Figure 4: Temperature distribution on the surface of Japanese cedar. Ultrasound was irradiated for 3 minutes. Temperature around the holes got 4°C higher than the surrounding area.

The next specimen had insect damages as shown in Figure 1B. Plate B was reversed and the horn was set at the surface of the plate as shown the top portion in Figure 5. The ultrasound was irradiated for 3 minutes with 10 kg of additional weight and the temperature distribution was measured as shown in Figure 5. The temperature on the cross section was also measured as shown as the side view. The temperature around the insect damage was obtained higher than 10°C, the maximum temperature was measured up to 40°C. It was found that the ultrasound energy in wood was converted to the heat energy, this system could be very positive to use for the pest control without any chemicals.

Right picture in Figure 6 is a sliced cedar log, 12 mm thick and 85 mm diameter, 2 mm drilled holes having 8 mm and 4 mm depth were open. The tip of the horn was located on the surface of the cedar log and the ultrasound was irradiated without any additional weight. It was found that the temperature distribution was affected by coarse or fine-grained, density, hardness, and moisture content, but the temperature around the drilled holes was obtained higher.

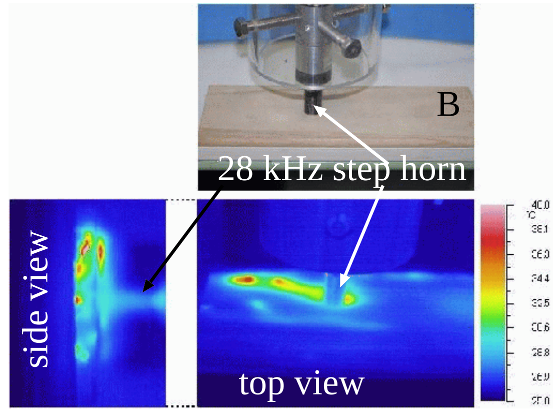

Figure 5: Temperature distribution of cedar board. The insect damage was clearly shown as the higher temperature.

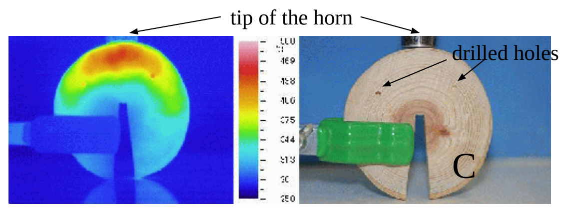

Figure 6: Sliced test piece of small Japanese cedar log having 2mm drilled holes(Right). Temperature distribution after 3 minutes(Left).

CONCLUSIONS

The ultrasound at 28 kHz was irradiated in wood and the temperature distribution was measured by the microbolometer. It was found that the ultrasound energy was converted to the heat energy and the temperature was increased more around the cavity made by the insects. It was also measured that the higher the moisture content, the higher the temperature was increased. This means that is is easy to obtain higher temperature for the use on live trees(data are not shown here).

The temperature inside the wood was measured up to 40°C, most of the larvae might be damaged, this system could be very positive as one of the more environmentally friendy pest control methods.

REFERENCES

[1]T. Otsuka, Y. Kamishima and K. Seya,"Aerial Ultrasound Source by Stepped Circular Vibrating Plate",Japanese Journal of Applied Physics Vol.22(1983) Supp. 22-3,pp.108-110

[2]T. Otsuka, K. Higuchi and K. Seya,"Ultrasonic Levitation by Stepped Circular Vibrating Plate",Japanese Journal of Applied Physics Vol.29(1990) Supp.29-1, pp.170-172

[3]T. Otsuka and T. Nakane,"Ultrasonic Levitation of Liquid Droplet",Japanese Journal of Applied Physics Vol.41(2002) pp.3259-3260 Part 1. No.5B, May 2002

[4]Mary R. Fleming,et al,"Noncontact ultrasound detection of exotic insects in wood packing materials" Forest Products Journal, Jun 2005, 55,6; ABI/INFORM Global pp.33-37