

Effects of press sizes on internal steam pressure during particleboard hot-pressing process

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Abstract

Internal steam pressure produced during the hot-pressing cycle in particleboard production is critical to the newly developed bond strength that will determine the overall performance of particleboard. The difference between the accumulation of internal steam pressure for small panels made in the laboratory and that of large commercial-sized panels makes it difficult to transfer knowledge gained from the laboratory to the commercial plant. The objective of this research project is 2-fold: first, to investigate the effect of panel size on the initial development and subsequent dissipation of internal steam pressure during the hot-pressing cycle; and second, to learn how to improve of small laboratory presses to better mimic conditions experienced in the large press used in the manufacturing plant. In this study, changes in the panel size from 56 by 56 cm to 86 by 86 cm resulted in changes in the maximum steam pressure of up to 3.5-fold. A collar made from a steel rod was used, which prevented steam from escaping and helped to build higher internal steam pressure in smaller panels. Finally, the effects of a “burp” (briefly opening the press during the press cycle) or use of a forming screen were also studied in relation to internal steam pressure.

Hot pressing is the single most critical process step for determining the overall performance of particleboard. A number of parameters affect hot pressing, including press temperature, mat moisture content (MC), press closing speed, and resin characteristics (Maku et al. 1959, Kelly 1977, Hawke et al. 1992, Lee and Maloney 1995, Park et al. 1999). During hot pressing, heat initially transfers by conduction from the hot platens to the outer layers of the furnish mat, where it continues to migrate toward the core. As temperature in the outer layers of the mat exceeds 100°C, heat begins to vaporize water. As more water in the mat is converted to steam, the steam pressure begins to build. Elevated steam pressure pushes heat and moisture into the core of the mat, which causes further heating of the wood furnish in the core. This conductive and convective heat energy raises the temperature of the mat, plasticizes the wood furnish, and cures the resin binder. Internal steam pressure (ISP) increases the rate of heat transfer into the core of the mat, which is critical to mat consolidation, formation of density profile, and overall press-cycle time. High steam pressure inside the mat, however, could be detrimental to the newly established internal bond. If ISP is greater than internal bonding strength, the panel could blow when the press is opened.

Steam pressure is a function of numerous process variables, such as press temperature, mat MC, press closing speed, and

resin characteristics (Kelly 1977 Suchsland and Woodson 1986). Many individual studies have been conducted to investigate the effect of process variables on the buildup of steam pressure inside the panel, and several theoretical models have been developed to simulate the pressure-increasing process (Humphrey and Bolton 1989, Kamke and Wolcott 1991, Length and Kamke 1996, Dai and Wang 2004, Frazier 2004). Although the theoretical models provide a better understanding of the hot-pressing process, few (if any) have been fully validated and applied to the manufacturing process (Cai et al. 2006). One reason is lack of available research facilities with the capacity to simulate industrial practice (Hague et al. 1999).

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During the hot-pressing cycle, ISP within the board will continue to rise as long as the rate of moisture vaporization exceeds the rate of pressure dissipation through the edges of the board. Two moisture gradients exist in a particleboard mat during the hot-press cycle: one of increasing MC from the hot surfaces to the core and another of decreasing MC from the middle of the mat to the edge (Strickler 1959). Steam pressure and the rate of steam escaping from edges depends on many factors of the mat, such as porosity, resin type, closing speed, density, and MC. As panel size increases, the ratio of the volume to the edge area increases, resulting in more water being added to the system as well as less relative area from which the vaporized water can escape. In addition, the longer pathway from the middle to the edges of the board creates more resistance to the movement of steam. Thus, permeation for internal steam escaping from the center is decreased, which helps to build high ISP. All of these factors are very important to the performance of particleboard, and many of them have been thoroughly investigated. Unfortunately, the results of steam pressure and MC distributions from different researchers are difficult to compare because of different particle configurations, mat density, MC, and panel size (Kelly 1977).

Since particleboard was developed about 60 years ago, laboratory research has played an important role in understanding and improving the manufacturing process. Two significant laboratory studies have reported the effect of steam pressure and heat transfer on the performance of particleboard (Kelly 1977, Kamke 2004). Nonetheless, there are significant differences between the small scale of a research laboratory and the large scale of a commercial plant, which makes it difficult to transfer knowledge gained from the laboratory to the plant. The objective of this research was to investigate the effect of increasing panel size on ISP during hot pressing.

