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Monitoring the Wood Drying Process with an Image Processing System (I) : Drying Characteristics of Tree Disk of Black Locust*1

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ABSTRACT

Acquisition of precise information on drying characteristics of wood is indispensable for the improvement of drying schedules and wood quality. Recognition of the exact moisture content at which drying defects such as checks occur during drying with given drying conditions may be essential to reduce drying losses. In this study an image-processing system was combined with a laboratory-scale wood dry kiln for experiments and the surface of tree disk of black locust (*Robinia pseudoacacia* L.) was monitored to investigate the behavior of check formation over all the drying process. This system showed good potential for improving drying schedules and wood product quality.

Keywords : Wood drying, Tree disk, Image processing, Formation of checks

1. INTRODUCTION

Acquisition of precise information about drying characteristics of wood during drying is indispensable for the improvement of drying schedules and wood quality. Recognition of the exact moisture content (MC) at which drying defects such as checks occur during drying with given drying conditions may be essential for finding ways to reduce losses appearing on kiln drying of wood. Since Noguchi et al (1980) detected the acoustic emission (AE) signals during drying to monitor the internal stresses which caused checking, there has been lots of study to apply AE monitoring technique to monitor and control drying process(Noguchi et al, 1983, 1987). Cunderlik et al (1996) monitored the drying cracks by AE and scanning electron microscopic methods. However it was not possible to observe continuously the behavior of defects during drying. Observation and analysis of the images of defects that change continuously during drying may be a good way to monitor the drying characteristics. But the image processing technique generally has been adapted to decide lumber grade or detect defects for optimization of sawing process(Szymani & McDonald, 1981).

In this study image-processing system was combined with a laboratory-scale wood dry kiln for experiments and monitored the surface of tree disk of black locust (*Robinia pseudoacacia*

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L.) to investigate the behavior of check formation over all the drying process. Potential of this system for improving drying schedules and wood product quality was also evaluated.

2. MATERIALS and METHODS

2.1. Drying characteristics monitoring system

Figure 1 shows drying characteristics monitoring system. Drying temperature, relative humidity(RH) and air velocity were automatically controlled by microcomputer system. MC during drying was determined by a load cell and the data for MC, drying temperature, RH and air velocity were recorded by a microcomputer. In this study air velocity was fixed at 1.5 m/sec.

The image processing system consists of a CCD camera with a resolution of 270,000 pixels, a frame grabber board with a resolution of 640 pixels by 480 pixels, and a lighting equipment. Software for data acquisition and control was developed and combined with that for image processing together. The image of tree disk was taken and saved at every 10 minutes and analyzed.

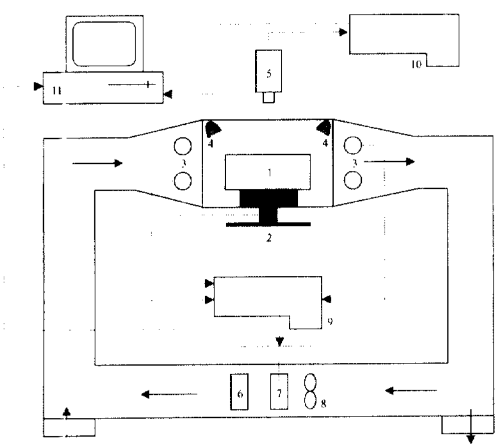

Fig. 1. Schematic of drying characteristics monitoring system. 1. Wood specimen; 2. Load cell; 3. Temperature and relative humidity sensors; 4. Lights; 5. CCD camera; 6. Steam generator; 7. Electrical heater; 8. Fan; 9. Data acquisition and control board; 10. Frame grabber board; 11. Personal computer.

2.2. Samples and drying conditions

40 mm-thick disks of green black locust with diameters from 17 to 20 cm were selected as samples because the appearance of severe end-checks or V-crack was expected during drying of tree disks and black locust is one of the check-prone species. Tree disks are used as a raw material for carvings, turnings and numerous other novelty items mainly due to the inherent beauty of log cross sections.

