Improving Lumber Yield Using a Dual System

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ABSTRACT

Rough mills embody the process of cutting up kiln-dried lumber to components used by discrete wood products manufacturers to manufacture products like furniture, kitchen cabinets, flooring, or other items. Rough mills traditionally have either ripped the lumber first (e.g., the lumber is first cut into strips lengthwise) then cut the strips to the required part lengths or they crosscut the lumber first to part lengths (e.g., cutting the lumber to shorter, full width segments) then ripped the segments to the required part widths. Both processes offer advantages and disadvantages and, depending on the input lumber geometry (e.g., size) and the cutting bill requirements (e.g., the size of the resulting components) may result in higher yield for individual cases. Using ROMI 4.1, a rough mill simulator that simulates real-world rough mills and can combine rip and chop operations, this study investigated the potential benefits from using such a dual system. Findings suggest that cutting bills requiring small parts when cutting from lower quality lumber produce better yield when a rip-first approach is used, while cutting bills asking for wide and long parts perform better when material is chopped first. However, in every case, yield can still be improved when the decision to rip or to chop first is made on each individual board.

1. Introduction

Manufacturers of solid wood products like furniture, flooring, kitchen cabinetry as well as a plethora of other products face the task of cutting components from rough, kiln-dried lumber. The process is complicated because lumber is a heterogeneous raw material with varying widths and lengths and contain unusable defective areas spread throughout the boards [1]. Such components are cut in rough mills, e.g., processing facilities where a series of machines and allied equipment is used to cut components from kiln-dried lumber [2]. Rough mills strive to produce these components at minimum overall cost in the quality and quantity required [3]. An important measure for the effectiveness and efficiency of a rough is lumber yield, which is the ratio of the aggregate components surface area output to the aggregate lumber surface area input [1]. Rough mill managers pay close attention to lumber yield since lumber costs typically make up as much as 40 to 60% of total hardwood product costs [4]. Thus, a one to two percent increase in lumber yield for an average furniture manufacturer in the U.S. can potentially save the company between $150,000 and $300,000 a year [5].

Traditionally, there have been two distinct methods of processing lumber into rough dimension parts in rough mills" rip-first (sawing lumber along its length into narrower pieces) and chop-first (sawing lumber across its length into shorter pieces). In rip-first rough mills, a board is first ripped into strips that are of the same widths as the rough dimension parts needed. These long strips are then chopped to part lengths while avoiding any unacceptable defects. In chop-first rough mills, the board is chopped to part lengths while avoiding the larger unacceptable defects. The board segments chopped to length are then ripped to the widths of the rough dimension parts, while avoiding any remaining unacceptable defects. In general, rip-first processing favors the production of longer, narrower parts, while chop-first processing favors the production of larger, wider parts. It is no surprise then, that the choice of processing system is usually dictated by the demands of the cutting bill (e.g., the list of component part sizes and quantities required for an order).

Depending on the distribution of component sizes in a cutting bill (i.e., if a cutting bill asks for more narrow and long components or for more wide and short components), some cutting bills are better suited for rip-first or chop-first processing. Also, the type of processing (rip-first or chop-first) is dependent on the lumber quality (called "grade" in industry parlance) used for a given job. Chop-first processing typically performs best when processing higher grades

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(hardwood lumber is sorted according to its quality, which in turn is determined by the presence of defects; higher grades contain a higher proportion of defect-free areas than lower grades), while rip-first processing has an advantage with lower-grade lumber. Thus, the selection of the processing method becomes a compromise, one that is typically decided by the type of processing system (rip-first or chop-first) installed in a given rough mill. However, depending on the cutting bill requirements and the lumber grade available, yield improvement potential exists for a dual-line mill, this is one that has both rip-first and chop-first processing lines.

The importance of improving yield in the rough mill and thereby reducing lumber costs are well documented. West and Hansen [6] estimated that total material costs for U.S. furniture producers are about 50% of total product costs. Lumber costs are between a quarter and a half of the total material costs for solid wood furniture [8][7][9][4]. Accordingly, Wengert and Lamb [10] p. 19) state that "*Efforts to reduce operating costs by saving labor, saving energy, or reducing drying time are usually quite unrewarding* [compared to improvements in material yield]." Saving 1% of raw material (i.e., increasing yield by 1 %) potentially saves 2% of total production costs [5][10]. Improving rough mill yield not only saves raw material (cost), but at the same time increases production capacity of the operation because less lumber is processed for the same output [11].

