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Forestry and Natural Resources
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Timber Processing

# Quality Control in Lumber Purchasing: Lumber Stress/Casehardening

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## Casehardening Lumber

Lumber dried to moisture contents of 6 to 8 percent, suitable for the manufacturer of products used indoors, develops stress. Lumber in this category is said to be "casehardened." Drying stresses are a normal result of the drying process. Stresses can develop in the air-drying yard, in the predryer during dehumidification drying, or particularly during steam kiln drying. Drying stresses may be either transverse or longitudinal, the transverse type generally creates the most problems.

The severity of the drying stresses varies with the drying method and the drying conditions. As the lumber is machined, especially during the ripping operation, the stresses are relieved, and unacceptable distortion often results (Figure 1). Thus, these stresses should be relieved during the drying operation for lumber, which is then cut up and used in manufacturing products.

To understand stress or casehardening, the manner in which a board dries needs to be considered. During drying, the surface loses moisture first; moisture from inside the board migrates outward and evaporates. A moisture gradient going from a high-moisture content in the core to a low-moisture content on the surface or shell develops.

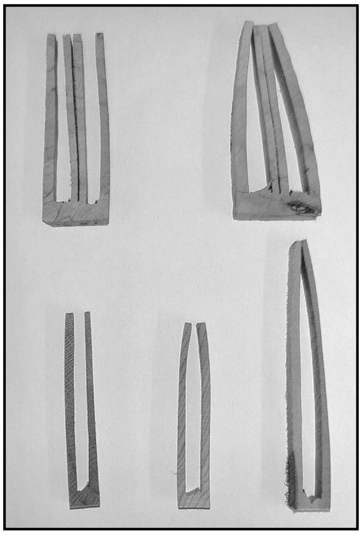

**Figure 1. Top and bottom samples on left show no casehardening; top and bottom samples on right show casehardening. The sample at the bottom middle is slightly casehardened.**

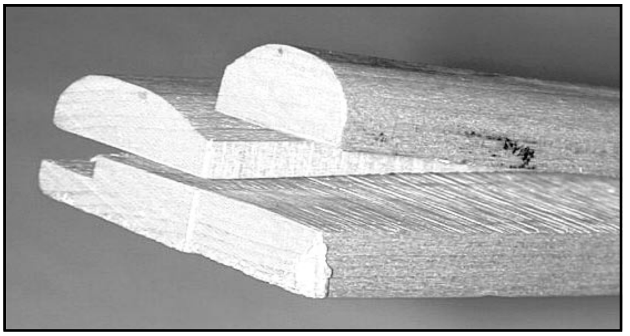

**Figure 2. This stile from a cabinet door was split into four quadrants. The upper right quadrant turned out. The upper left quadrant with a thinner profile remained about flat. The two quadrants on the bottom pinched together and closed the saw cut. The lumber was casehardened and resulted in excessive warp in the cabinet door.**

As a board continues to dry, the surface eventually tries to shrink. In the early stages, it is restrained by the core, which is fully swollen. The shell is stressed in tension, and surface checks (cracks) may develop. The core is in compression. As drying continues, the core begins to shrink and pulls the shell into compression. Surface checks may close. The core is now in tension. The transverse stresses, which have developed, are more or less uniform across the thickness, width, and length of the piece. The lumber appears normal, but it is not. The stress needs to be relieved.

### *Results of Casehardening in Lumber*

If casehardened lumber has not had the stress relieved, several problems can develop when the wood is machined. These include warp, such as cup and crook, excessive planer splits, and end checking. The defects normally develop at the time of machining or immediately afterwards.

Warping is probably one of the most noticeable defects that can result from casehardened lumber (Figure 2). During the resawing of thick stock into thinner material, stresses in the boards are unbalanced, and cup or bow with the concave edge toward the saw will result. The curvature or distortion develops because the core of the board is normally in tension, and it is pulling the surface or shell inward. Ripsawing may relieve longitudinal stress. When the board is ripped, crook may develop with the concave edges towards the saw. This obviously results in manufacturing problems or discarding of the material.

