OPTIMIZATION OF KILN DRYING BY MOISTURE SORTING

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Kiln drying of green lumber is still a challenge to the industry. Despite great efforts of scientists, technologists and equipment manufacturers, a kiln operator of today faces unpredictable results each time he has to select an efficient drying schedule. Most modern kilns are equipped with quite advanced temperature controllers and a few knobs, buttons and recorders to adjust, select and monitor kiln operation. However, all of these have rather limited influence on the final results. This report shows, that the final moisture content distribution of kiln dried lumber is determined before that lumber has been placed in a kiln. The following analysis has been based on data from an extensive mill trial, which was carried out over time period of one year [1].

Let's start our discussion by taking a look at some moisture content (MC) characteristics of green lumber. Figure 1 illustrates a typical MC distribution for SPF processed by a mill. These data were recorded during two (2) consecutive days with an in-line moisture meter (MPB's model LS-120-G). Each MC scan in Figure 1 represents readings for an entire kiln load. As one can see, the moisture content varies between 7 and 140% MC. The mill processes up to 25% of dry lumber (i.e. below 20% MC), which is indicated by a peak at 14% MC. It is interesting to note, that the MC distribution changes quite substantially, from one load to another. For example, the calculated MC mean values for the two loads presented in Figure 1 are 49% and 59%, respectively. These type of MC variations are usually not recognized by the presently used kiln drying strategies.

For the purpose of the present analysis, the MC characteristics of lumber has been represented by two (2) parameters, i.e. the initial MC range R_{in} ($R_{in} = MC_{max} - MC_{min}$) and the MC mean value (M). These parameters have been used as variables in a system of coordinates which is illustrated in Figure 2. The initial MC characteristic of unsorted lumber is represented by the point (120,59). A series of experiments have been carried out in order to determine how these two (2) parameters would change during the drying process. The experiments have showed, that their ratio (i.e. R_{in}/M) *remains constant* during the drying process. This is illustrated by a straight line, which connects the initial point with the point (0,0). Each point along that line indicates how the MC mean values change with the change of corresponding values of the MC range. This characteristic may be expressed by the following equation:

$$R_{in}/M = \text{constant}$$

This equation describes *the drying principle*, which is a basic characteristic of kiln drying processes. By using the drying principle, one can determine the most efficient sorting and drying strategies.

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[1]The presented analysis is based on preliminary data prepared by S. Warren of H.A. Simons Ltd., Vancouver, B.C. and the staff of West Fraser Mills at Williams Lake, B.C.