2. METHODS

ROMI 4 is a rough mill simulator designed to simulate a wide range of rough mill operations using digitized board data and cutting bills that can consist of as many as 300 components [11]. For this study, ROMI 4 and a set of five cutting bills were used to examine the potential yield benefits of combining rip-first and chop-first processing in a dual-line rough mill. Table 1 presents a summary of the cutting bill specifications used. The cutting bills are listed in order from the easiest to the hardest part demands, where the difficulty depends on the number of different dimensions and the sizes of the parts. Cutting bills A, B, D, and E are industrial cutting bills from actual furniture and case goods rough mills. Cutting bill A is for the production of kitchen cabinet parts, B for bedroom furniture, and cutting bills D and E are for producing large case goods. These cutting bills were also used as test cases for the development of the part prioritization methods used in ROMI-RIP, a previous version of the simulator which used only a rip-first approach [12]. The remaining cutting bill, C, was developed by Buehlmann to investigate yield for various rip-first rough mill configurations and grade mix specifications [1].

Table 1. Descriptions and difficulty rankings of cutting bills used.

Cutting bill	Widths	Lengths	Comments
(easiest)			
A	7[a] 1.75 to 5.25[b]	14[a] 10 to 31.5[b]	Most parts are narrow. Wider parts are narrow.
B	7 1.5 to 4.25	12 19.5 to 87.75	Wide cuttings are short. Good distribution of lengths and widths.
C	4 1.5 to 4.25	5 10 to 72.5	Mix of long and short parts. Most parts demands are in narrower widths and medium lengths. Large need of long and wide parts.
D	5 2 to 4.5	5 16 to 84	Widest parts are short. Equal numbers of short and long parts.
E	5 4 to 6	3 29 to 84	Only one short and two very long parts. More long, wide parts than short.
(Hardest)			

[a] Number of different sizes requested
[b] Range over all different sizes (inches)

ROMI 4 [11] simulates a dual-line rough mill (a mill that can process a board using rip-first or chop-first to maximize yield) by sequentially determining the optimal yield for each board from rip-first and chop-first processing. The processing method that gives the highest component yield is used to process the board for the final yield-count. ROMI 4 tracks the count, grade, and footage of the boards processed such that yield is reported by processing method, by lumber grade, and overall. ROMI 4 was set-up in such a way that the dual-line rough mill simulated the use of a gang ripsaw with a fixed-blade-best-feed arbor and a single chop-saw. Two single-line rough mill configurations were simulated, a rip-first system with a fixed-blade-best-feed gang ripsaw, and a chop-first system. Essentially, we made a comparison between a dual-line system and a pure rip-first system and a chop-first system working independently. The optimal fixed-blade arbor spacing configurations were determined using the arbor optimization feature of ROMI 4. The optimizer determines the best fixed-blade spacing sequence based on cutting bill part sizes, part quantities, and lumber width distribution.

Five different lumber grade mix samples were created; from highest to lowest quality: 1) 100% FAS; 2) 50% FAS 50% 1 Common; 3) 25% FAS, 25% 1 Common, and 50% 2 Common; 4) 100% 1 Common; 5) 50 % 1 Common 50% 2 Common; 6) 100% 2 Common. Each grade mix sample was replicated 10 times with each one being a random sample from the entire lumber database [13]. Each cutting bill was processed using the ten random lumber samples for each lumber grade mix for each cutting bill. Thus, a total of 900 simulations were performed (5 cutting bills x 3 processing methods x 6 grade mixes x 10 replicates). The usable yield for each simulation was recorded and averaged within each cutting bill, grade mix, and processing method group. Usable yield is the sum of the primary part yield and salvage yield that was cut to required primary part sizes. No orphan or excess part yields were included in the calculation of the usable yield percentage. Tables 2, 3, 4, 5, 6, and 7 list the average usable yield for each cutting bill and processing combination by lumber grade mix and the difference between dual-line and the rip-first and chop-first methods.

