STEAM HAS POTENTIAL TO REDUCE THICKNESS SWELL BUT OBSTACLES MUST BE OVERCOME

So for, steam application at the press has been fairly limited in the board industry.

The age-old art of bending wood is a topic the Forest Products Laboratory (FPL) is frequently asked about. Although no longer actively researched, the Knowledge developed 60 years ago remains valid and serves as a basis for more recent research on dimensional stability of composites.

Wood is stiff, so to bend it without breaking, it needs to be softened. The most practical approach to that is to apply heat and moisture. The optimum MC range for severe bends lies between 15 20%, while the recommended heat treatment is boiling water or saturated steam at atmospheric pressure (i.e. 100° C) for 1.2 minutes per mm of thickness. This relaxes bending stresses so that when bent and dried, wood retains its new shape.

Like lumber, when particles. strands or flakes are pressed. they are deformed and bent. In pressing of composites there is plenty of heat but little moisture. For most OSB operations. mat moistures range from 4-8%, below the optimal 15-20% for lumber. Stresses that develop when such a mat is densified are released either when the pressure is removed resulting in springback, or when moisture changes occur, resulting in dimensional instability.

Wood consists primarily of lignin and cellulose. Lignin serves as the glue that binds the cellulose matrix together. To permanently bend wood, this glue has to be softened and then rehardened in the new shape. Like water that changes from solid to liquid, lignin changes from a hard, crystalline state to a softer, rubbery

Figure 1. Glass transition temperature of lignin as function of moisture content

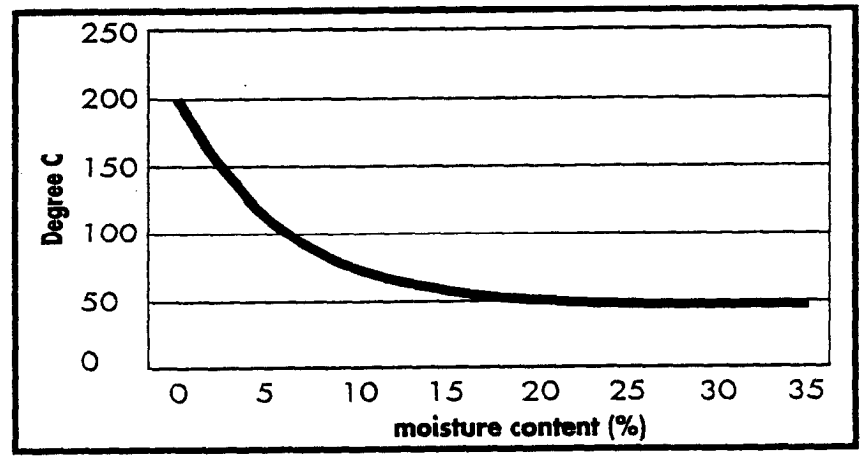
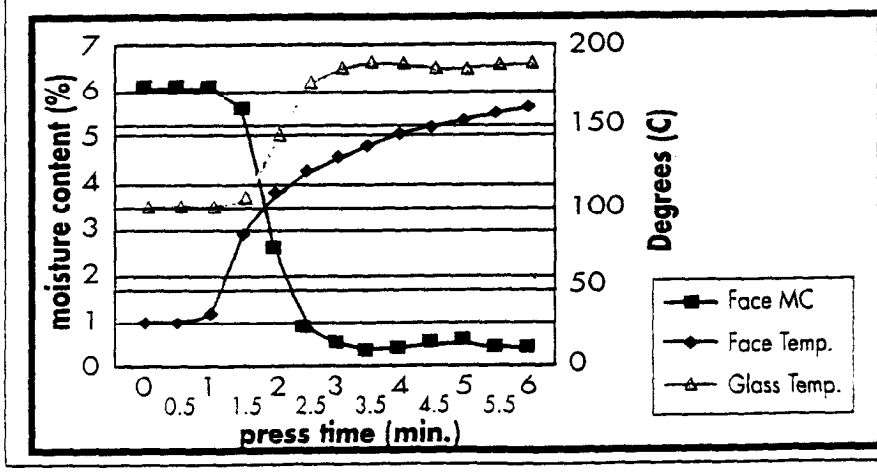


Figure 2. Mat temperature, moisture content and glass transition temperature of lignin



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condition over a range of temperatures. These "glass transition" temperatures are considerably reduced with the addition of moisture, as shown in Figure 1.