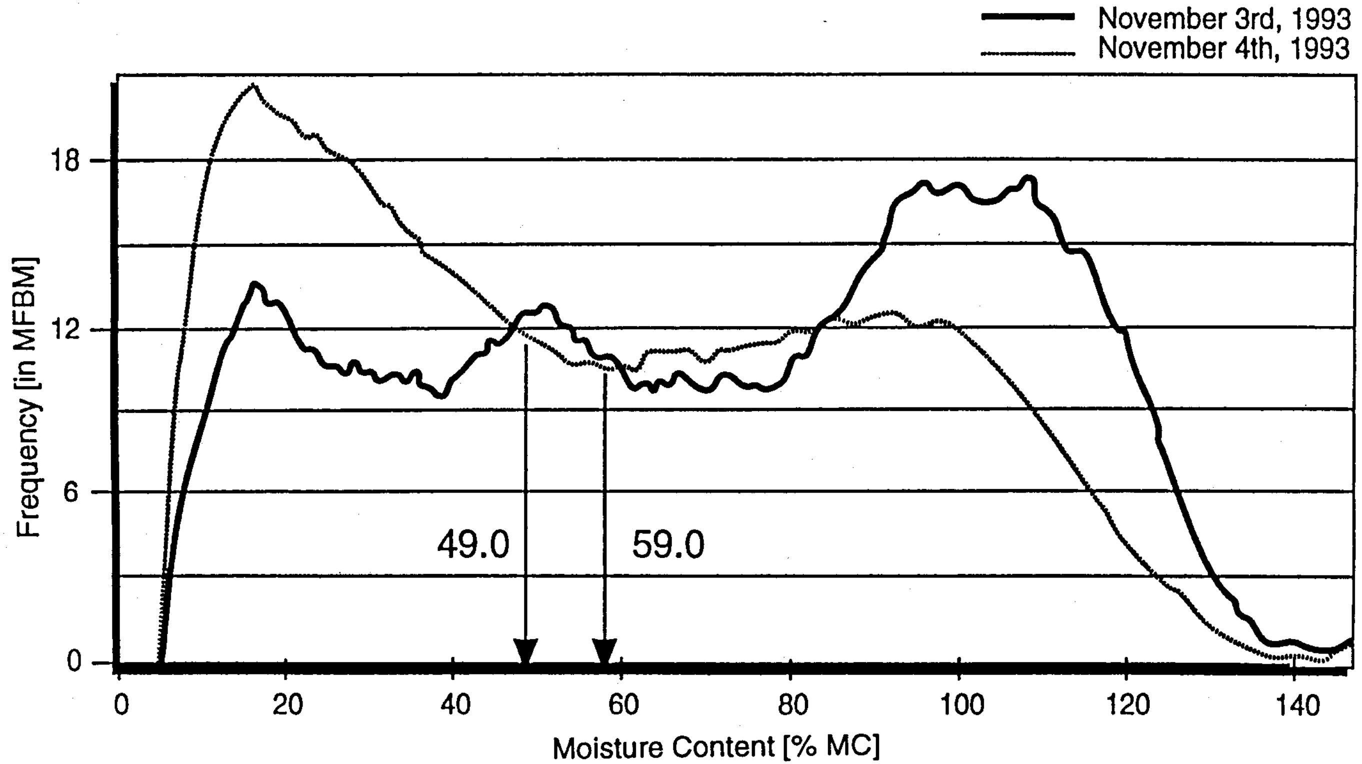

Figure 1. Moisture distributions for two kiln charges of "similar" material.

