Press-drying plantation loblolly pine lumber to reduce warp losses: economic sensitivity analysis

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Abstract

Several studies have suggested that press-drying, as an alternative to high-temperature kiln-drying, is effective in reducing warp and grade loss from warp in dimension lumber cut from plantation-grown loblolly pine trees. Using estimates developed in these studies for press-drying time and potential warp reduction, an engineering economic analysis of press-drying was conducted. The analysis showed the sensitivity of the maximum allowable cost of a press to a) current level of warp loss; b) reduction in warp loss by press-drying c) press-drying time; d) cost of degrade; and e) increase in green target thickness required to accommodate thickness loss caused by platen pressure.

In previous studies (5,6), warp of plantation-grown loblolly pine, nominal 2- by 4-inch (standard 38- by 89-mm) lumber, which contains a high percentage of juvenile wood, was compared after high-temperature kiln-drying and press-drying. Crook and bow, and resultant grade loss, were less in the press-dried boards. The comparisons between press- and kiln-drying are shown in Table 1 (6). There are still technical uncertainties about the effectiveness of press-drying in reducing warp, and more research is recommended (6). However, in addition to more research, It seems worthwhile to analyze some of the economics of press-drying. The objective of this report is to present estimates of the sensitivity of the economics of press-drying to some of the variables involved.

Engineering economic analysis

An engineering economic analysis of press-drying was conducted in terms of the sensitivity of the maximum allowable cost of a press to several production variables.

Methodology

Using the estimates developed for press-drying time and potential warp reduction, the sensitivity of the economics of press-drying to these variables can be approximated. We employed an internal rate of return (IRR) method (2,3) and present the results in terms of the maximum capital investment justifiable for a hot-press. The general relationship used was:

$$-C_i + \frac{S((1+i)^n - 1)}{i(1+i)^n} + \frac{S'}{(1+i)^n} = 0 \qquad [1]$$

where:

- C_i = maximum amount of capital that can be economically invested
- S = periodic savings from reduced grade loss
- i = periodic IRR on investment
- n = number of periods for analysis
- S' = salvage value after n periods

Equation **[1]** treats S as a series of uniform payments and S' as a single payment. For this analysis, the first term of Equation **[1]**, C_i, is defined as investment cost differential between the press and the dry kiln. In the second term, S is defined as:

$$S = P(W_c)(W_r)(V_u - V_d) \qquad [2]$$

where:

- P = production rate per period n (board feet (BF) (0.0024 m^3)/time)

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TABLE 1. – *Average warp and percentage of boards downgraded by warp.*

Warp type	Press	Kiln	Reduction
			(%)
	Warp (1/32 in.)		
Crook	2.9	4.9	40.8
Bow	5.1	7.3	30.1
Twist	2.7	2.8	3.5
	Downgraded boards (%)		
Crook	3.9	12.9	69.8
Bow	2.5	9.1	72.5
Twist	3.5	2.4	-45.8
Any	8.7	20.7	57.0

TABLE 2. – *Base values for sensitivity analysis.*

Condition	Base value
Production rate	60×10^6 BF/yr.[a]
Operating days	350/year (2 weeks down)
Kiln-drying cycle	24 hours
Press-drying cycle	2.1 hours, average press time for the three studies weighted for number of boards in each study. We assumed three shifts per operating day and allowed one less press cycle per day for contingency and maintenance.
Current warp loss	17.5 percent degraded from STUD grade because of exceeding warp limits
Reduction in warp loss	55 percent
Cost of kiln	$4.3/BF (8)
Cost of warp loss	Assumed products are studs and two-thirds of downgrade is from STUD grade ($0.253/BF) to UTILITY ($0.171/BF) and one-third is from STUD grade to ECONOMY ($0.117/BF). Weighted average cost of downgrade is thus $0.098/BF (4,7).
Internal rate of return	15 percent (1)
Service life	25 years
Period of analysis	10 years
Compounding	Quarterly

[a] 1 BF = 0.0024 m^3.

W_c = current warp loss in kiln-drying (percent/100)

W_r = reduction in warp loss by press-drying (percent/100)

V_u = value of undegraded boards ($/BF)

V_d = value of degraded boards ($/BF)

Equation **[2]** assumes that additional thickness loss caused by 25 psi (172 kPa) of platen pressure does not require an increase in green target sawing thickness compared to that used in kiln-drying. The equation assumes that the approximately 2 percent additional thickness loss observed in the studies can be accommodated either in the current sawing allowance or by sawing improvements. If not, the yield loss should be added to the analysis. To do this, Equation **[2]** is modified as follows:

S = Savings from reduced warp loss, corrected for additional volume loss
- Sales not realized at undegraded value
- Sales not realized at degraded value

$$S = P(1-L)(W_c)(W_r)(V_u - V_d) - [PL(1-W_c)V_u + PL(W_c)V_d]$$

where:

L = volume loss from additional thickness loss (percent/100)

In the third term of Equation **[1]**, S' is defined as $S' = (C_p - C_k) - D$

where:

C_p = capital cost of press or required press capacity × unit cost of press

C_k = capital cost of kiln or required kiln capacity × unit cost of kiln

D = differential depreciation between press and kiln

Both capital costs can be calculated by:

$$C_p \text{ or } C_k = \frac{P}{J} U$$

where:

U = unit cost of press or kiln

J = drying cycles per period

and D can be calculated by:

$$D = \frac{(C_p - C_k)}{F} n$$

where:

F = service life (in number of periods)

thus,

$$S' = (C_p - C_k)\left(1 - \frac{n}{F}\right) \qquad [3]$$

Because $C_t = C_p - C_k$, Equation **[1]** can be written

$$C_t = \frac{S(k-1)}{i\left(k - \left(1 - \frac{n}{F}\right)\right)} \qquad [4]$$

where:

$k = (1 + i)^n$

Assumptions in economic model

We made several assumptions that simplified the analysis without seriously affecting the value of its sensitivity

1. The use of capital for investment (equity or debt) was not assumed. When the concern of an analysis is to judge the profitability of a potential project, this distinction is not necessary (2).

2. Taxes were not considered, which did not affect relative rankings of competing alternatives **(2).**

3. No attempt was made to include a risk factor, although it would probably be high for press-drying given the incomplete knowledge about the technology. According to a survey of major forest products firms, risk is considered primarily in subjective terms **(1).** Therefore, little quantification of effects on return was incorporated in our analysis. Some risk was taken into account by using a short investment period (compared to service life).

4. Labor and maintenance costs were assumed to be the same in press- and kiln-drying, although their extent in press-drying is unknown.

5. Service life was assumed to be the same for both press and kiln, with straight-line depreciation.

6. Press design was assumed to be the same or similar to that of current multiple-opening plywood presses that typically have 4- to 5-foot (1.2- to 1.5-m) by 8-foot (2.4-m) openings. But since the platen pressure requirements were lower (25 psi (172 kPa) compared with 100 to 225 psi (689 to 1,550 kPa) for a plywood press), the press cost was lower than that of a plywood press.

Sensitivity analysis

Reasonable base values were assumed for the terms of Equations **[1]** to **[4]**, varying factors of main interest (press-drying time, current warp loss, reduction in warp loss, cost of warp loss, and increase in green target thickness) while keeping other factors constant to observe their influence on the maximum capital investment justifiable for a press. These base values are described in Table 2.

The results of the sensitivity analysis are summarized in Figures 1 through 4 in terms of the maximum allowable capital cost of a press, C_i. Because exact design details and thus cost of a suitable press and

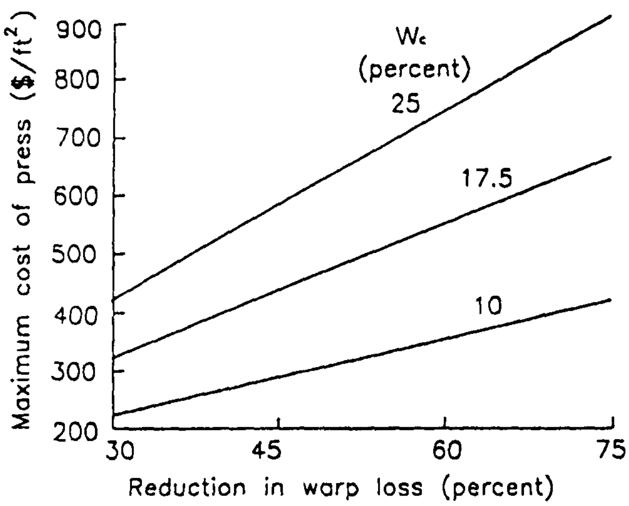

Figure 1. — Variation of maximum allowable press cost with reduction in warp loss at several levels of current warp loss (W_c) for nominal 2- by 4-inch (standard 38- by 89-mm) lumber.

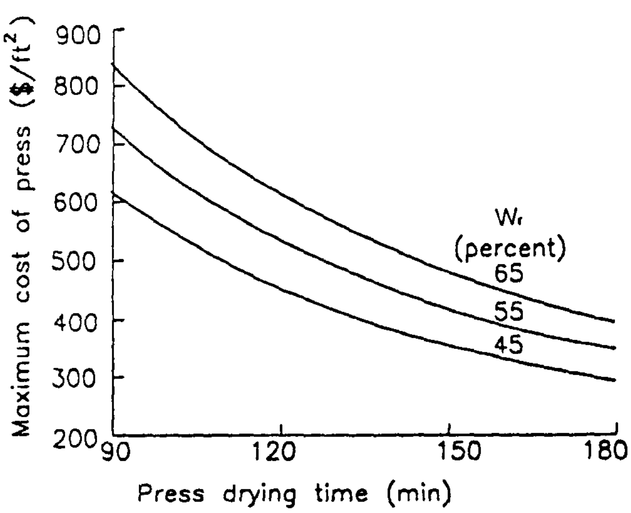

Figure 2. — Variation of maximum allowable press cost with press-drying time at several levels of reduction in warp loss (W_r).

