

SERIALS

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**STRESSES AND DETECTION OF CASEHARDENING  
DURING KILN DRYING**

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## STRESSES AND DETECTION OF CASEHARDENING DURING KILN DRYING

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If one imagines wood as consisting of numerous zones it is plain to see that stresses will be produced if two adjacent zones attempt to shrink in different ratios. They oppose each other. One zone is in tension and the other in compression. Wood does not shrink until it has reached a moisture content of about 25 per cent. From this condition, which is known as the fiber-saturation point, its normal shrinkage is directly proportional to the amount of moisture lost.

A difference in moisture content between two zones, when at least one of them is below the fiber saturation point, will cause stress. This may be only a temporary condition (moisture difference stress), for as their moisture contents become equal their shrinkage may also equalize, in which case the cause of the stress has been eliminated. Unless a considerable difference of temperature exists between the points, moisture cannot transfuse through wood without a moisture difference between the surface and center, therefore seasoning must inevitably produce stress. If, however,

there is still a difference in shrinkage when both zones reach the same moisture content it means that the shrinkage of one zone has been somewhat prevented and has dried in a set, expanded condition. This condition is called "set stress", or casehardening. It is not temporary and it requires a special treatment to induce this set zone to shrink the same as the other, thus relieving stress.

Casehardening as used in this article does not mean, as the word implies, that the surface layers of the wood are hardened as steel is casehardened. The term is used rather to describe the condition of wood which contains stresses produced by a difference in shrinkage between the surface and the center of a board when the moisture content is equal throughout. This stress is not to be confused with the stress produced by bending under a load or the internal stress produced by a difference in shrinkage due to difference in moisture content.

Ranging from the wet wood above the fiber-saturation point in the interior to the drier surface, there are countless zones in different stages of dryness. Each zone possesses a capacity to shrink in proportion to its moisture loss, but no zone is permitted to shrink normally, being

restrained from doing so by an adjacent zone of higher moisture content.

The rate of change in moisture content between two points in a section is called the moisture gradient, and the greater the gradient the more the normal shrinkage of any particular zone will be prevented. The outer section of a board, which loses its moisture first, is forced to dry to a certain extent in incompletely shrunken, or set expanded condition. This dry, partially shrunken shell prevents the full shrinkage of the zone next to it. As drying progresses each zone is successively prevented from shrinking, not only by the interior wood of higher moisture content but also by the drier set-expanded outer portion. As drying reduces the moisture content of a group of cells within the piece below the fiber-saturation point, they become a zone of tension supported by a wet unshrunken zone on one side and set incompletely shrunken zone on the other.

Because the wood is incompletely shrunken or set in an expanded condition, it does not necessarily follow that the material is casehardened, for if the shrinkage is prevented to the same degree in all portions of a board of uniform moisture content then all stresses will be eliminated.



No matter how perfect the external appearance of a board may be, its serviceability is greatly reduced if it has dried without normal shrinkage. As soon as the surface of such a board becomes wet, some of its latent shrinkage powers are restored. Stresses again develop, which on redrying make resawing impractical.

It is impractical to set any hard and fast rule for the determination of casehardening. A study of the moisture distribution throughout the cross-section of the stock will be indicative. The greater the moisture gradient below the fiber-saturation point in the wood and the shorter the span over which this gradient is operative, the more severely the surface must be set. But perhaps the most satisfactory way for testing for casehardening is to cut a one-inch section from the board some distance from the end and slot it so as to form a number of prongs as shown in figure 1. Before slotting, the solid block shown in figure 2, the stresses in the wood are balanced and counteract one another. When cut into, however, the balance of the stresses may be disturbed and the prongs will bend either in or out until the stresses once more become balanced as shown in figures 2a and 2b. The action of each prong merely indicates a

balance of the stresses which it contains. It is evident a prong will bend differently as its size is varied. The fact that prongs resulting from slotting a section in the center do not bend in either direction, figure 3, is not an indication that there are no stresses in the wood, but merely shows that the stresses are balanced. On resawing each of the prongs the outer portions may turn outward and the inner portions inward as shown in figure 3a.

The method of cutting prongs can not definitely be outlined, but it will be found advantageous to cut at least one thin prong at the surface of the section and another thin one at the center as shown in figure 4.