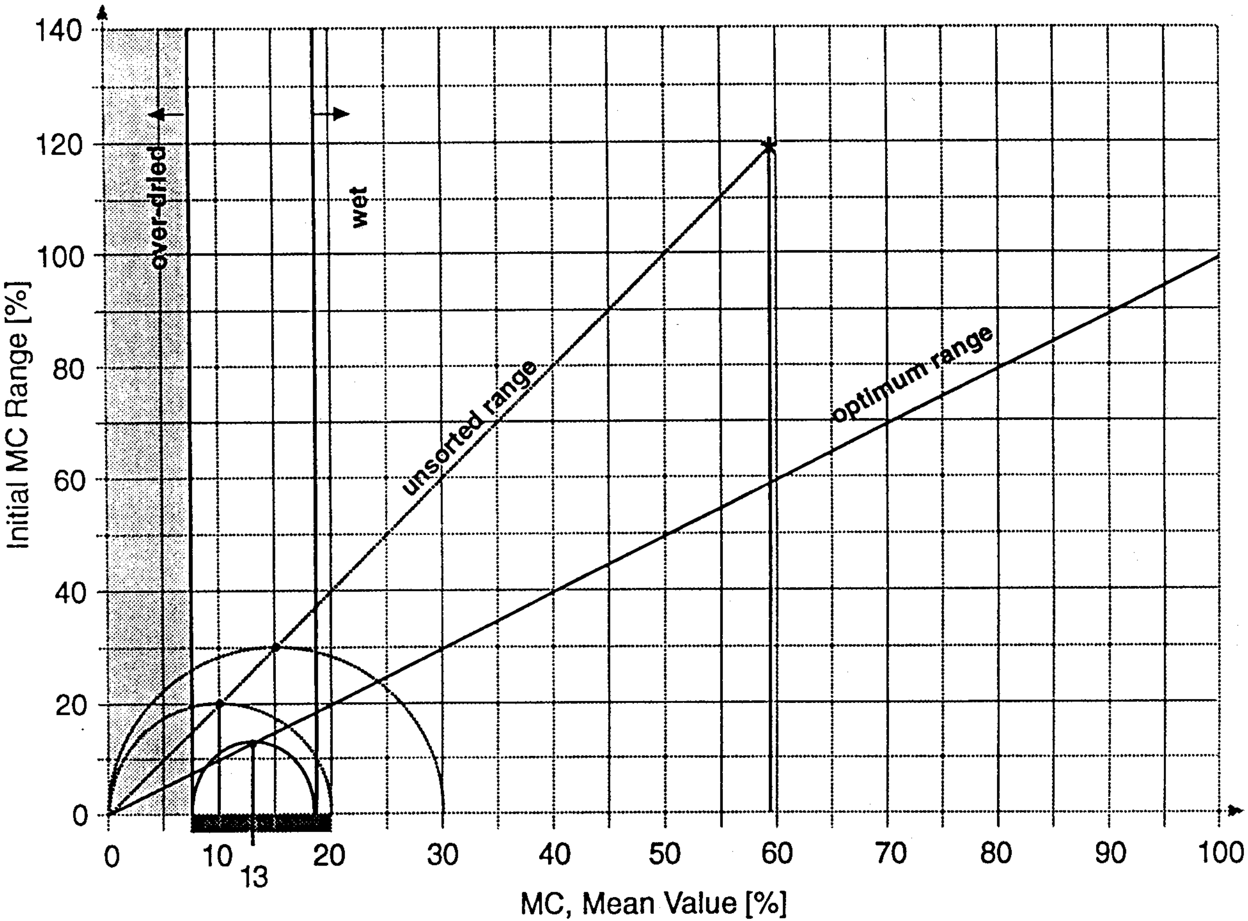

Figure 2. MC range by MC average coordinate system showing unsorted material.

The following analysis illustrates how this principle may be used in practice.

Ideally, one would like to dry the entire load below 19% MC. On the other hand, the tests have showed, that lumber which is dried below 7 - 8% MC will be exposed to severe overdrying conditions and its commercial value will be substantially reduced due to degrading [1]. Therefore, the boundary conditions for optimally dried SPF lumber may be determined as the range between 7% and 19% MC. The additional data which are required for this analysis are showed in Figure 4, where the drying times have been presented as a function of the MC mean values (for an entire load). The drying times have been determined for a kiln at the mill. It should be pointed out, that such data are kiln specific, i.e. they should be determined for a given kiln, prior to selection of a drying schedule.

In the discussed case (see Figure 2), the R_{in}/M ratio for *unsorted* lumber is 2.0. According to the drying principle, this R_{in}/M ratio will not change during the drying process, i.e. the final MC parameters will be characterized by the same ratio as that for the initial one. This has been illustrated in Figure 3 by means of semicircles, with their centers at 15% MC and 10% MC. These MC values corresponds to the mean MC values at two (2) different drying times, i.e. 28 hours and 34 hours, respectively (see Figure 4). The points, which are interceptions of the semicircles with the horizontal axis, correspond to maximum and minimum of the MC values for dried lumber for a given drying time. Therefore there are two (2) options which are available as far as the drying time is concerned:

(1) 26 hour drying time.
In this case, the final MC mean value will be 15% MC with the MC range between 5 and 30% MC;

(2) 34 hour drying time.
The final MC mean value will be 10% with the MC range between 5 and 20% MC.

The shorter drying schedule will end up with a large fraction of wet lumber. The selection of the second schedule, i.e. 34 hours, will lead to a large fraction of overdried lumber. The quantitative estimate of these results (based on the normal distribution) is summarized in Table 1.