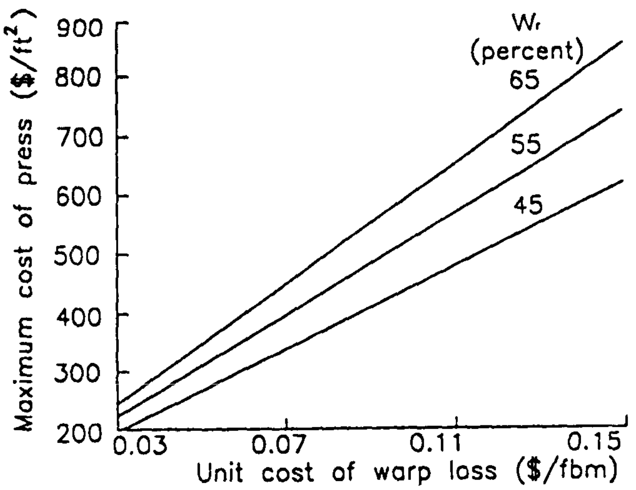

Figure 3. — Variation of maximum allowable press cost with unit cost (cost/BF) of warp loss at several levels of reduction in warp loss (W_r).

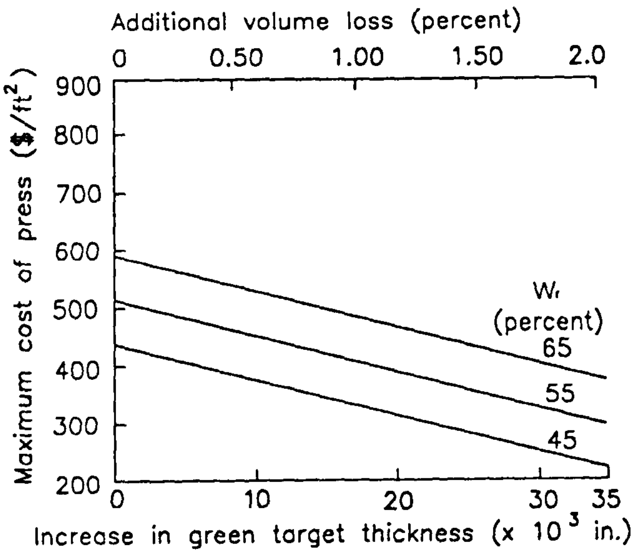

Figure 4. — Variation of maximum allowable press cost ($/ft.^{2}) with increase in green sawing target thickness and percentage of excessive volume loss (assumes 1.72-in. (43.7-mm) green target thickness for boards as base).

loading system are not known, these graphs only provide guidelines for press design. Figures 1 to 3 assume green target thickness does not need to be increased to allow for additional thickness loss in the press.

As a reference point, multiple-opening plywood presses currently cost approximately \$265/ft.^{2} (\$2,852/m^2) of platen. However, this does not include the cost of the loading and unloading system (which is approximately equal to C_i in a plywood system where each press has its own loading-unloading system), nor does it reflect the lower cost of reduced platen pressure requirements. When press-drying time is 2.1 hours, two hundred 5- by 8-foot (1.5- by 2.4-m) press openings, or five 40-opening presses, would be required for the annual production of 60×10^6 BF in 350 operating days of 3 shifts. It might be possible to develop a loading-unloading system that moves between presses and thus serves them all. A 2-hour press cycle might allow enough time to stagger loading and unloading times.

The effect of increase in green target thickness on C_i is shown in Figure 4. The decrease in C_i with increase in green target thickness is steep enough that target thickness requirements would have to be carefully considered in any development of a press-drying process. However, an alternative to press-drying at constant pressure would be to press-dry to set thickness stops so that thickness loss would be the same as that for kiln-drying. This approach could be a subject for future investigation.

Concluding remarks

Previous studies have shown that press-drying may be effective in reducing losses from warp in plantation loblolly pine lumber. Whether the realization of these reductions in grade and value loss is economically viable depends on current levels of warp loss, actual reduction in warp loss realized, press-drying time, cost of grade loss and mix of grades, increase in green target thickness required to accommodate additional thickness loss caused by platen pressure, and actual cost of a press and loading system designed for this purpose. Whether or not press-drying is technically and economically feasible is still uncertain, but the analysis presented here can offer some guidance in equipment design.

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