Materials

Particleboard furnish was provided by Columbia Forest Products (Portland, Oregon) and consisted of a mix of approximately 80 percent black spruce, 12 percent poplar, and 8 percent jack pine. The furnish was dried to 3.0 percent \pm 0.2 percent MC for all of the experiments. The resin used was an experimental soy-based phenolic adhesive provided by Heartland Resource Technologies (Pasadena, California). The bonding performance of this low formaldehyde emission soy-based resin is practically similar to the urea-formaldehyde resin. Based on the previous study, resin was applied to the face furnish at a rate of 10.0 percent (solid resin to dry wood) using an atomizing sprayer with a 0.71-mm (0.028-in.) orifice with 137.9 kPa (20 psi) for resin feeding and 275.8 kPa (40 psi) for atomization inside a 1.2-m (48-in.-) diameter drum blender. Resin was applied to the core furnish at a rate of 7.0 percent (solid resin to dry wood) using a Model V-1401 Hobart mixer (Hobart, Troy, Ohio). Mat MC of the resin-applied face and core were 15.4 percent and 12.3 percent, respectively.

The particleboard consisted of a face:core ratio of 37:63 and a target density of 668.7 kg/m³ (41.75 pcf). The boards were pressed to a target thickness of 19.1 mm (0.75 in.) and the primary variable was mat size of 56 by 56 cm, 86 by 86 cm, and 116 by 116 cm. Boards with dimensions of 56 by 56 cm and 86 by 86 cm were made on a 91- by 91-cm oil-heated press and compared with other boards with dimensions of 56

by 56 cm, 86 by 86 cm, and 116 by 116 cm pressed on a 122- by 122-cm steam-heated press. The press temperature was 170°C and press time was 180 seconds after reaching final thickness. A temperature and steam pressure probe (Press-Man Probe with serial number of 3031 from Alberta Research Council, Edmonton, Alberta, Canada) was placed in the center of each board before pressing to record temperature and internal gas pressure during the press cycle. Two other variables were also studied: use of a steel collar to inhibit internal steam dissipation through the mat edge and use of forming screens to increase steam dissipation through the faces and eventually away from mat. Several boards were pressed with a 0.95-cm (0.375-in.) round steel collar that was inserted in the mat approximately 1.3 cm (0.5 in.) from the edge. A forming screen donated by a commercial oriented strandboard (OSB) producer was also used for a number of the board samples. This screen was steel-wire woven mesh, which was typically used to convey OSB mats. It was about 2.0 mm thick and weighed about 13.5 kg/m². Two replicate boards were made for each run and their internal steam pressures were recorded. Because the two internal pressure curves displayed on the computer screen were very similar, no analysis of variance was attempted in this study.

Results and discussion

Effect of panel size

To examine the effect of panel size on ISP, 56- by 56-cm panels were made, and their internal steam curves were compared with one of the larger size panels of 86 by 86 cm. **Figure 1** shows that the maximum ISP of the larger panel is about 73 kPa, whereas the smaller panel is only 21 kPa. The geometry of the larger size panel results in greater distance and, therefore, more resistance to steam escaping, thus showing higher buildup of steam pressure. The high ISP could lead to blows if upon opening the press, the ISP exceeds the internal bond strength of the panel (Kelly 1977, Cai et al. 2006). The large difference in the maximum ISP between the two panels also suggests that mechanical and physical performance of the two panels could be very different (Kelly 1977, Dai and Wang 2004). This observation is important, especially when researchers try to evaluate product performance under various treatments (e.g., new resin or other chemicals) using the laboratory press. Selecting the proper panel size in the laboratory can determine whether the experimental results are indicative of results expected in an industrial setting. This simple test also indicates that relatively small

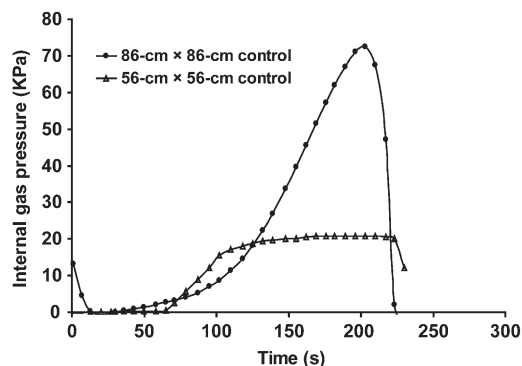


Figure 1. — Internal steam pressure of two different panels on oil-heated 91- by 91-cm press. Cycle time was 180 seconds.

changes in the panel size (from 56 by 56 cm to 86 by 86 cm) result in an approximately 3.5-fold increase in the maximum ISP. Given the observation that 86 by 86 cm is still significantly smaller than any commercial panels (which are typically 132 cm wide and of various lengths), the impact of panel size on ISP raises the question of how much additional pressure would be expected in a commercial-sized panel.