All drying tests were conducted with green tree disk samples using three drying conditions shown as Table 1. Drying temperature was maintained uniformly from green to 10% MC at 60℃ for test 1, 45℃ for test 2 and 35℃ for test 3, respectively. RH was fixed at 90% from green to 30% MC for all drying tests and lowered to 80% for test 1 and test 2 , and 40% for test 3 from 30% to 10% MC to save drying time.

2.3. Image analysis technique

Sample was put on the load cell tray that was covered with black sheet. The gray level of

Table 1. Drying conditions for 40 mm-thick tree disks of black locust.

Moisture content	Test 1		Test 2		Test 3	
	T(℃)	RH (%)	T(℃)	RH (%)	T(℃)	RH (%)
Green ~ 30%	60	90	45	90	35	90
30% ~ 10%	60	80	45	80	35	40

T: temperature, RH: relative humidity

black sheet was about 45, which was low enough to discriminate the sample from the background. It was found at the preliminary tests that the range of gray level for bark, sapwood, heartwood, and end check occurred on the end surface of the sample was 105~160, 185~200, 165~175 and 50~80, respectively. End check had lower gay level than any other regions and it was possible to discriminate end checks from sound wood. Each end check was labeled and number of pixels was counted. Therefore, number of labels represented the number of the occurred end checks and number of pixels in each end check represented the area of each end check.

3. RESULTS and DISCUSSION

Figure 2 illustrates the process in which V-crack developed at test 1. Drying characteristics curves which are the results from the analysis of tree disk images during drying are shown in Figure 3. Checks occurred at the pith side of disk at the beginning stage and then extended in radial direction until the maximum number of checks was shown at about 45% MC. Number of checks decreased gradually as drying progressed below 30% MC. Total area

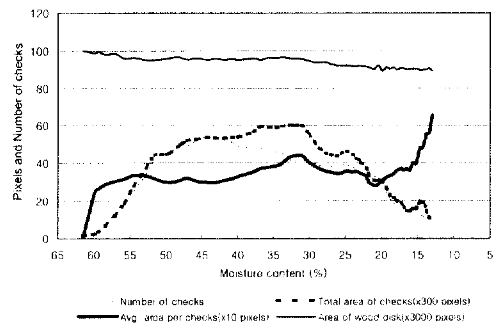

Fig. 3. Drying characteristics curves of 40 mm-thick tree disk of black locust at Test 1.

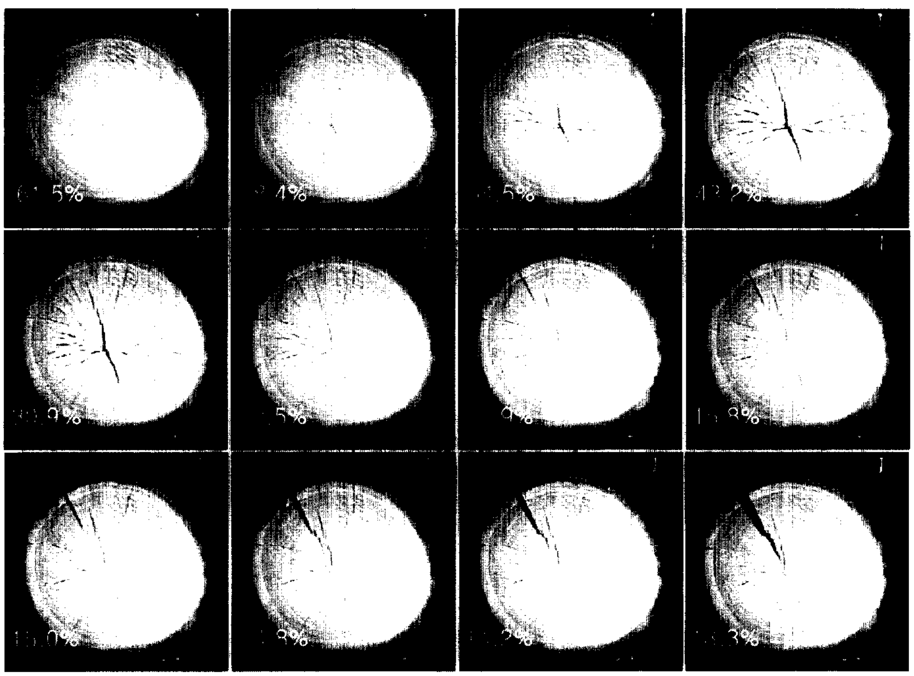

Fig. 2. Development of check formation on 40 mm- thick tree disk of black locust with different MCs during drying at Test 1.