It is obvious from the above presented data, that there is no way, that *unsorted* lumber may be properly dried, i.e. without either a substantial portion of it being severely overdried or underdried. The rate of overdrying may be reduced at the expense of allowing for a part of lumber to be underdried. An operator may only make a compromise between these two extreme possibilities. It does not matter how well a kiln is equipped or what type of controllers are used during the drying process. That type of equipment will allow only for making compromises between what fraction of lumber will be overdried and what fraction will be underdried. In most cases such a compromise is rather accidental than a conscious one, as the initial MC mean value is not known to an operator. For example, the 10% MC difference in the mean values for the two (2) loads showed in Figure 1, will require a four (4) hour adjustment in the drying time (i.e. 30 versus 34 hours) in order to obtain the same results. One may appreciate the challenge which a kiln operator is faced with in such a situation.

Let's analyze how such a situation may be improved by implementation of MC sorting of green lumber. The initial conditions which have been determined as the optimum conditions are presented graphically in Figure 2 by a line called "optimum range". This line illustrates the initial MC conditions at which the requirements for the properly dried lumber are met. The R_{in}/M ratio for the optimum range is 1.0.

According to data in Figure 2, the points characterizing the favorable initial conditions should be located on (or preferably below) the optimum line. In such a case, it would be possible to dry all lumber down to 7 - 9% range, without overdrying it. The semicircle, with its center at 13 % MC, represents the final MC characteristics of such dried lumber.

Staff at the mill use the sensor to sort green lumber into three (3) ranges. The first range is sorted as dry (below 20% MC). This lumber is not being dried, it is sent directly to a planer. The remaining lumber is sorted into two (2) groups, with the sorting point at 80% MC. The average MC values for these two (2) groups are 41.5% and 91.5% MC for mid-range and wet-range, respectively.

Figure 3 illustrates the initial sorting conditions for the sorted lumber. The R_{in}/M ratio for the mid-range and for wet-range are much closer to the optimum conditions. Therefore, both sorts are in much more favorable initial conditions for efficient drying than that in the case of unsorted lumber.

The data in Figure 4 have been used to determine the drying time for the sorted lumber. As it has been indicated before, the drying time for *unsorted* lumber is 34 hours. During that period of time, the MC mean value changes, from the initial 59% to the final of 10% MC. It is not surprising that the same schedule may be used for the lumber sorted as the wet. In that later case, the average MC value will change from 90% down to 15% MC. The mid-range lumber, with the initial MC mean value of 41.5% and the final of 12%, will require much shorter drying time, i.e. 22 hours. That later schedule indicates clearly that quite substantial cost benefits can be realized if the MC sorting strategy is implemented. For example, the kiln productivity has been increased by 43% (see Table 2).

Moreover, the analysis shows that the largest cost benefits related to the MC sorting are realized by eliminating degrade of lumber. The quantitative estimate of these results for the *sorted* lumber (based on the normal distribution) is summarized in Table 3.

It has to be pointed out, that the data presented in Tables I and III are theoretical estimation based on the proposed model. The mill trial data and their comparison with the described model will be presented in a separate report.

CONCLUSION

This report shows, that in order to optimize the kiln drying process, the *drying principle* should be applied together with the following data:

1. The MC mean value for an entire kiln load;
2. The MC range for an entire kiln load;
3. Drying time data for the MC mean values for a given kiln.

The last parameter is more or less known and used by most kiln operators. However, the first two (2) parameters are either unknown or completely ignored by the industry.

The MC sorting of green lumber is the last, and up to now it has been the only missing operation, required for the implementation of the Integrated Kiln Drying Systems (IKDS) [2]. Now , with the availability of appropriate equipment and the MC sorting methodology, it will be possible for the industry to implement that fully computerized system.

Table 1. Quantitative characteristics of *unsorted* lumber.

Drying time [in hours]	Mean value [% MC]	Range [% MC]	Number of Wets	Number of Overdried
28	15	5-30	17%	7%
34	10	5-20	less than 1%	23%

Table 2. Kiln Productivity Improvements.

