Lumber defect detection abilities of furniture rough mill employees

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Abstract

To cut parts from boards, rough mill employees must be able to see defects, calculate the proper location of cuts, manually position the board, and remain alert. The objective of this study was to evaluate how well rough mill employees perform the task of recognizing, locating, and identifying surface defects independent of the calculation and positioning process. Using a scoring procedure developed for this study, it was found that six rough mill employees in three plants performed at about 68 percent of perfect. Thus, a computer vision system now under development need not be perfect to improve on current practice. The economic potential is considerable for such equipment if only a small yield improvement can be obtained.

Objective

The remanufacture of lumber into specific size parts for furniture has not changed appreciably in the last century. Basically, the process consists of subjecting rough sawn, kiln-dried, random width and length lumber to a crosscut sawing and ripsawing process that produces the rough parts in the quantity desired. The lumber is sometimes presurfaced but more frequently jointed and surfaced after cutting into smaller sizes.

In both the crosscut and ripsawing operations, the operator visually examines the board for defects and attempts to position the saw cuts to eliminate unacceptable defects while maximizing the yield of usable parts. Operators must 1) be able to see and recognize the defects; 2) have the mental aptitude to properly locate the cuts; 3) possess the physical strength to position the board manually; 4) resist boredom and maintain an alert mental attitude; and 5) while looking at one side, remember what the other side looks like. Failure of any one of these five elements (recognition, calculation, positioning, alertness, and memory) will result in diminished yield and higher costs. In order to maintain productivity, only limited amounts of time are allowed for the recognition and calculation process. In addition, rough mills typically have a work environment which can easily distract the operator. All these factors combine to lessen the potential for perfect worker performance.

Analyses of plant operations have shown that yield improvements are the key to success in the rough mill. Rough mill training programs have been devised and various devices have been used to assist the operators, including limited computerization of the calculation problem. The authors have participated in numerous yield tests and training programs and have found them generally useful only within a limited time frame. The rough mill will frequently show considerable improvement after yield testing and employee training, but the favorable results tend to dissipate within 6 months to a year for a number of reasons. For example, trainable employees are also trainable for higher skilled jobs and are transferred to a different department. Untrained new employees then move into the rough mill at the entrance level. Additionally, management may turn its attention to other departments, feeling the rough mill problem has been solved.

The problem of maintaining productivity in the rough mill will continue, and the ultimate solution may

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TABLE 1 - *Defects represented in the sample with defect code in parentheses.*

(K)	Knot	(S)	Stain
(P)	Pith	(D)	Decay
(WH)	Worm holes	(C)	Split, check, or shake
(MS)	Mineral streak	(H)	Holes
(W)	Wane	(B)	Included bark

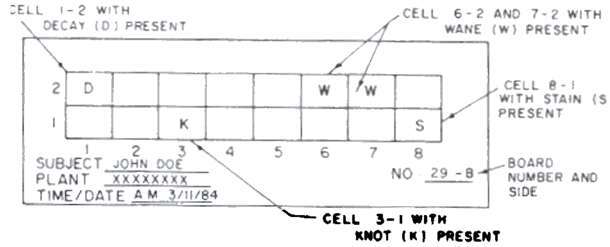

Figure 1 - Test sheet used to evaluate worker performance

at some future time involve the virtual elimination of the employees through use of highly sophisticated computer-aided manufacturing methods. Such a system has been proposed and reported elsewhere (3, 4). In the system, computer vision will be used to locate and identify defects on surfaced lumber. A prototype software system has been developed and tested (1).

Yield studies (2) have been performed in which boards were marked for defects and the desired parts carefully fitted around the defects to determine the maximum yield that could be produced from that board (the calculation process). However, an extensive survey of the literature revealed that plant testing of employee defect detection ability, independent of the calculation and positioning functions, had not been explored nor had experimental techniques been developed.

The objective of this study was to evaluate how well rough mill employees performed the task of recognizing, locating, and identifying defects on surfaced lumber. Such data are needed to compare the performance of machines designed to do these functions. A secondary objective was to evaluate some simple tests that might relate to performance and aid in improving employee selection and training.

Experimental procedure

Materials and worker testing

Five hundred board feet of air-dry, surfaced, random width, 8-foot-long, No. 2 Common southern red oak were selected for the test sample from a 1,000-board-foot supply. Boards were selected so that each contained five or more of the defects listed in Table 1. All defects were represented in the total sample.