Figure 2 shows ISP for three different sizes of panels: 56 by 56 cm, 86 by 86 cm, and 116 by 116 cm. Panels were made on a 122- by 122-cm (4- by 4-ft) steam-heated press. Press temperature was set the same as the previous press, but the press cycle time was 120 seconds longer to ensure that the resin was fully cured. The result in **Figure 2** shows that the maximum ISP of the 86- by 86-cm panel is about 80 kPa and the maximum of the 56- by 56-cm panel is around 21 kPa. This is similar to the results from the oil-heated press. Maximum ISP of the 116- by 116-cm panel, however, was about 93 kPa, which increased only about 16 percent compared with the 86- by 86-cm panel. This illustrates that the effect of panel size on maximum ISP is not linear.

For larger particleboard panels, the greater distance from the middle of the panel to the edge makes the particleboard mat less permeable and prevents steam from escaping as quickly as it would in a smaller panel. This causes buildup of steam pressure in the early stages of the press cycle. But, as the press cycle time increases, more steam will be generated inside the mat. The increased ISP will force the steam to escape through voids between particles and ultimately from the edges of the panel. When other process parameters (e.g., density, MC, and particle geometry) are the same, panel size will determine the permeability and porosity of the particleboard mat, which will subsequently affect the rate at which steam can escape. **Figure 3** shows the maximum ISP for three different sizes of particleboards. Although **Figure 3** shows only three data points, maximum ISP seems to have a logarithm relationship with the size of boards. The relationship indicates that maximum ISP increases at a decreasing rate as particleboard size increases.

Collar effect

The most widely used press in our laboratory is a 91- by 91-cm (36- by 36-in.) oil-heated press. The size of most laboratory-made panels is between 56 by 56 cm and 86 by 86 cm. Unfortunately, the maximum ISP varies enormously between these panel sizes (**Fig. 1**). In order to mimic the high ISP seen with a larger panel, a collar was used to “seal”

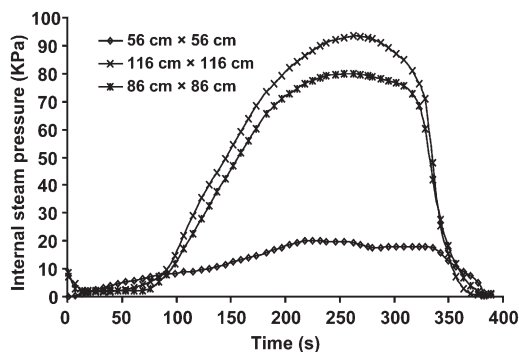


Figure 2. — Internal steam pressure of three different panels on steam-heated 122- by 122-cm press. Cycle time was 400 seconds.

the edges and reduce the area from which steam can escape. The collar was constructed of a 0.95-cm (0.375-in.) steel rod in a 89.7- by 89.7-cm square, which was about 1.3 cm (0.5 in.) smaller than the particleboard mat. The collar was then placed on the top surface of the formed particleboard mat before placing it into the press. As the press closed, the collar squeezed the particles underneath to densify mat edges and reduce mat permeability. High-density edges greatly reduced edge permeability, thus increasing maximum ISP (**Fig. 4**). ISP also built up much more rapidly when using the collar.

Maximum ISP depends on many processing parameters, but this study focused mainly on panel size. It appeared that the collar entrapped more steam in the large 86- by 86-cm panel than it did in the 56- by 56-cm panel, and this greatly increased the maximum ISP. By extrapolating **Figure 3**, the maximum ISP for a commercial-size panel 244 by 244 cm would be about 120 kPa under similar processing conditions. Using the collar in the laboratory could result in a maximum ISP similar to a commercial-size panel. Furthermore, this study suggests that steam accumulation and maximum ISP in the laboratory could duplicate those in the industrial mill simply by selecting the right panel size and collar thickness. **Figure 4** shows that the maximum ISP obtained using the collar on the 86- by 86-cm panel is about 125 kPa (similar to the ISP extrapolated for commercial plants).

