Sample Paper/Template

Title

Author Name
Affiliation
City, State/Province, Country (*if other than USA*)

Co-Author Name
Affiliation
City, State/Province, Country

Abstract

The abstract is the essence of the whole work summarized in the first paragraph of your paper. An abstract should contain **approximately 250 words** describing how and why the work was done, the results and conclusions, and conclude with the significance. The abstract helps many authors begin writing their paper so it is a good place to start. A typical abstract will include one or two sentences of introduction; one sentence stating the objective; one or two sentences about the experiment or work done; one to three sentences about the results; and conclude with one or two sentences. Note that if you use an acronym in the abstract, define it there and once more when used again in the paper; after which, use only the acronym. For example, define the acronym commonly used for oriented strandboard (OSB) as so and only once more as shown in the following paragraph. We would like to thank **Siguo Chen** of the Alberta Research Council for allowing his paper to be used as this sample/template.

Introduction

This paper is a good example of how to write your paper for publication in the Symposium Proceedings. Refer to the **Publication Style Sheet** for more information. Please write a **minimum five-page paper**. In this paper, note how measurement abbreviations are used, and how figures are referenced and literature is cited throughout the paper.

Oriented strandboard (OSB) has the majority of the structural panel market in North America for residential sheathing, and is one of the fastest growing business segments for North American forestry companies. North American OSB production was estimated at 19.2 billion ft.^{2} in 1999. With new mills being built and expansions of existing mills, OSB production is estimated to increase by more than 10 percent to 21 billion ft.^{2} by 2002. This estimate surpasses the APA - The Engineered Wood Association's forecast of 20.4 billion ft.^{2} (Structural Board Association 1999). The technology of OSB manufacturing has significantly improved in the last decade. Major advances have been realized in pressing control, resin technology, and stranding. Variability in density remains a common problem to the OSB manufacturers. Figure 1 shows the density profiles across the width of master panels from four different producers. Density affects most of the physical and mechanical properties of the panel (Suchsland and Woodson 1986). Recent studies at the Alberta Research Council (ARC) have indicated that local density variation of OSB panels influences the ultimate load in a concentrated static load test. Panels with the same average density (640 kg/m^3) have different ultimate load depending on the local density around the test point (Fig. 2). Reduction in density variation will result in improved quality and reduced costs by lowering the average panel density.

Effective and efficient density measurement is key to reducing density variability. Destructive density measurements of OSB panels are slow and expensive in terms of labor cost. Non-destructive density measurement equipment such as X-ray and γ-ray are also expensive and difficult to maintain. This paper describes a Far Infrared (IR) Panel Density Measurement System that is designed for on-line measurement of OSB density variability. The IR camera can be mounted at a convenient location in the mill to measure 100 percent of the density of the production on-line.

Operation Principle

The fact that IR radiation is a function of object surface temperature makes it possible for an IR camera to calculate and display this temperature. The propagation of heat through the thickness of a composite panel is rapid enough that surface temperature quickly reflects volume properties. If a panel contains an anomaly in its density, and the panel starts at an initial uniform temperature, then as it is quickly heated or cooled, the anomaly will produce an irregularity in the distribution of surface temperature. This cause and effect is because during the course of temperature change, lower density areas of the panel will lose or gain heat more rapidly while higher density areas lose or gain heat more slowly. The rate of temperature change depends on the thermal storage capacity that is a function of density, and is the basic theoretical principle on which IR OSB density measurement is based.

When an OSB panel comes out of the hot press, it commonly has an initial uniform temperature. If the platens have a non-uniform temperature pattern and the pattern is consistent, by measuring a large number of the panels coming out of the platens, the background temperature distribution can be determined for calibration of the panel temperature. IR thermography would see warm spots indicating the higher density areas and cool spots indicating lower density areas, which provides a fast, inexpensive method to measure OSB density

Pilot Plant Experiment

A Far IR imaging system was installed at ARC's Forest Products Pilot Plant to image hot panels. The experiment included three stages. The first stage was a preliminary test using an oven to heat panels to a uniform temperature before imaging. In the second stage, efforts were made to fabricate panels with known density patterns and image the hot panels after they came out of the press. In the third stage, commercial 4- by 8-ft. OSB panels of different thickness was put into the hot press to heat to a uniform temperature before IR imaging. Destructive measurement was followed at stages two and three to verify the IR measurement.

First Subheading is left aligned and in **bold**.

Second Subheading is indented and in *Italics.*

Several 4- by 4-ft. panels of relatively uniform density had patterns of thickness variation cut into their surfaces. These panels were heated in the oven until reaching an equilibrium temperature, then were removed, and allowed time to cool. As they cooled, a sequence of Far IR images of the panels were taken and the data digitized with 12 bits of resolution in images approximately 400 pixels per inch (PPI).

IR images were taken during both the cooling and heating processes. Panels at room temperature (approximately 20°C) were placed in front of the open oven doors, and heat impulses from the oven were allowed to propagate through the internal structure of the panels. This approach resulted in clearer images if the oven-panel-camera system could be set up properly to allow for a uniform heating of the panel.

Those procedures quickly showed that an effect was present, but only if the variations in the panel thickness were of significant size (approximately 1- to 2-in. in diameter and 20 % density in thickness or greater).

Stage 2: Panel Fabrication

Two OSB panels measuring 4- by 8-ft. by 7/16-in. with a target density of 640 kg/m^3 were manufactured using Aspen strands. The platen temperature was 405°F (207°C). After exiting the press, the panel was placed horizontally on top of insulating cardboard on the floor just beyond the press area. The panel was continuously monitored for 15 to 20 minutes using the Far IR camera that was installed approximately 5 meters above the floor looking downward at approximately 60°. Images were taken every 45 to 60 seconds.