of checks showed same trend with a peak at about 30% MC. However checks occurred near bark at about 30% MC and enlarged as MC lowered. V-crack was developed when the check on the circumference of disk extended and connected with check around the center of disk. Therefore average area per check which maintained relatively constant until MC reached 15% increased rapidly when V-crack occurred. It took 57 hours to dry from 61.5% to 13.3% MC and average drying rate was about 0.85%/hr. The reason for this high drying rate is that moisture moves much faster in the longitudinal direction than in both transverse directions and the main surface for moisture evaporation of tree disk is end surface(Lee, 1990). Areal shrinkage of tree disk was about 12.7%, where the area of disk was expressed by the number of pixels.

In spite of lowering the drying temperature from 60℃ to 45℃ at test 2 there was no significant difference between test 1 and test 2. Peaks of number and area of checks were shown at about 40% MC and V-crack was also developed around 15% MC. Sixty-three hours were taken to dry from 53.8% to 13.3% MC and drying rate was 0.64%/hr (Figure 4 and Figure 5). Areal shrinkage was about 8.0%.

Drying rate was sufficiently decreased by

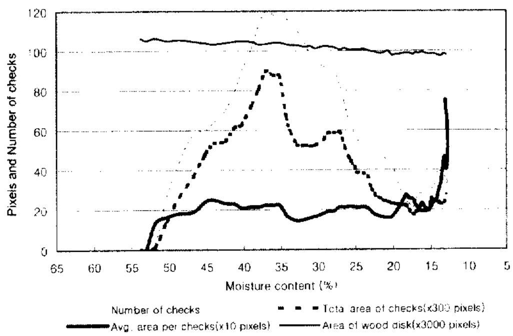

Fig. 5. Drying characteristics curves of 40 mm-thick tree disk of black locust at Test 2.

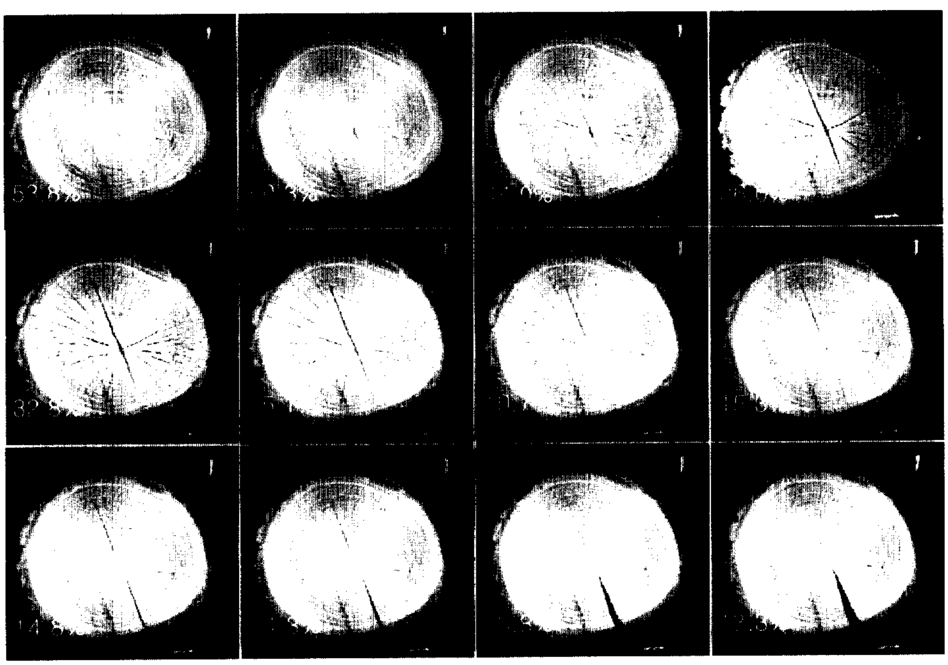

Fig. 4. Development of check formation on 40 mm-thick tree disk of black locust with different MCs during drying at Test 2.