3. RESULTS

Table 2 contains the yield results for the 100% FAS lumber sample for all cutting bills and the yield improvement of the dual-line over the rip-first and the chop-first processing lines. Overall, there is little difference between the three processing methods. For three cutting bills the difference between the dual-line and the rip-first processing line is 0.5% (absolute) part yield or less (Table 2). The greatest difference was with cutting bill B, where the dual-line achieved 4.8% better part yield than did the chop-first processing line. It should be noted that the part size distribution characteristics of cutting bill B (Table 1), which demands a large portion of all component to be long narrow parts, do not favor chop-first processing. In contrast, chop-first processing out-performed rip-first and the dual-line method with cutting bill C by 0.4% (absolute) yield. This unexpected anomaly is due to the way that parts are prioritized by the simulator. While the chop-first component optimized for the production of single large parts on some boards, the rip-first component achieved a higher total of prioritized part values by fitting in more, smaller parts. Thus, the rip-first component missed opportunities to cut larger, harder to obtain part sizes. The end result was that the dual-line and the rip-first systems had to process more lumber to cut the larger part sizes.

Table 2. Yields for FAS lumber and sample cutting bills.

Cutting bill	Dual-line	Rip-first	Chop-first	Dual-line vs rip-first improvement	Dual-line vs chop-first improvement
A	77.1	77.1	75.7	0.0	1.4
B	75.0	74.5	70.3	0.5	4.8
C	78.0	77.8	78.4	0.3	-0.4
D	69.5	68.1	69.5	1.4	0.0
E	70.40	69.38	70.25	1.02	0.15
Average				0.6	1.2

Yield results for the 50% FAS and 50% 1 Common lumber sample are presented in Table 3. Overall, results for this lumber sample followed the same trends as those observed with the 100% FAS lumber sample. However, the differences between the processing methods increased, with dual-line achieving 1.0 and 3.0% part yield better on average than rip-first or chop-first only processing, respectively. In addition, the yield advantage of chop-first on cutting bill C increased to 0.7% part yield.

Table 3. Yields for 50% FAS, 50% 1 Common lumber mix and sample cutting bills.

Cutting bill	Dual-line	Rip-first	Chop-first	Dual-line vs rip-first improvement	Dual-line vs chop-first improvement
A	71.8	71.6	68.0	0.2	3.8
B	67.6	67.6	60.0	0.0	7.6
C	71.1	69.6	71.8	1.5	-0.7
D	58.6	55.6	57.4	3.0	1.2
E	62.9	62.4	60.0	0.5	2.9
Average				1.0	3.0

The third grade mix processed contained 25% FAS, 25% 1 Common, and 50% 2A Common lumber (Table 4). With the exception of cutting bill D, the yield difference between dual-line and rip-first were all 0.4% or less (Table 4). As the quality of the lumber grade mix declines, chop-first yield declines more rapidly than rip-first yield. This is evidenced by the dual-line advantage increasing on average to 7.1% better than chop-first processing.

Table 4. Yields for 25% FAS, 25% 1 Common, and 50% 2A Common lumber mix and sample cutting bills.

Cutting bill	Dual-line	Rip-first	Chop-first	Dual-line vs rip-first improvement	Dual-line vs chop-first improvement
A	64.1	63.8	58.6	0.3	5.5
B	56.7	56.3	46.3	0.4	10.4
C	60.3	60.1	55.2	0.2	5.1
D	43.4	39.9	35.2	3.5	8.2
E	52.5	52.3	46.3	0.3	6.2
Average				0.9	7.1

The dual-line method obtained higher yield than the rip-first or the chop-first systems for all cutting bills using the 100% 1 Common lumber sample. Here, the dual-line system obtained an average of 1.1% and 7.5% (absolute) higher primary yield than did rip-first or chop-first processing, respectively (Table 5).

Table 5. Yields for 1 Common lumber and sample cutting bills.