Suppose now that we had sensors that could track key changes within a hot-pressed mat, With moisture content of 6%, a press at 190° C would seem at first glance to be enough to obtain temperatures above the glass transition temperature for lignin at that MC. After the press closes, the temperature near the face does indeed rise (Figure 2, right scale). But, much to our consternation, the target also begins to move. As moisture vaporizes and migrates toward the core, the MC in the face region drops (Figure 2, left scale). This raises the glass transition temperature such that it stays above mat temperatures during the critical period when pressure from press closure is greatest. This means that, for the most part, the wood is compressed in lignin's crystalline rather than plasticized state. When the pressure is released, the squashed cells tend to regain some of their former shape. Further irreversible swelling occurs when wetting induces more recovery.

Studies by researchers Frederick Kamke and Michael Wolcott indicated that mat moistures of about 15% are needed for the glass transition temperatures to be surpassed under similar circumstances. But that leads **to** impractically long press times in order to allow steam to dissipate, hence such MCs are not **used.**

Figure 3. Press schedule for mats exposed to 1,500 kPa of steam for 40 seconds

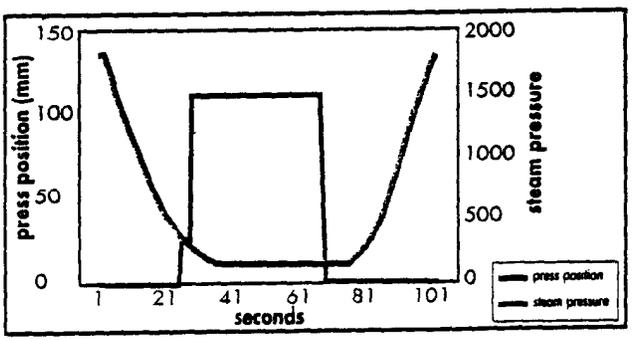

Table 1. Thickness swell in boards treated with steam at various pressures and exposures (a) out of press and (b) after vacuum pressure soaking and redrying (mm).

	Pressure (kPa)	Temp. (C)	Time (sec) 0	5	10	20	40	80
			(swell in millimeters)					
a)	1050	190	1.4	—	0.9	1.2	1.4	1.2
	1500	205	1.3	1.7	0.7	0.7	0.7	—
	1950	220	1.1	0.6	0.0	0.4	0.3	—
b)	1050	190	2.0	—	1.9	1.0	0.9	0.7
	1500	205	2.0	2.0	1.5	1.0	0.4	—
	1950	220	2.1	2.2	1.6	0.4	-0.1	—

It is in this light that studies on steam pressing by Robert Geimer, recently retired FPL wood technologist, provide insights into dealing with thickness swell in wood composites. As in wood bending, steam can be applied to soften wood mats during the period when pressures on them are greatest. Steam injection takes advantage of composites' porosity to almost instantaneously raise temperatures to the curing point of resin, shortening press times. But extended steaming also elevates moistures so that glass transition temperatures stay within reach of typical mat temperatures. Hence the possibility for plasticizing wood is greater.

