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Effect of High-temperature Redrying on Drying Characteristics of CCA-treated Lodgepole Pine Dimension Lumber[*1]

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고온 재건조가 CCA 처리 Lodgepole Pine 각재의 건조 특성에 미치는 영향[*1]

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摘 要

본 연구는 CCA로 防腐처리된 Lodgepole pine 角材의 再乾燥시 高温乾燥法의 적용이 乾燥速度 및 乾燥缺陷의 발생에 어떻게 영향하는가를 고찰하고자 수행되었다.

고온건조시 건조속도는 通常 熱氣乾燥시보다 約 2.5배 증가되었으며, 방부처리재의 재건조속도는 처리前의 전건조속도보다 약간 감소됨을 보였다.

表面割裂의 발생程度는 전건조시의 경우, 고온건조시 보다 甚하였으나 재건조시에는 건조방법간에 큰 차이가 없었다. 방부제의 浸透를 圖謀하기 위하여 自傷처리(Incising)된 각재의 경우에는 재건조시 切開部의 延長에 의해 할렬의 정도가 증가됨을 보였다. 뒤틀림(Warping)의 발생정도는 고온건조시가 통상 열기건조에 비해 심하지 않았으며, 全 건조과정을 통하여 발생된 뒤틀림은 WWPA가 定해놓은 Lodgepole pine 2等級(No. 2 grade)의 뒤틀림 許容値의 範圍內에 있음을 보였다. 結論的으로, 고온건조시 증가되는 건조속도와 건조재의 質에 큰 영향을 주지않는 범위내에서 발생되는 건조결함을 고려할때, Lodgepole pine의 전건조및 CCA 처리후 재건조를 위해 큰 문제없이 고온건조법이 적용될 수 있음을 보였다.

1. INTRODUCTION

Of all the wood products treated with preservatives in the United States, approximately 65 percent is treated with waterborne preservatives, mostly chromated copper arsenate(CCA) (Mickelwright 1988). Since impregnating waterborne preservative solutions put large amounts of water into the wood, and considerable shrinkage occurs as subsequent drying takes place, redrying after treatment is crucial for wood to be used in structures where dimensional stability after installation would be desired. Accordingly, the treated products should be dried to approximately the moisture content(MC) it will ultimately reach in service. High-temperature drying(HTD) is gradually being employed by the treating industry because it has no significant effect on the strength of wood and also has economical advantages compared to conventional kiln drying(CKD)--shorter drying time. smaller

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energy consumption, etc. Perhaps the majority of southern yellow pine lumber and increasing amounts of western softwood lumber are dried in high-temperature kiln.

This study was conducted to evaluate the effects of high-temperature redrying upon the drying characteristics of lodgepole pine(*Pinus contorta* var. *latifolia* Dougl. ex Loud) dimension lumber treated with CCA-Type C. Additionally, effects of incising on the development of surface checks were also evaluated.

2. EXPERIMENTAL METHOD

2.1 Material

A total of 200 pieces of surfaced, green lodgepole pine dimension stock, nominally 5.1-by 10.2-centimeters in cross section by 2.4-meters long, was obtained from a local sawmill. Most material was flat-sawn. Based on the presence of pith and / or the annual ring curvature it should be expected that some material contained significant juvenile wood. All material was graded by the 1983 Western Wood Products Association(WWPA) grading rules(WWPA 1983). On the basis of knot size and location from edge, it was determined that approximately 80 percent of the material was No. 2 with the remainder being Select Structural and No. 1.

The material was sorted into the three piles according to the grade, and then randomly arranged into the two groups for initial CKD and HTD so that each drying charge had similar quality distributions.

2.2 Experimental Procedures

2.2.1 Initial Drying

Initial kiln drying of green lumber was performed in a steam-heated dry kiln using the T9-C3 schedule recommended by Dry Kiln Operator's Manual(Rasmussen 1961) for CKD and 110.0℃ dry-bulb and 93.3℃ wet-bulb temperature for HTD. The air velocity through the kiln charge was about 122 meters per minute for CKD and about 244 meters per minute for HTD. The drying charge was constructed by flat piling the material, forming a pile about 1.2 meters wide and 9 courses high using 1.9 centimeter-thick stickers between courses. A top load of concrete weights of 489㎏ / ㎡ was applied to minimize warp in the top courses. After stacking was completed. both ends of the lumber were coated with 100 percent acrylic exterior paint to prevent excessive end checkings. Six sample boards were used to monitor drying in each kiln load. After drying, all dried material was equalized for 20 hours under the condition of 71.1℃ dry-bulb and 57.8℃ wet-bulb temperature(7 percent equlibrium moisture content), and then conditioned for 10 hours using 71.1℃ dry-bulb and 62.8℃ wet-bulb temperature(12 percent equlibrium moisture content).