Low- and high-density anomalies were attempted in the fabrication. In the first panel, larger structural defects were created at the core layer. Low-density holes (4- to 5-in. in diameter) and strips (approximately 4-in. width, 24-in. length) were clearly detected by the IR imaging system.

In the second panel, smaller scale, density variation spots were created. When strands were deposited to 2/3-total mass of the mat, eight columns of high and low density spots were made. Each column had four spots of different sizes ranging from 1- to 4-in. in diameter. The spots were 1-ft. apart in both panel length and panel width directions. A certain percentage of strands from one column of spots were taken and added to the column next to it, thus creating alternated high and low density spots. The percent of strands taken and added were intended to vary from approximately 10 to 40 percent density by weight. Caution was taken to minimize disturbance to the rest of the mat. Although attempts were made to create both high- and low-density spots, only the low-density spots were successfully created. Neither the IR images nor the destructive measurement clearly showed the high-density spots as expected. This result is probably because, when depositing the other one-third of the strands, a large portion of them falling on top of the high spots was scattered.

The primary heat loss is not only through the upper surface of the panel conducting heat into the air. The edges lose heat faster than the center of the panel resulting in cooler edges that do not indicate lower density. Likewise, the center of the panel is usually hot, which does not indicate higher density. Edge cooling needs to be modeled to get an accurate estimate of density. However, the created low-density areas can be clearly identified by the IR sensed temperature map even without an edge correction (Fig. 3). The panel reached these temperatures about 5 minutes after it came out of the press.

After IR imaging, the second fabricated 4- by 8-ft. panel was cut into 2- by 2-in. specimens to obtain the actual density map (Fig. 4). By qualitatively comparing the temperature map with the density map, it is immediately evident that the IR image system picked up most of the fabricated low-density spots very well. The sizes and locations of these spots are clearly indicated by low temperature areas on the IR temperature map.

Stage 3: Re-heating Commercial Panels

Three commercial 4- by 8-ft. OSB panels with different thicknesses were put into the hot press for 5 to 7 minutes. The same imaging procedure used in Stage 2 was applied in this stage. IR images were color-enhanced and projected onto the respective OSB panels. The IR predicted areas of different densities, which were represented by different colors sketched on the panel and cut out with a jigsaw. Circular sub-samples of 1.5-in. and 2.5-in. in diameter were taken from the central part of the jigsaw-cut specimens for density measurement. The correlation between the measured density and the IR estimated temperature is shown in Figure 5.

Mill Trial

The IR system has been installed and tested in several OSB mills. There are factors, which influence the IR density measurement in a mill, including non-uniform cooling, space constraints, movement of panels, and non-uniform platen temperature.

In addition to the edge cooling effect encountered at the pilot plant setting, the non-uniform cooling mechanism in the mill adds to the complexity. Hot panels are unloaded from the press and stay in the cooling rack before they are conveyed to the finishing line for trimming and cutting. The leading edge of the panel stays away from the press and cools down faster than the back part of the panel. When conveyed to the finishing line, the leading edge encounters the cooler air all the way to the camera, which increases the convection and results in an even cooler leading edge. Edge cooling modeling is therefore a very important aspect of the on-line IR density measurement of OSB. Figure 6 is an IR image of a master panel taken at an OSB mill on-line, showing a typical pattern of edge cooling.

Depending on the mill situation, there are often space constraints preventing the camera from being installed at an ideal location relative to the press and the panel. If the camera is too close to the press, the convection will still be a dominant term of heat loss, and there will not be enough time for the panel to reach thermal-equilibrium. The IR image of a master panel is combined from several smaller images. Each one covers a section of the panel along the length and the entire width. The camera has to be high enough above the panel to oversee the entire width of the master panel. If such a height were not accessible, then the camera would have to be inclined at a flatter angle, which decreases the quality of the IR image. A comparison of IR images taken at ARC using different camera angles shows the negative effect of a reduced angle (Fig. 7).

IR images are normally taken while the panel is traveling on the conveyor belt. The moving panel causes a blurred IR image, which decreases the accuracy of the density measurement. Owing to various reasons, sometimes the platen temperature is not uniform, thus providing incorrect information for the determination of the panel density variation.

Measures have been taken to deal with these difficulties and progress is being made. Figure 8 shows the raw IR image taken on-line, the edge-corrected IR image, and the X-ray image of a master panel. The edge-corrected IR image reasonably resembles the X-ray image except for the leading edge (top of the image). Two lower density stripes located at the lower part of the panel, appearing lighter on the images, are clearly presented on the IR images.

Subdividing the images into 6- by 6-in. cells, and scaling the IR image to the X-ray image, relative densities of cells were obtained. For the bottom section (5/6 of panel), the cell-to-cell correlation of IR and X-ray measurements is good, with an R^2 of 0.42 (Fig. 9). For the top section (1/6 of panel), however, IR and X-ray measurements are not well correlated. The leading edge cooling remains a problem. The ARC is currently working on thermodynamic modeling of edge cooling and adjusting the dynamic range of the IR camera to improve the accuracy of IR measurement.

Summary and Conclusions

Density variability is a common problem to OSB manufacturers. Effective and efficient measurement is key to reducing density variability. The feasibility of using IR thermograph technologies to measure OSB density has been demonstrated in this paper. Research has proven that the IR system developed by ARC and VisionSmart Inc. functions satisfactorily in pilot plant settings. Continuously monitoring the OSB density variability at OSB mills remains a challenge. Non-uniform edge cooling modeling proved to be most difficult. Although the accuracy of density modeling needs to be improved, mill trials have been promising. Currently, the system accurately detects five density variations based on a 6- by 6-in. sample size. Improvements are still being made to the system to improve the accuracy.

Acknowledgements

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