A data sheet containing an outline of the board was divided into 16 identifiable rectangular cells (Fig. 1). Each board was identified and carefully examined on both sides by the principal researcher to establish the defects present and their cell location. These data were recorded (by defect code) on individual test sheets for each board. Sheets of the same type were used in plant tests but did not contain the defect codes.

Three different furniture dimension plants were selected for study. At each plant, two experienced rough mill employees who expressed willingness to participate were tested. Each was tested twice, once during an "alert" and once during a "non-alert" time. A "non-alert" time was defined as at the end of the workday on a Thursday or Friday. An "alert" time was the morning of a Tuesday or Wednesday.

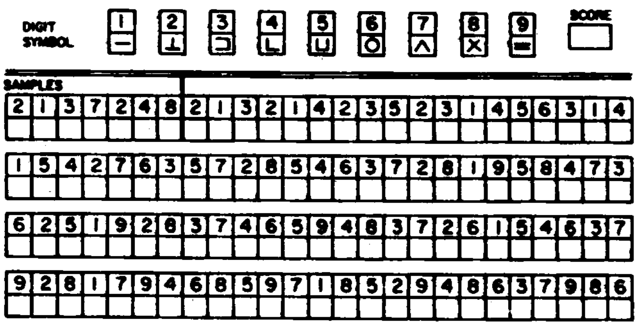

Figure 2. — Test sheet for Wais-R digit symbol recognition test.

Test subjects were observed during normal work to determine the average time needed to process boards at the work station. The average time per board was used to establish a standard time allowed each subject to observe test boards. Each subject was shown sample boards containing the defects and a list of the defect codes.

During the test, the subject observed a given board for the standard time allotted, then turned and marked the test sheet with the defect codes in the perceived cells as in Figure 1. A new test board was then presented and the process repeated. A minimum test period of one-half hour was used during which about 30 boards were inspected by each subject. The opposite side of the same set of boards was used for the "non-alert" time test. All six subjects reviewed the same boards.

In addition, each subject was given a visual acuity or "eye chart" test for both right and left eyes using a Graham-Field No. 2867-1261 chart at 20-foot distance and a standard color chart test to detect possible color recognition problems. Subjects were also given a 90-second digit symbol recognition test from the revised Wechsler Adult Intelligence Scale (Wais-R) (5). The test evaluates the subject's hand-eye coordination and memory, and was given to evaluate its potential as an aptitude test for potential job performance. An evaluation sheet is shown in Figure 2. In this test, the subject must visually associate the symbol related to the digit and mark the test sheet with the proper symbol below the number. The subject's score is based on the total number of correct responses made within the allotted time.

Scoring

Scoring of the test results was based on the subject's ability to recognize the number, type, and cell location of defects as a percentage of the predetermined actual. If for a given board, the subject determined the exact number of defects, correctly identified all the defects and placed them in the correct cell, a perfect score of 100 percent was given for each criterion. Anything less than a perfect answer was based on the relative proportion correct for each board but could not exceed 100 percent. Thus, if a subject recalled only 5 of 10 defects on a board (even though they were incorrectly identified as to type and location) a score of 50 percent was given for number of defects.

Scoring of the defect location and type category consisted of a weighted point total giving 100 percent for correctly identifying the proper cell of a defect and 50 percent when the defect was placed in an adjacent cell. When a defect was placed beyond the adjacent cell, a zero was given. For location scoring, the defect need not be correctly identified. A score of 100 percent was given for the defect type when the defect was correctly identified and located in the correct cell or within two adjacent cells. A zero score was given when the defect was incorrectly identified or beyond the two adjacent cell limitations.

The scores for each board were then totaled and divided by the number of boards evaluated by the subject to compute a mean score for each of the three criteria. A composite score was also computed as the mean of the three criteria scores.

Results

The results of the rough mill employee testing are given in Table 2. The results show substantially lower than perfect scores in all three criteria and in composite scores. The results are surprising since all subjects were experienced and willing rough mill employees. There was considerable variation in scores between subjects and between companies in all three criteria. The composite scores ranged from 59 to 74 percent. This variation probably reflects employee skill variations, degree of training, general management attitudes, and the product being manufactured.