2.2.2 Incising

After initial drying, half of the material from each drying charge was incised using a commercial incisor which had two vertical and two horizontal rollers fitted with 0.5 centimeter-long teeth. Incisions were oriented parallel to the grain on all four faces of the lumber. The number of incisions was about 3444 per square meters.

2.2.3 Preservative Treatment

The CCA-treatment was done at a commercial plant using a CCA-Type C(oxide base) formulation at a 1.6 percent concentration. The full-cell treating cycle was employed. The treating cycle consisted of the application of initial vacuum of 597 mmHg for 30 minutes, followed by filling the cylinder with preaervative solution under vacuum. The pressure was increased to 8.4kg/㎠ and held for 40 minutes. The final vacuum of 584 mmHg was applied for 15 minutes.

2.2.4 Redrying after CCA-treatment

Before redrying, the treated material was close-piled and covered by polyethylene film outdoors during October for three weeks. This provided a fixation period between treatment and redrying.

Half of the initially kiln dried and half of the initially high-temperature dried material was combined and redried by the CKD schedule described previously. The remainder of the material was dried using HTD schedule described previously.

Table 1 shows the treatment type and code for each treatment group.

2.2.5 Measurement of Drying Defects

Table 1. Treatment type and code for each treatment group

Treatment[1]	Code
CKD-Incising-CCA-CKD	CICC
CKD-Nonincising-CCA-CKD	CNCC
CKD-Incising-CCA-HTD	CICH
CKD-Nonincising-CCA-HTD	CNCH
HTD-Incising-CCA-CKD	HICC
HTD-Nonincising-CCA-CKD	HNCC
HTD-Incising-CCA-HTD	HICH
HTD-Nonincising-CCA-HTD	HNCH

[1] CKD, CCA, and HTD represents conventional kiln drying, CCA-treatment, and high-temprature drying, respectively.

Drying defects due to initial drying and redrying after treatment were measured. Five pieces of lumber from each treatment group were randomly sampled for measuring surface checks. Checks developed during intial drying were marked with a red crayon before CCA-treatment in order to distinguish from checks developed during redrying. The length of checks was measured using a digital caliper, and the width of checks using a special measuring device.

Warping was measured in all pieces of dried material. Bow, crook, and twist were measured after initial drying and redrying. This consisted of placing the piece of lumber on a flat table with a clamp at one end. The bow, crook, and twist were measured in 16ths of an inch(1.6㎜) by placing a graduated metal wedge between the lumber and the table at the point of the greatest deviation.

3. RESULTS AND DISCUSSION

3.1 Drying Rate

The initial, final MC, and drying rate for each drying charge is given in Table 2. Drying curve, a graphical representation of the MC of a kiln charge over drying time for each drying charge is illustrated in Fig. 1.

Final MC of high-temperature dried material was slightly lower than that of conventionally dried material regardless of initial drying and redrying. This result was in agreement with published literature(Lowery et al. 1968), even though the difference was very small. It does appear that the average drying rate from the green condition to final MC using HTD schedule was approximately 2.5

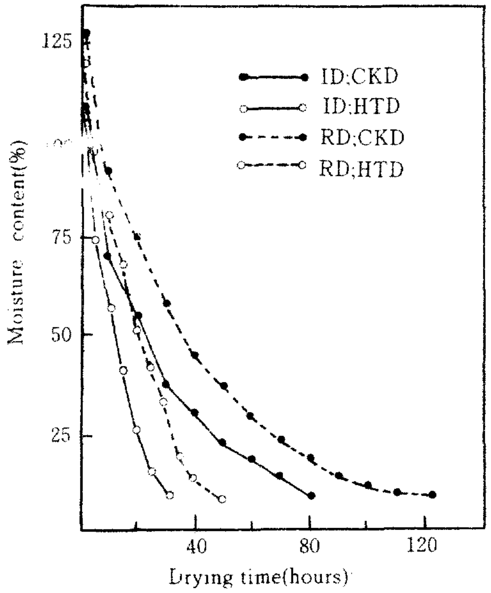

Fig. 1. Drying curve for each drying charge

times as fast as that in CKD conditions for both initial drying and redrying. The slower drying rate with HTD schedule found in this study compared to other HTD research(about four times as fast as that in CKD) could be attributed to the relatively mild drying conditions employed and possibly poor permeability of the heartwood of lodgepole pine. However, similar drying rate was reported with the HTD of lodgepole pine stud(Luza 1972).