The action of the prongs indicates the stress in the piece at that time but does not necessarily show whether or not normal shrinkage has taken place. Set, or prevented shrinkage, is the cause of permanent casehardening, and is an important factor for this reason. Set should be eliminated, as fast as possible, from a board even though the set is uniform throughout the piece in order that there may be no undue chances for the stock to change shape after it is manufactured. The moisture difference in various sections, and in various parts of the section, are ordinarily so great that it is impossible to determine how nearly equal

and to what extent the material is set. It is only after room drying, when all the parts of the section contain the same amount of moisture, that the difference in shrinkage can be compared, or the set determined. In losing exactly the same amount of moisture each prong should shrink exactly the same amount. If they are not the same length after room drying the difference is due to the fact that the long prongs have not been permitted to shrink normally, and have become set in a condition of incomplete shrinkage. If the surface of the board dries and sets before it has shrunk normally the board as a whole is prevented from shrinking normally. The center fibers will tend to continue to shrink and, if the resultant tension is greater than the cohesion of the fibers, they will pull apart, thus producing honeycombing as shown in figure 5.

"Set-stress", or casehardening, makes it impossible to utilize the highest percentage of the wood in manufacture and also causes large seasoning losses due to honeycombing. The only known way in which casehardening can be prevented is by drying the stock in such a way that its interior portions will dry nearly as rapidly as the surface, thus permitting the wood to shrink as a unit, or else (theoretically)

by very slow drying in dry air at low temperature producing an abrupt moisture gradient so that the entire stick becomes equally set throughout, thus eliminating shrinkage. Ordinarily either method of drying is so slow as to be commercially impractical. Kiln drying, even when using mild conditions, will produce a certain amount of set which should be relieved either by steaming or subjecting to a humidity just high enough to permit the surface of the stock to absorb the proper amount of moisture depending upon the condition of the material. Either one of these treatments will soften the wood fibers so that on redrying they will again shrink normally.

#### Casehardening Test Key

1. When the prongs of the resawed piece turn out at the time of sawing they indicate that the surface is drying, shrinking, and in tension. The center is in compression opposing surface shrinkage.
2. If after room drying to a uniform moisture content the prongs are of unequal length, the long prongs are set in an expanded condition. This set existed when the section was first cut and if the moisture content at that time ranged above 18 per cent in the center the stock should be steamed in saturated air at 160 degrees from one-half to three hours, depending on the thickness and the moisture content of the stock and the species being dried. If the stock was below 18 per cent in the center at the time of



sawing, the charge should be treated in a higher temperature (160 to 185 degrees), and in a humidity just high enough to permit the surface to absorb moisture slightly.

3. If the prongs stay straight, or become straight after all prongs have reached the same moisture content the stock is in excellent condition and no treatment is needed.
4. If after room drying the outer prongs still turn out, then the inner prongs are set in an expanded condition. This condition can occur in the kiln only when the center is considerably below the fiber-saturation point. To soften these inner zones the charge should be treated in a high temperature for a period of about 24 hours and a moderately high humidity as follows: if the stock is below 12 per cent in the center use 65 or 70 per cent humidity; when the center contains 12 to 15 per cent moisture use 70 or 80 per cent relative humidity; if the center is below 7 per cent it is dangerous to either give a high humidity or a steaming treatment. A conditioning treatment at this stage may cause an outward cupping which can never be remedied practically. This condition is called reverse casehardening.
5. When the prongs of the resawed section turn in at the time of sawing they indicate that the surface is in compression. Room drying will cause them to turn in more severely. Treat with steam at 160 to 180 degrees for from one-half to three hours if center is not drier than 18 per cent. This combination of stresses and moisture content is rare. These stresses will ordinarily occur when the moisture content in the center is much lower than 18 per cent, in which case a high humidity treatment should be given (160 to 180 degrees) and a relative humidity ranging from 65 to 80 per cent, depending on the moisture content of the center. See 4 for information on how to determine the proper humidity to use.



*Method of cutting test sections from plank*



Fig. 1



Fig. 2

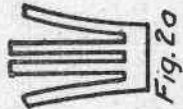


Fig. 20



Fig. 26

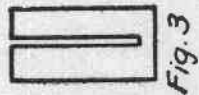


Fig. 3

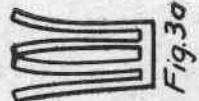


Fig. 3a

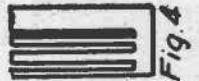


Fig. 4



Fig. 5

**DIAGRAMS OF CASE-HARDENED SECTIONS**