Tests that demonstrate this point were conducted along the lines illustrated in Figure 3, which shows the press position during a 105 second cycle, and the timing and intensity of steaming. The variables were length of steaming and press times at maximum closure. In all trials, steam was applied eight seconds prior to press closure and ceased eight seconds prior to decompression. Thus the duration of steaming and press closure were always the same. Total press cycles varied between 80 and 230 seconds, depending on length of steaming. For reference, a set of boards was pressed conventionally for five minutes. The results for a subset of the studies, showing initial thickness gain relative to the target thickness of 11 mm (springback), and additional swelling after soaking and redrying, are contained in Table 1.

These data reflect the potential of steam to reduce thickness swell in wood composites. It is noteworthy that good results require steam pressure to be sustained into the period when the mat is compacted to the maximum. As compared to no treatment, out of press springback is reduced in proportion to the steam pressure: the higher the pressure, the lower the springback. Similarly, increasing steam pressures reduce swelling due to a vacuum-pressure-soak and redry treatment, but duration of steaming also has a significant effect and together they almost eliminate it.

This is the major benefit of steam treatment, but there are also disadvantages that may account for its limited application. According to Doug Miller of Siempelkamp, there are merely seven commercial steam presses worldwide (Table 2).

One difference associated with steam injection is that the rapid temperature rise and the resulting wood plasticization result in a flat density profile. This lowers bending properties that the in-

Table 2. Commercial steam-injection press locations worldwide.

Country	Company	Product	Supplier
New Zealand	Juken Nisho (Triboard)	MDF/OSB	Siempelkamp
Portugal	Madiberia	MDF	Siempelkamp
U. S.	Weyerhaeuser	Particleboard	Siempelkamp
U. S.	Pan Pacific	MDF	Siempelkamp
U. S.	Trus Joist/MacMillan	Strand lumber	Siempelkamp
U. S.	Trus Joist/MacMillan	Strand lumber	Siempelkamp
U. S.	CanFibre	MDF	Dieffenbacher

creased panel density, due to reduced springback, only partially offsets.

Another concerns the use of phenolic resins. Geimer's results were good with urea formaldehyde and isocyanate, but inconsistent with phenol. The increase in moisture associated with steam plasticized the cured resin also, resulting in blows when the press opened, or in panel strength reductions.

A third relates to the conditions of high moisture and their potential to extend press times in order to avoid blows. However, it is possible to reverse the process and pull a vacuum, allowing venting without having to relax platen pressure, risking damage to the newly formed bonds.

Finally, steam injection is costly and complex. Extending the capability to multi-opening presses poses difficulties in maintaining even flow rates and pressures throughout the assembly. The technology to date has allowed for single-opening presses only, which limits capacity if the goal is the production of thinner commodity panels.

Alternatives to direct injection of steam include the so-called "dampfstossverfahren" or steam shock procedure. Thin machine-cut face flakes with about 20% MC are used in combination with a core of nearly dry but stocky particles. These conditions are most applicable to traditional particleboard. The vaporized moisture in the faces rapidly migrates to and heats up the core, but the porosity allows this to dissipate quickly. I have not seen thickness swell results from this procedure, but, based on the Geimer results, it is doubtful that it is as effective in reducing dimensional instability as direct steaming. OSB production entails a milder variant in which the MC of the faces is generally two to three percentage points higher than the core.

Preheating the mat with steam ahead of a continuous press is another option that has become available. Improved stability is reported for this technique also.

Thickness swelling is a recognized weakness of wood composites. Besides inconveniencing users, who have to sand or apply filler to smooth surfaces, it induces strength loss by popping some of the glue bonds. Dimensional stability of OSB is considered important enough by members of the Structural Board Assn. that they voluntarily participate in yearly tests to monitor the performance of their panels, but at this time the results, which are preliminary, are being withheld. Independent studies published by researchers over the years, however, have generally shown that commodity grade OSB swells two to three times as much as plywood. Given the growth of OSB, it can be inferred that for many applications the lower performance is not critical. Where higher performance is required, such as siding, the usual recourse is to increase the resin content, from the normal 2-3% range to 54%. For such applications, steaming may offer another, perhaps more economical, means of dealing with the problem. PW