Cutting bill	Dual-line	Rip-first	Chop-first	Dual-line vs rip-first improvement	Dual-line vs chop-first improvement
A	66.2	65.4	60.4	0.8	5.8
B	59.3	59.0	48.9	0.3	10.4
C	64.2	63.3	58.2	0.9	6.0
D	45.4	42.3	37.1	3.1	8.3
E	55.8	55.6	48.9	0.2	6.9
Average				1.1	7.5

For the 50% 1 Common, 50% 2A Common lumber sample the average improvement increased to 1.5% and 9.7% higher primary yield than did rip-first or chop-first processing, respectively (Table 6). However, with cutting bill E (the most difficult), the dual-line and rip-first processing systems obtained the same yield. This is because in only one or two instances of all the simulation replicates made using the dual-line were any boards processed using the chop-first component of the dual-line system.

Table 6. Yields for 50% 1 Common, and 50% 2A Common lumber mix and sample cutting bills.

Cutting bill	Dual-line	Rip-first	Chop-first	Dual-line vs rip-first improvement	Dual-line vs chop-first improvement
A	60.9	58.8	54.0	2.1	6.9
B	51.7	51.1	39.4	0.6	12.3
C	56.1	55.3	47.2	0.8	8.9
D	34.5	30.4	22.3	4.1	12.2
E	47.8	47.8	39.4	0.0	8.4
Average				1.5	9.7

Using the 100% 2A Common lumber sample, the dual-line method obtained higher yield than the rip-first or chop-first methods for all cutting bills (Table 7). Here the dual-line method obtained an average of 1.9% and 9.1% higher primary yield than did rip-first or chop-first processing, respectively. The largest improvement of the dual-line method compared to rip-first only processing occurred with cutting bill C. The reader is asked to recall, that this cutting bill has components that favor chop-first processing. Thus, the ability to selectively rip or chop-first, returns a much better part yield, proving the benefits of having a dual-line system for the cut-up of lumber in rough mills.

Table 7. Yields for 2A Common lumber and sample cutting bills.

Cutting bill	Dual-line	Rip-first	Chop-first	Dual-line vs rip-first improvement	Dual-line vs chop-first improvement
A	54.4	51.8	47.2	2.6	7.2
B	40.4	39.6	28.7	0.8	11.7
C	44.0	39.5	33.6	4.5	10.4
D	14.9	13.2	7.8	1.7	7.1
E	37.9	37.8	28.7	0.1	9.2
Average				1.9	9.1

4. Summary and Discussion

Overall, the differences between the dual-line processing method and rip-first were minimal in many cases. For example, yield improvements of 0.5% yield or less were seen in 14 of 30 instances. However, depending on the cutting bill and grade mix, yield improvements of 1.0% or better were observed in 11 of 30 instances. Comparing the yields of chop-first to the dual-line method shows that higher yields can be obtained with the dual-line in almost all cases, especially when processing lower quality lumber grade mixes. Given that a 1% increase in yield can potentially decrease production costs by 2% [5][10], these yield improvements, although small, can result in significant savings for the typical rough mill.

The anomaly with cutting bill C, where chop-first obtains better yield than dual-line, was witnessed with other cutting bills and grade mixes in a preliminary study. We determined that the cause of the anomaly was due to a lack of prioritization on larger part sizes with the dual-line process. Chop-first processing operates by identifying the largest clear areas on the boards and then determines what the highest prioritized value part can fit in the clear area. Any remaining clear areas are then optimized similarly in turn. This approach has the advantage of obtaining large, difficult to obtain part sizes whenever possible. Rip-first processing on the other hand, optimizes yield by determining the sum of prioritized values for all parts than can be cut from the board. This has the disadvantage that the sum of many smaller parts can be higher than that of a single large, difficult to obtain part size. By increasing the priority levels for parts this anomaly was avoided, with the exception of cutting bill C. However, if priority levels are increased too much, then yield suffers for all processing methods, thus the adjustment of prioritization levels is a delicate process. Ultimately, we used the same elevated prioritization levels for all cutting bills for the dual-line method, and the default values for the rip-first and chop-first methods.

In a future study we plan to further investigate the potential of dual-line processing using a greater variety of cutting bills and a second variation of the dual-line method using an all-blades-movable gang-ripsaw. Finally, we plan to examine the feasibility of the dual-line rough mill and its impact on the least-cost grade mix solution in a future paper.

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