	% of boards	Drying Time	Increase in Kiln Productivity
Unsorted	100%	34 hours	0%
Sorted: Dry	25%	0 hours	25%
Sorted Mid	50%	22 hours	18%
Sorted Wet	25%	34 hours	0%
Total (for sorted)			43%

Table 3. Quantitative characteristics of *sorted* lumber.

	Mean value [% MC]	Range [% MC]	Number of Wets	Number of overdried
Mid-range	12	7-20	1%	1%
Wet-range	15	11-19	less than 1%	less than 1%

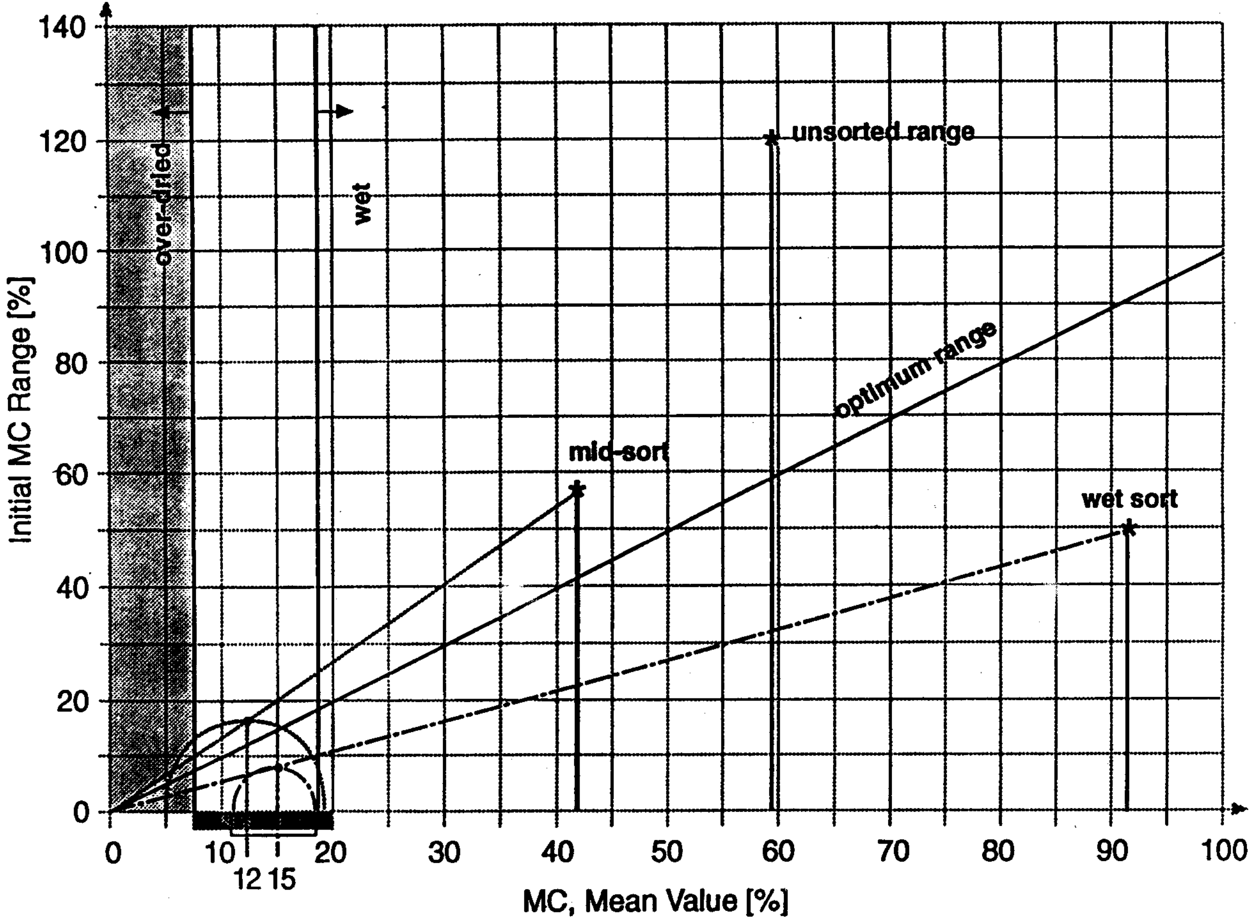

Figure 3. MC range by MC average coordinate system showing the mid-MC sort and the wet sort.