End checking can occur in the core of freshly crosscut casehardened boards. One case has been reported where excessive end splits developed in panels immediately after high-frequency gluing.[1] The splits were all in the wood and not the glue line. The problem was thought, at first, to be due to high moisture content in the wood, but an oven-dry test showed it all to be about 6 percent. The kiln operator had been relieving transverse stress. However, longitudinal stress was still present, as indicated by the test described later. Special kiln sets were made to relieve the longitudinal stress, and the problem ended.

During planing, if the cut is not uniform on both sides, the board will cup, with the concave face being the one most heavily machined. The lips on edge grooved material may turn inward and break as the tongue or spline is inserted. In producing moulding and trim during routing and carving (where unequal cuts are necessary) cupping will likely result.

Planer splits can occur in relatively flat lumber which is casehardened. The splits result from the internal drying stresses and the action of the knives.

Boring will also be difficult in casehardened lumber. The bit is being pinched by the board.

Squares can also be casehardened. If casehardening exists, splits along the length and end splits may develop even though the moisture content is at 6 to 8 percent.

# Tests for Drying Stresses

Drying stresses and moisture content can be checked on lumber. Figure 3 shows an example of how to cut the specimens. The moisture content and transverse stress specimens are about one inch in width along the grain and full width of the piece. First, the average moisture content section is weighed as soon as it is cut from the board. The scales should have a precision of 0.5 percent of the weight of the section and read in grams. The moisture content section is then oven-dried at 101° to 105°C to a constant or oven-dry weight. To determine if the weight is constant, simply keep weighing the specimen every couple of hours until it stops losing weight. The moisture content is then calculated by the following formula.

$$\text{Percent moisture content} = \frac{\textit{original weight - oven dry weight}}{\textit{oven dry weight}}$$

This gives the average percent moisture content of the sample based on oven-dry weight, and it should fall within the range specified, or 6 to 8 percent for hardwoods, used for interior products.

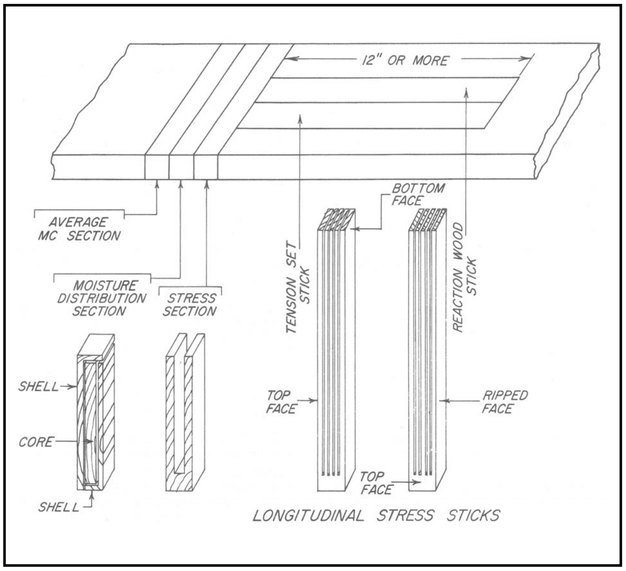


**Figure 3. Method of cutting sections for final moisture content and drying stress tests. MC is moisture content (Courtesy of the U.S. Forest Products Laboratory).**

Next, the moisture content of the shell and core are calculated. The thickness of the shell portion of the sample is about $^1/_4$ the total thickness of the moisture distribution section. The shell part and the core section should be weighed immediately upon cutting. They are then oven-dried, and the moisture content calculated as before. A uniform moisture content throughout the piece is ideal. If the moisture content is not uniform, the stress test could be misleading.

The stress section is used to determine the presence of casehardening in the board. The core of the section is simply removed with a band saw. If the two outer prongs pinch in, the section is casehardened or has residual drying stress. The prongs turn in because the tension stress in the core is released by the saw cut, and the inner faces of the prong shorten because of the release of the stress. Figure 4 shows sections with different degrees of stress and for different thicknesses of lumber. If the stress is severe, the prongs will snap together. In this case, the stress section can be turned down and band sawed in such a way as to allow diagonally opposite prongs to bypass each other.

