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SIMULATION OF LUMBER PROCESSING FOR IMPROVED RAW MATERIAL UTILIZATION

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ABSTRACT

Lumber processing simulation allows the user an opportunity to examine ways to best utilize the many grades of lumber available to the user. It is most important that the simulation must be able to accurately model the processing plant steps and be capable of obtaining the desired part sizes in the correct quantities. This gives management the ability to increase production and reduce costs associated with lost yield. Flow simulation allows the user to try out different plant layout scenarios as well as engineer a plant prior to construction.

1 INTRODUCTION

Managers and plant engineers in the furniture, flooring, and other solid wood industries have typically made decisions based on limited information centered on past experience. Increased technologies in manufacturing parts from lumber, along with increased lumber costs have created an atmosphere of change in the wood industry. Tools for making educated decisions are needed to better plan for this type of manufacturing.

Two types of simulation programs are discussed in this text. One type is process simulation which determines the best way to manufacture rough dimension parts from lumber. The process simulation software is offered by the USDA - Forest Service in the form of the ROMI-RIP and ROMI-CROSS [Thomas 1995a, Thomas 1995b, Thomas 1997] rough mill analysis programs. The other simulation type is flow simulation which is offered as a service by the Robert C. Byrd Hardwood Technology Center.

2 BACKGROUND OF PROCESSING PARTS FROM LUMBER

There are several process simulators available to the wood industry that perform cut-up optimization for plywood and panel processing. These simulators use simple optimization strategies for standard sized resources with no defects. This luxury is not available when manufacturing parts from lumber. Lumber is divided into various grades based on size of the board and number and size of defects, such as knots and splits. Within each grade, lumber can be a number of standard lengths and is typically manufactured in random widths, which further complicates the issue.

Manufacturing facilities that process lumber into furniture or dimension parts are called rough mills. There are two fundamental types of rough mills; a “rip-first” rough mill and a “crosscut-first” rough mill (although there are hybrid mills). In rip-first processing, each board is ripped, sawn lengthwise, into strips. These strips are then cut to the required part lengths. In crosscut-first processing, each board is crosscut to the required part lengths. These short pieces are then ripped to the required widths.

3 PROCESS SIMULATION

The ROMI-RIP and ROMI-CROSS process simulators were designed as analysis tools for rip-first and crosscut-first rough mills, respectively. The goal in developing these simulators was to make them as flexible in design as possible, enabling the simulators to accurately model each rough mill’s processing situation (equipment setup, cutting bill, and methodology). These programs allow users to address the many “what-if’ questions that arise in the design and the everyday operation of rough mills. Questions such as: What yield and processing requirements can I expect for this cutting bill? Is this cutting bill better suited to gang-rip-first or crosscut-first processing? What if I process more short lumber and/or narrow lumber? What if I process two or more cutting bills together? What if I can increase my sorting capacity? What yield gains can I expect if I purchase optimizing saws? What if I can include small sound knots in my parts‘? These are only a few of the questions that can be examined using the ROMI-RIP and ROMI-CROSS process simulators.

To simulate cut-up processing, digitized board data are needed. These data need to describe the size of the board and the defects on each board face, including size, type, and location. The board data are represented internally in a run-length-encoded structure. This allows fast references to the data and minimizes the amount of storage required. We use the 1997 red oak lumber data bank developed at the Princeton, WV, Forestry Sciences Lab. [Gatchell, Thomas, and Walker 1997].

3.1 Details of Computer Programs

When processing to meet the requirements of a cutting bill, ROMI-RIP and ROMI-CROSS examine each board and produce as many as four kinds of yield in the following sequence: (1) primary, (2) primary sized salvage ("smart salvage"), (3) excess primary, and (4) excess salvage. First, all primary part sizes required by the cutting bill are removed from the board using two cutting stages, a cutting stage is a single rip or chop operation. In a rip-first rough mill the first stage is ripping to width, in a crosscut-first rough mill the first stage is crosscutting to length. The next step in rip-first rough mills crosscuts the strips to required lengths. The next step in crosscut-first rough mills rips the board segments to required widths. Next, the remainder of the board strip (rip-first) or segment (crosscut-first) is examined to determine whether narrower or shorter parts required by the cutting bill can be found. These parts are called "smart salvage." If no smart salvage parts can be found, then excess primary parts are produced. Excess primary parts are parts whose size is contained in the cutting bill, but are no longer required by the cutting bill. Parts not needed by the cutting bill but requiring three or more cutting stages are tallied as excess salvage. When the simulators are not processing to meet a cutting bill, all parts are tallied as either primary or salvage.