Regardless of CKD and HTD schedule, drying rate of redrying was somewhat lower (approximately 30 percent) than that of initial drying. This decreased rate was attributed to the decrease in rate in the hygroscopic range(from 30 percent MC to final MC) as shown in Table 2. However, no difference in drying rate between the two drying schedules was observed from the green condition to 30 percent MC. It is believed that this decreased rate with the redrying of CCA-treated material might be attributed to some impediment of available bound water pathways due to the salt deposition in the cell wall structure by CCA-treatment.

3.2 Drying Defects

3.2.1 Surface Checks

Table 3 gives data on surface check development for initial drying and redrying along with incising and non-incising. After initial drying, as shown in Table 3, check formation was much more severe in high-temperature dried material than in conventionally dried material, and also more checks developed in high-temperature dried material. This could be explained by the difference in the moisture gradients (and related internal stress gradients) that would be developed during the two drying conditions.

Table 2. Initial, final moisture content(MC), and drying rates for each drying charge

Drying Charge	Initial MC(%)	Final MC(%)	Drying rates(%/hr)		
			Green−30%	30%−Target MC	Avg
Initial drying					
CKD	111.8	8.8	2.05	0.52	1.27
HTD	108.1	8.4	4.11	1.80	3.12
Redrying					
CKD	130.6	8.9	2.10	0.32	1.00
HTD	127.0	8.6	4.23	1.02	2.42

Table 3. Average values for check parameters according to treatment group

Treatment group	Check length(cm)				Check width(cm)			
	After ID*1		After RD*2		After ID		After RD	
	Avg.	CV*3(%)	Avg.	CV(%)	Avg.	CV(%)	Avg.	CV(%)
CICC	19.66	47	37.97(93)*4	42	0.99	21	1.65(69)	24
CNCC	25.93	40	37.69(45)	47	1.68	24	2.26(34)	30
CICH	22.20	36	44.27(99)	40	1.09	19	2.08(90)	19
CNCH	21.26	51	31.72(49)	46	1.55	17	2.26(47)	23
HICC	59.51	61	98.73(66)	56	4.32	31	7.09(64)	30
HNCC	67.03	54	90.65(35)	64	3.63	21	4.29(18)	27
HICH	53.70	59	94.67(76)	60	3.15	27	5.79(85)	33
HNCH	57.20	64	85.42(49)	71	3.28	37	4.29(31)	38

*1. ID represents initial drying.

*2. RD represents redrying.

*3. CV represents coefficient of variation.

*4. Values in parenthesis show percent increase in check parameters(length and width) after redrying.

After CCA-treatment and redrying, there was no big difference in increase in check formation between the two drying schedules even though check formation was slightly severe in the high-temperature redried material. Most of checks which were developed during initial drying closed during CCA-treatment and partially reopened at an early stages of redrying. These checks extended their length and width as redrying progressed. In addition, a small number of checks were newly developed during redrying, particularly along the incision scar in the incised material. It was also noted that checks associated with the incision scar were somewhat deeper than other check types as would be expected. Almost all surface checks were very shallow and would not be considered of importance in influencing lumber properties. Therefore, HTD schedule for redrying CCA-treated material could be employed since some surface checks in construction-grade lumber are acceptable, even though the severity of check formation was greater with HTD than with CKD regardless of initial drying and redrying.

Of all the pieces examined for surface checks, about 90 percent had the majority of checks on the bark side of the piece.

3.2.2 Warpage

Table 4 gives the average amount of warp of each treatment group as determined by total deflection from the reference planes measured in 16ths of an inch(1.6mm).