Moisture gradients across the thickness of the board can also result in prong movement, but not immediately as with casehardening. Moisture gradients result from improper drying or improper storage. Residual drying stresses and moisture gradients can also interact. When a moisture gradient exists, the core of a stress section is not at the same equilibrium moisture content as the air where it is cut. With time, the moisture content of the core will change, and the inner face will shrink or swell. Most commonly, the core is at a high enough moisture content that it shrinks when cut, the prongs move in, and it appears to be casehardened.

Table 1 is a systematic summary to identifying casehardening and moisture gradient problems based on prong movement (Figure 4).

The time required for prong movement is a good indication of whether residual drying stresses or moisture gradients or a combination of these two cause prong movement. Residual drying stresses cause prong movement immediately, whereas a change caused by moisture content requires up to 12 hours to complete. The delayed observations should be made in an environment that is at 6 to 8 percent equilibrium moisture content (75°F and 30 to 40 percent relative humidity for example). If immediate prong movement is observed, followed by additional prong movement, then both factors are the cause. In either case, prong movement points to a condition that should be corrected to avoid warp upon resawing or machining. Either additional stress relief or equalization, or both, procedures are required.

Reverse casehardening (Figure 4) occurs when the lumber is over conditioned when relieving drying stresses. It is a stress condition that cannot be corrected.

Longitudinal stresses can also develop in a board and should be monitored for the reasons discussed earlier. A method to prepare longitudinal stress or tension set sticks is shown in Figure 3. Each stick should be 1 inch wide and at least 12 inches along the grain and the full thickness of the board. Saw kerfs shown as thin void areas in Figure 3 should be placed along the length and parallel to the original surface (face) of the board. If both of the outer prongs bow inward and pinch the saw, the sample probably has longitudinal drying stress. If only one outer prong pinches the saw, the sample probably has growth stresses from reaction wood.

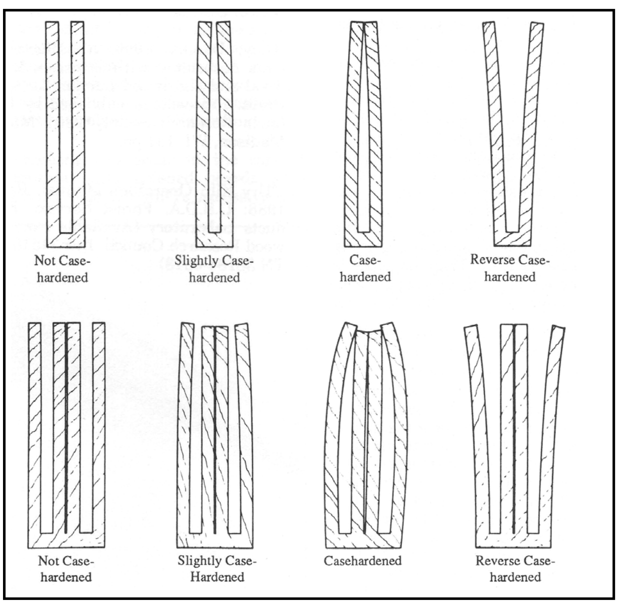


**Figure 4. Visual degree of casehardening and lumber. Lumber that is less than 1 1/2 inch thick is cut into three prongs, and the middle prong is removed; lumber that is 1 1/2 inch thick or thicker is cut into six prongs, and the second and fifth prongs are removed.**

To check for longitudinal stress in squares, 1/8-inch-thick sections were cut along the grain.[1] These sections were then broken along the grain. The pieces were fitted back together. When the pieces fit perfectly, no defects developed in the turning operation. When stress was present, a small crack indicating casehardening could be seen between the pieces, and splits occurred on the turned stock.

To test for growth stresses or reaction in dry wood, cut a sample similar to the tension test. However, in this case, place the saw kerfs perpendicular to the board surface. If the prongs bow in, the sample has longitudinal stress due to reaction wood. Reaction wood can result for growth stresses which occur naturally, or tension wood which is generally present in the upper part of leaning trees. Neither is the result of poor drying practices, and neither is considered a grading defect in hardwood lumber. Their presence is generally too sporadic to facilitate separation, and excessive degrade generally does not result.