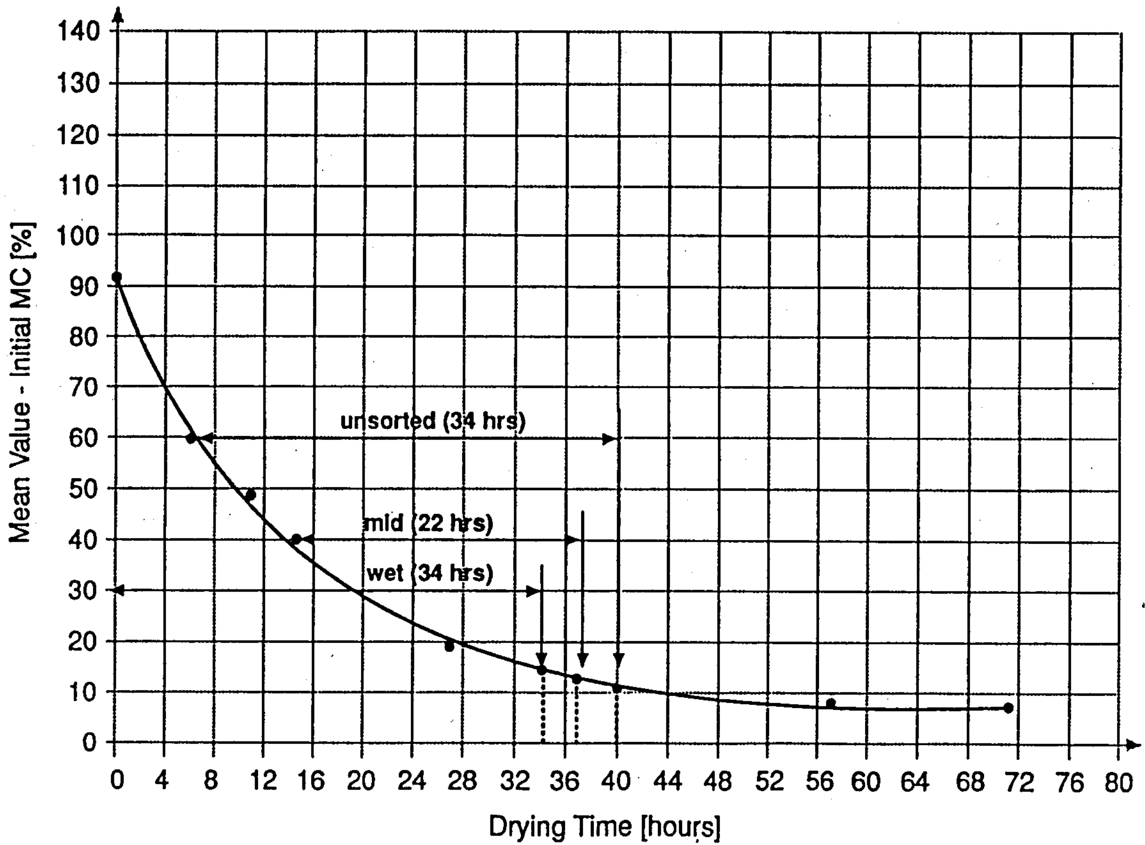

Figure 4. Moisture change versus time for SPF lumber.

REFERENCES

[1] "Evaluation of the Economic Benefits of Moisture Sorting", April 1994, - prepared by S. Warren (H.A. Simons Ltd., Vancouver, B.C.)

[2] W. Jamroz, in "ASTM Hand-Held Moisture Meter Workshop", 1994, published by the Forest Products Society, Madison, WI.