Regardless of drying schedule, more than half of warp observed was a combination of bow, crook, and twist. Bow was the least severe type of warp and is probably more easily restrained by applied concrete weights than crook and twist. Crook was unexpectedly severe in the study, possibly due to the presence of juvenile wood at the narrow edge of lumber in some test material as shown in

Table 4. Mean total deviations of warp for each treatment group (unit : mm)

Treatment group	After ID*1				After RD*2			
	Crook	Bow	Twist	Total	Crook	Bow	Twist	Total
CICC	4.83	2.29	3.30	10.41	6.86	3.30	5.08	15.24(48)*3
CNCC	5.33	2.54	3.30	11.08	7.37	3.30	4.06	14.73(31)
CICH	5.33	2.03	3.30	10.67	7.37	2.54	4.32	14.22(32)
CNCH	5.33	2.54	3.05	10.67	6.10	2.79	3.30	11.94(12)
HICC	4.32	1.78	2.54	8.38	5.33	2.03	3.05	10.67(25)
HNCC	4.57	2.29	3.30	9.91	5.59	2.54	3.56	11.68(16)
HICH	4.06	2.54	3.05	9.65	4.83	2.79	3.81	11.43(19)
HNCH	3.81	2.54	2.79	4.57	4.57	2.79	3.05	10.41(14)

*1. ID represents initial drying.
*2. RD represents redrying.
*3. Values in parenthesis show percent increase in total warp after redrying.

Fig. 2. When comparing the degree of warp between conventionally and high-temperature dried material, the former showed more warp than the latter irrespective of initial drying and redrying. This fact corroborates published data(Kimball and Lowery 1967, Koch 1972, Luza 1972, and Salamon 1966).

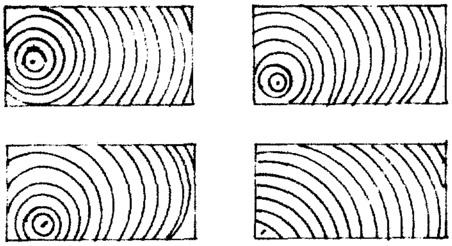

Fig. 2. Example of the location of pith and ring orientation

The mean values of each type of warp were compared with the maximum allowances for warp in lodgepole pine structural light framing having the same dimensions with test material as set by the WWPA grading rules (Table 5). All material remained within current WWPA grading rule limits(No. 2 grade basis) throughout initial drying and redrying after CCA-treatment.

Table 5. Maximum warp allowed by the current WWPA grading rule in 2 by 4's, 8 feet long(WWPA 1983)

Lumber class	Crook (mm)	Bow (mm)	Twist (mm)
Select structural	6.25	19.05	9.65
No. 1	6.35	19.05	9.65
No. 2	9.65	28.58	12.70
No. 3	12.70	38.10	19.05

3.2.3 Other Drying Defects

Some end checks were developed before initial drying. During initial drying some of these checks were enlarged. A few initial end checks developed into end splits during initial drying. End checks somewhat increased during redrying. About half of the intergrown knot checks during initial drying, and then extended as redrying progressed. Also a few ring failure were observed in the cross section. All defects mentioned above were more severe in high-temperature dried material than in conventionally dried material.

Although resin exudation was observed in both conventionally and high-temperature dried material, the amount of exudation was more severe in the latter. Color change in the high-temperature dried material was also observed after initial drying. However, this coloration was not a problem in final treated products because of the CCA salt coloration.

4. CONCLUSIONS

From the results of this study the following conclusions were made:

1. Drying rate of HTD was 2.5 times as fast as that of CKD regardless of initial drying and redrying. When compared drying rate between initial drying and redrying, regardless of CKD and HTD, drying rate of redrying was somewhat slower than that of initial drying. This decreased drying rate with HTD could be attributed to the decreased in rate in the hygroscopic range.
2. Surface check formation after initial drying was greater in high-temperature dried material than in conventionally dried material. However, there was no difference in further check formation during redrying between the two drying schedules.
3. Check formation during redrying was mostly due to the reopening and extension of checks developed during initial drying in non-incised material and to the extension of the incision scar in the case of incised material.
4. The degree of warp was somewhat greater in conventionally dried material compared to high-temperature dried material irrespective of initial drying and redrying. Warp developed throughout the initial drying and redrying was not in excess of current grading rule limitations.
5. When considered drying rate and drying defects observed in this study between CKD and HTD, it could be concluded that HTD could be used to condition lodgepole pine dimension stock before treatment and also to redry treated stock without significant losses in lumber quality.

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