# Equalizing and Stress Relief

Equalizing periods are normally used at the end of the kiln cycle to reduce the amount of moisture content variation within and between boards and to better prepare the material for subsequent conditioning. The conditioning step relieves the transverse drying stresses. With the proper conditioning, longitudinal drying stresses can also be relieved.

Proper equalizing and conditioning are the responsibilities of the dry kiln operation and should always be practiced when the lumber is intended for remanufacture. The exact procedures are presented in the Dry Kiln Operator's Manual.[2]

Equalizing starts when the direct kiln sample has reached an average moisture content of 2 percent below the discard final average moisture content. Equalizing continues until the wettest sample reaches the desired final average moisture content. When conditioning hardwoods, the EMC is set at 4 percent above the desired final average moisture content. Conditioning time may range from 16 to 48 hours.

## References

[1] Clay, Dennis. 1990. *Manufacturing Problems Associated with Stress in Drying Softwood and Hardwood Lumber for Quality and Profit*. Proceedings published by Forest Products Research Society, 2801 Marshall Ct., Madison, WI. 131 pp.

[2] *Dry Kiln Operator's Manual*. Revised July 1988. USDA Forest Service, Forest Products Laboratory (Available from the Hardwood Research Council, Box 34518, Memphis, TN 38184-0518).

**Table 1. Systemic summary to identify casehardening and moisture gradient problems based on prong movement. Provided by Jim Steen of Pike Lumber Company, Akron, Indiana.**

1. **Immediate Observation:** No Movement
   - a. **Delayed Observation:** No Movement. (No stress or moisture gradient problems.)
   - b. **Delayed Observation:** Movement Occurs.
     - i. Casehardening Movement. (Indicates that the core moisture content is higher than shell moisture content, which could indicate that the piece was stress relieved before the core reached the target moisture content and the subsequent movement is a result of the inside surface of the prong test shrinking.) This type of movement also occurs early in the drying cycle when the shell has started to set but the core has not.
     - ii. Reverse Casehardening Movement. (Indicates that the shell moisture content was higher than that of the core, and that it was offsetting the effect of reverse casehardening.) This type of situation would be rare, but in theory, it is possible.
2. **Immediate Observation:** Casehardened Movement.
   - a. **Delayed Observation:** No Further Movement. (Indicates that casehardening exists, and there is no moisture gradient.) This is caused by not conditioning or not fully conditioning a kiln charge of lumber.
   - b. **Delayed Observation:** Further Movement Occurs.
     - i. Further Casehardening Occurs. (Indicates that in addition to casehardening that the core was of higher moisture content than the shell.) This can occur when the final target moisture content was not reached in the core of the piece, and then it was either improperly or not at all conditioned.
     - ii. Casehardening Eases. (Indicates that although there is some failure to properly condition the piece, part of the initial movement is the result of the shell being of higher moisture content than the core.) This is common and is usually caused by improper storage somewhere in combination with inadequate conditioning.
     - iii. Casehardening Disappears. (Indicates that the shell is of higher moisture content than the core.) More than likely, this is the result of poor storage conditions.
3. **Immediate Observation:** Reverse Casehardening Movement.
   - a. **Delayed Observation:** No Further Movement. (Indicates that reverse casehardening has occurred and that there is not a problem with moisture gradient.) This usually results from over conditioning of the piece.
   - b. **Delayed Observation:** Further Movement Occurs.
     - i. Further Reverse Casehardening Occurs. (Indicates that shell moisture content was greater than core moisture content.) A scenario would be that over conditioned lumber was stored for an undetermined period in a higher than 6-8 percent moisture content area.
     - ii. Reverse Casehardening Eases. (Indicates that core moisture content was higher in the core than in the shell and at the same time over conditioned.) This could occur if lumber that was over conditioned was moved to a drier than 6-8 percent moisture content area for an undetermined amount of time before testing.
     - iii. Reverse Casehardening Disappears. (Indicates that the moisture content of the core was higher than the shell for some reason.) A scenario might be that correctly conditioned lumber was stored for an undetermined period in a place drier than 6-8 percent moisture content.

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