Burp effect

MC of the resinated mat prior to hot-pressing is sometimes high because of the application of low solid-content resin or insufficient drying time. The high MC will generate more

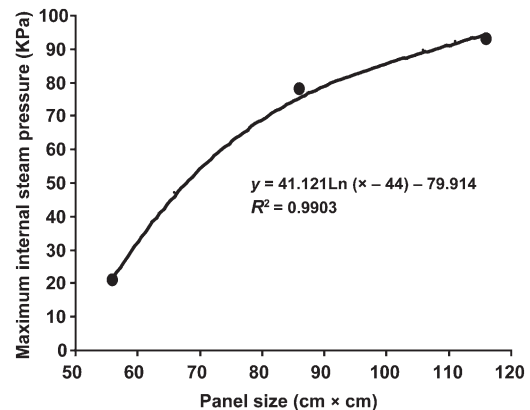


Figure 3. — Maximum internal steam pressure for three different sizes of particleboard.

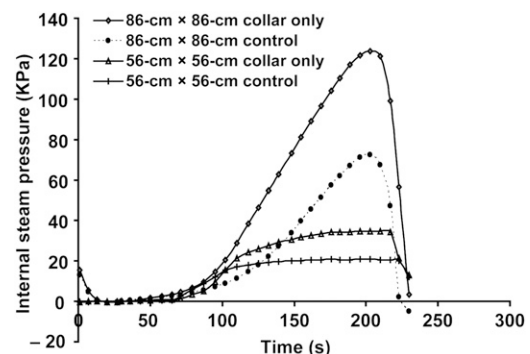


Figure 4. — Effect of a collar on the internal steam pressure.

steam inside the mat, resulting in higher ISP during the press cycle and potential damage to the board upon opening the press. The use of a burp (a slight opening of the press in addition to the target thickness to relieve steam pressure) is a commonly used technique to reduce the maximum ISP. The literature reveals little discussion of the effectiveness of this type of strategy in composite panel production.

There are two parameters in the burp step: the distance (over the nominal thickness) that the press is opened, and the duration it is kept open. The burp step was initiated about 100 seconds after the press reached the target thickness when the ISP builds up considerably. **Figure 5** shows the effect of the burp duration on ISP with the press opening from 19 mm (which is the nominal thickness) to 20 mm when making 56- by 56-cm panels. The longer duration of the burp will delay the time it takes for ISP to reach its maximum value. Burp duration, however, did not appear to be effective for reducing maximum ISP. **Figure 6** shows the significant effect of the burp-opening distance on internal steam pressure with the press duration of 30 seconds for laboratory-size 56- by 56-cm panels. The more the press opens (i.e., from 19 mm to 23 mm), the more steam escapes from the panel. Opening the press 4 mm from the target thickness allows a significant amount of steam to be released and greatly affects maximum ISP. **Figure 7** shows a similar observation for an 86- by 86-cm panel.

Screen effect

Wire screen is a commonly used conveying system in the manufacture of particleboard. In some commercial particle-

board mills, the screen transports the mat into the press and is subsequently pressed with the mat. **Figure 8** shows the effect that a screen can have on ISP. Maximum ISP decreases from 73 kPa for the control board (without screen) to 44 kPa for the board formed on a screen. Reduction (40%) in maximum ISP may not be as much as expected, however. For the control mat, high ISP forces saturated steam to flow along the center line to the mat edges. The screen with a great number of small openings provides another exit route for the steam under the mat during pressing. It allows the steam to evaporate from the bottom surface through the screen. Steam escaping through the screen is limited by the densified panel surface. The densified surface is still able to trap much of the steam and build up high ISP.