lowering the drying temperature to 35℃ at test 3 and V-crack was not developed even though there were some checks occurred at the center of disk in the early stage of drying as shown in Figure 6. It took about 110 hours to dry from 51.1% to 8.6% MC and drying rate was about 0.39%/hr. The height of all the drying characteristics curves were significantly lower than those of test 1 and test 2 (Figure 7). However areal shrinkage was 9.2% which was higher than that of test 2 and it was not possible to control the amount of shrinkage. Therefore decreasing the drying rate especially in the early drying stage may be a way to avoid V-crack in drying tree disks. Kubler(1974) has tried to avoid the V-shape cracks by decreasing the drying rate of cross sections of bur oak.

4. CONCLUSION

End-checks occurred immediately on 40 mm-thick tree disks of black locust at the beginning stage at temperature of 60 or 45℃. Number of checks showed its maximum at about 40~45% MC and decreased gradually as drying progressed and average area per check increased rapidly when V-crack occurred at about 15% MC. It was possible to prevent the development of V-crack by lowering the drying temperature

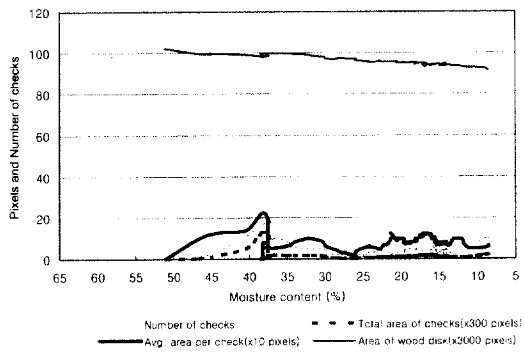

Fig. 7. Drying characteristics curves of 40 mm-thick tree disk of black locust at Test 3.

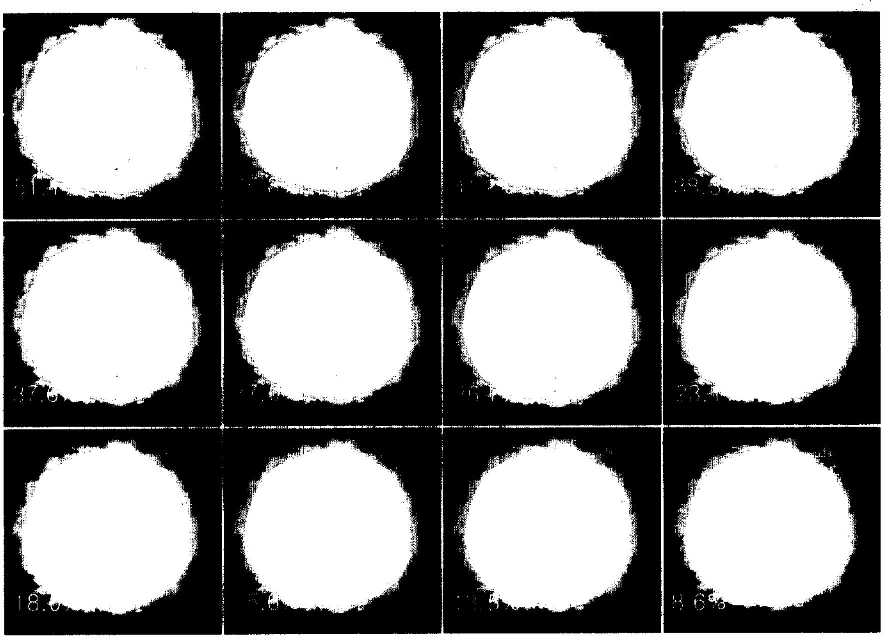

Fig. 6. Development of check formation on 40 mm-thick tree disk of black locust with different MCs during drying at Test 3.

to 35℃ and decreasing the drying rate.

On this study drying characteristics monitoring system showed a good potential for developing and improving drying schedules. Therefore further researches on the application of this system to dimension lumber are to be needed.

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