There appeared to be little consistent difference in test scores for individual criteria or composite scores between "alert" time and a "non-alert" time. In the morning, mean times for six subjects in three plants gave 68 percent of perfect for number of defects, 74 percent of perfect for location of defects, and 61 percent for identification of defects. In the "non-alert" time taken in the afternoon, the mean score was 74 percent for number of defects, 79 percent for location, and 54 percent for correct identification of the defects. Mean composite scores were 68 percent for "alert" time and 69 percent for "non-alert" time. One would expect lower "non-alert" scores had the tests been conducted over a longer time period.

Considering the three test criteria averaged over all subjects, companies, and test times, the highest mean score achieved was for location (avg. 74.5%) followed by number of defects (avg. 71.0%). The score for defect type was lowest (avg. 65.0%). It should be noted that the scoring technique used permitted positive location scoring for a miss of 1 foot. The low score for defect identification was partly the result of misnaming defects. However, some manufacturers allow certain defects and not others. Rough mill employees should be able to name defects as they appear on a board for ease of communication with quality control supervisors.

The grand mean composite score was 68 percent. It seems likely that this score would be even lower if the adverse effects of boredom and fatigue were considered and the subjects had not been willing, experienced employees, who were aware they were being tested.

Table 3 shows the results of the 90-second spatial digit recognition, visual acuity, and color tests. The Wais-R digit symbol score did not correlate with the test subject's performance on defect recognition. Scores for the test ranged from 32 to 78. The average was 49. The test may still be useful for new rough mill employees. Given two possible candidates for a rough mill position, the authors would choose the higher scoring individual on this test, other things being equal. There is also a possibility of using sample test boards similar to those

TABLE 2. — *Visual defect detection scores by rough mill employees.*

	Alert time				Non-alert time			
	No.	Location	Type	Composite	No.	Location	Type	Composite
				(% of actual)				
Company 1								
Subject 1	94	66	48	69	84	79	46	
Subject 2	74	53	49	59	100	57	56	
Company 2								
Subject 3	58	89	71	73	66	84	66	72
Subject 4	55	84	71	70	53	86	45	61
Company 3								
Subject 5	69	77	64	70	66	79	50	65
Subject 6	58	75	64	66	74	86	62	74
Mean	68	74	61	68	74	79	54	69

TABLE 3. — *Results of digit symbol recognition, visual acuity, and color testing.*

	Spatial digit symbol recognition	Visual acuity R.	Visual acuity L.	Color	Mean composite score
					(%)
Company 1					
Subject 1	78	20/25	20/40	Green	69
Subject 2	49	20/20	20/20	OK	64
Company 2					
Subject 3	43	20/20	20/20	Red	72
Subject 4	43	20/30	20/30	OK	65
Company 3					
Subject 5	50	20/70	20/50	OK	67
Subject 6	32	20/20	20/20	OK	71

in this study to determine the aptitude of new employees.

In the visual acuity test, a value of 20/20 denotes good vision while a higher second number indicates impaired vision. The vision acuity test did not correlate with the recognition score. In contrast to the actual work situation, the employees could position themselves closer to the boards and may have been able to see better than the vision test would indicate. The test revealed two subjects with rather poor vision in both eyes. Left uncorrected, such visual acuity would make defect detection at any distance very difficult.

Color blindness would make defects in certain species very difficult to see, and some defects are recognized by color. Additionally, color matching of parts is sometimes done in the rough mill. Two subjects had poor color definition: Subject No. 1 was deficient in blue and Subject No. 3 in red. Color blindness may or may not be important depending on the color and degree. But we would hypothesize that color blindness would affect the subject's ability to recognize defects.

Conclusion

This study of six experienced rough mill operators tested in three plants indicates a performance of about 68 percent of perfect in recognizing, locating, and identifying defects in surfaced southern red oak under the test conditions used. Additional testing of employees at other plants should be done to further evaluate the results obtained and procedures used in this study. The detection of a number of rough mill employees with poor vision suggests that vision should be checked in any operation requiring visual acuity.

It is likely that a machine that could perform the location and defect recognition functions will not be perfect, but such equipment holds considerable economic potential if only a small yield improvement could be obtained. Also, such equipment would not be affected by fatigue and other human factors that may diminish yield.

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