Edges of the mat are the only passageway for releasing steam built up inside the control mat (without screen). Use of a collar during the press cycle could significantly reduce steam escaping from the edges and thus increase maximum ISP (**Fig. 4**). The screen underneath the mat provides another channel to release internal steam. **Figure 8** shows the effect of the screen and collar on ISPs. With the collar alone, ISP builds to a maximum of 125 kPa. With the collar and the screen together, ISP only reaches a maximum of 42 kPa. Comparing ISP in processes that used both the collar and screen to the one using the screen only, showed that the ISP curves are similar (**Fig. 8**). Although the collar densifies the mat on its edges to resist steam escaping, the screen creates a path of least resistance and prevents ISP from building. The use of a screen is a highly

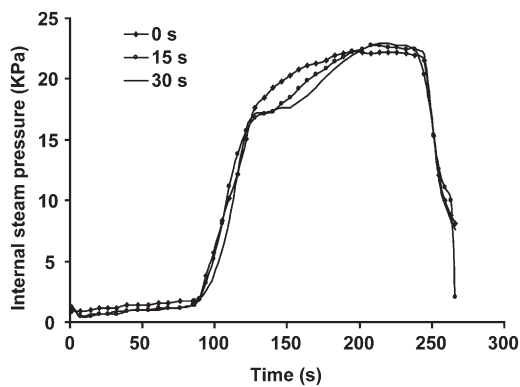


Figure 5. — Effect of burp duration on the internal steam pressure for 56- by 56-cm panel.

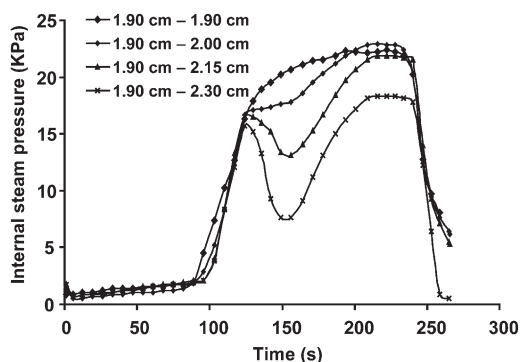


Figure 6. — Effect of burp opening position on the internal steam pressure for 56- by 56-cm panel.

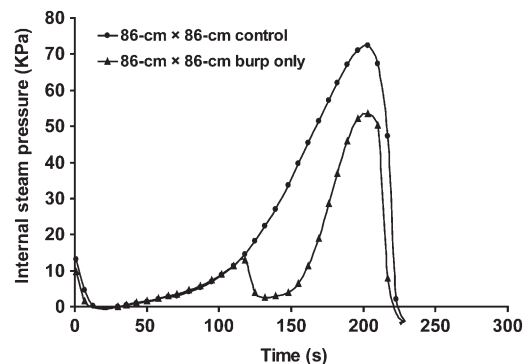


Figure 7. — Effect of burp-opening position on the internal steam pressure for 86- by 86-cm panel.

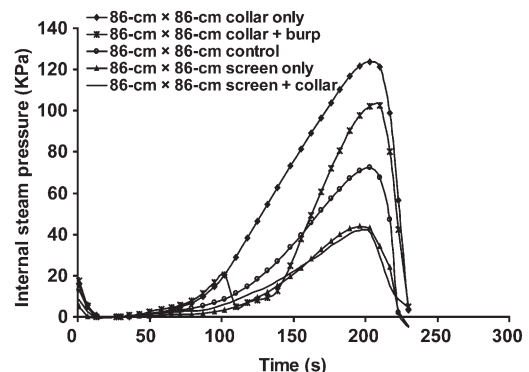


Figure 8. — Effect of the screen on the internal steam pressure for 86- by 86-cm panel.

effective way to release ISP during the hot-pressing of particleboard.

Summary and conclusions

In this study, ISP was studied in relation to panel size, use of a collar and screen, and inclusion of a burp during the press cycle. Panel size was found to have a significant impact on maximum ISP. Changes in panel size from 56 by 56 cm to 86 by 86 cm resulted in a 3.5-fold change in maximum ISP. The collar also tended to increase ISP. Using a collar to make laboratory panels could increase maximum ISP to a level found in full-size production panels. Briefly opening the press after the internal temperature reached 100°C (called a burp) was shown to release a significant amount of steam during the press cycle. Use of a forming screen, a commonly used conveyer belt in the particleboard manufacturing facility, was also shown to be an effective and predominant way to release ISP during hot-pressing of an 86- by 86-cm particleboard mat. Use of a forming screen might reduce the problems connected with high-MC particleboard because these processes apply low solid-content resin or reduce drying time. The effectiveness of the screen on internal steam accumulation for a large-size panel (i.e., commercial size panel) needs to be further investigated.

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