ROMI-RIP gives users seven different arbor types to choose from: (1) fixed blade, (2) fixed with movable outer blade, (3) optimizing fixed, (4) selective rip, (5) all-blades-movable, (6) best spacing sequence, and (7) best spacing sequence with movable outer blade. Of the seven arbor types the fixed, fixed with movable outer blade, optimizing fixed, and selective rip arbors correspond to available industrial arbor types. For these arbors the user must specify the arrangement of the saw spacings on the arbor. For the fixed and fixed with movable outer blade arbors each board is ripped with its right edge against the right edge of the arbor. For the optimizing fixed and selective rip arbors the placement of the board is optimized with regards to the board width and defect placement on the board. In addition, saw spacings on the selective-rip arbor can widen and narrow according to user specified tolerances to further accommodate board characteristics. The other arbors are research arbors used to determine the absolute maximum yield that can be obtained from any given board.

ROMI-CROSS operates in one of two chopsaw optimization modes. The first mode optimizes the placement of lengths in a board without regard to any board defects. The goal is to maximize the area in crosscut board segments. There is no guarantee that this will produce better part yield. For example, a single defect such as a split or an oversize knot can result in an entire segment producing no parts. The second chopsaw optimization mode seeks out the largest clear areas and maximizes the yield from those areas. Operating in this way, the simulator avoids unacceptable defects. This mode operates much like human operators.

Both simulators also allow specified defect sizes and type to be included in parts. This allows users to see the potential yield improvement of character-marked parts for their specific grade mix and cutting bills. The simulators can cut clear-two-face (C2F), clear-one-face (C 1F), and sound-two-face (S2F) part qualities. ROMI-RIP and ROMI-CROSS can process cutting bills with hundreds of different part size definitions. Each part definition stores the size of the part, the number of parts required, part value (if required), scheduling information, and whether or not the part is solid or can be obtained by gluing several narrower parts together (a panel).

3.2 Cutting Bills

Often a cutting bill contains more part sizes than the rough mill can process at one time. In cases like this a decision has to made as to be which parts should be scheduled for cutting first. As the requirements for a part in the cutting schedule is met, that part is removed from the schedule and the next closest sized part selected and inserted into the schedule. Both ROMI-RIP and ROMI-CROSS simulate part scheduling and replacement methods.

When processing a cutting bill, a decision must be made as to which parts should be cut from each board. Users can select one of several part prioritization methods. With one method the simulator assigns a value based on the part size and the remaining quantity. As parts are cut for a particular size, the priority for that part size is degraded, reflecting the decreased demand [Thomas 1996]. Other methods include optimizing for part length, part size, or allowing the user to specify a fixed value for each part size. The optimization goal is to find the set of cuttings that give the highest accumulated value for each board.

When using computerized optimization equipment, it is possible to keep constant track of the numbers of parts produced for each part size. This information can be used in determining part priorities (as discussed above), aiding part scheduling and replacement, and to avoid excess parts. In other cases, the parts are tallied at specific intervals with part priorities and scheduling being adjusted as needed. ROMI-RIP and ROMI-CROSS can constantly update part counts, simulating a feedback loop between the first and second saw stages. The programs can also simulate tally delays, updating part counts at specified intervals, common in most conventional rough mills.

For each analysis, ROMI-RIP and ROMI-CROSS provide many different types of information that summarize the analysis. Output includes board plots for each board processed (Figure 1) and detailed processing counts and statistics. The simulators report the amount of lumber processed (in board feet or cubic meters), the number of crosscuts and rips, the number of board strips or segments processed, and the number of parts produced. Not only is this information provided for primary, excess primary, salvage, and excess salvage parts, but for each grade processed.

Figure 2 shows a sample cutting bill report showing the part sizes and the specifications for each part. Each part's specification consists of its scheduling and replacement level, whether the part is solid or glued-up, and the quantity required. For each part size the total number of parts obtained is reported. If ROMI-CROSS was unable to meet a part size's quantity requirement, then "UNMET" is displayed at the right of part report. An additional summary page of the cutting bill report lists the parts sizes and the number of parts obtained from each grade processed. This allows analysis of the part distributions for each grade in the grade mix. In addition to providing detailed processing (strip, segment, part, rip, and crosscut count) information for the entire run, the same information is generated for each board.

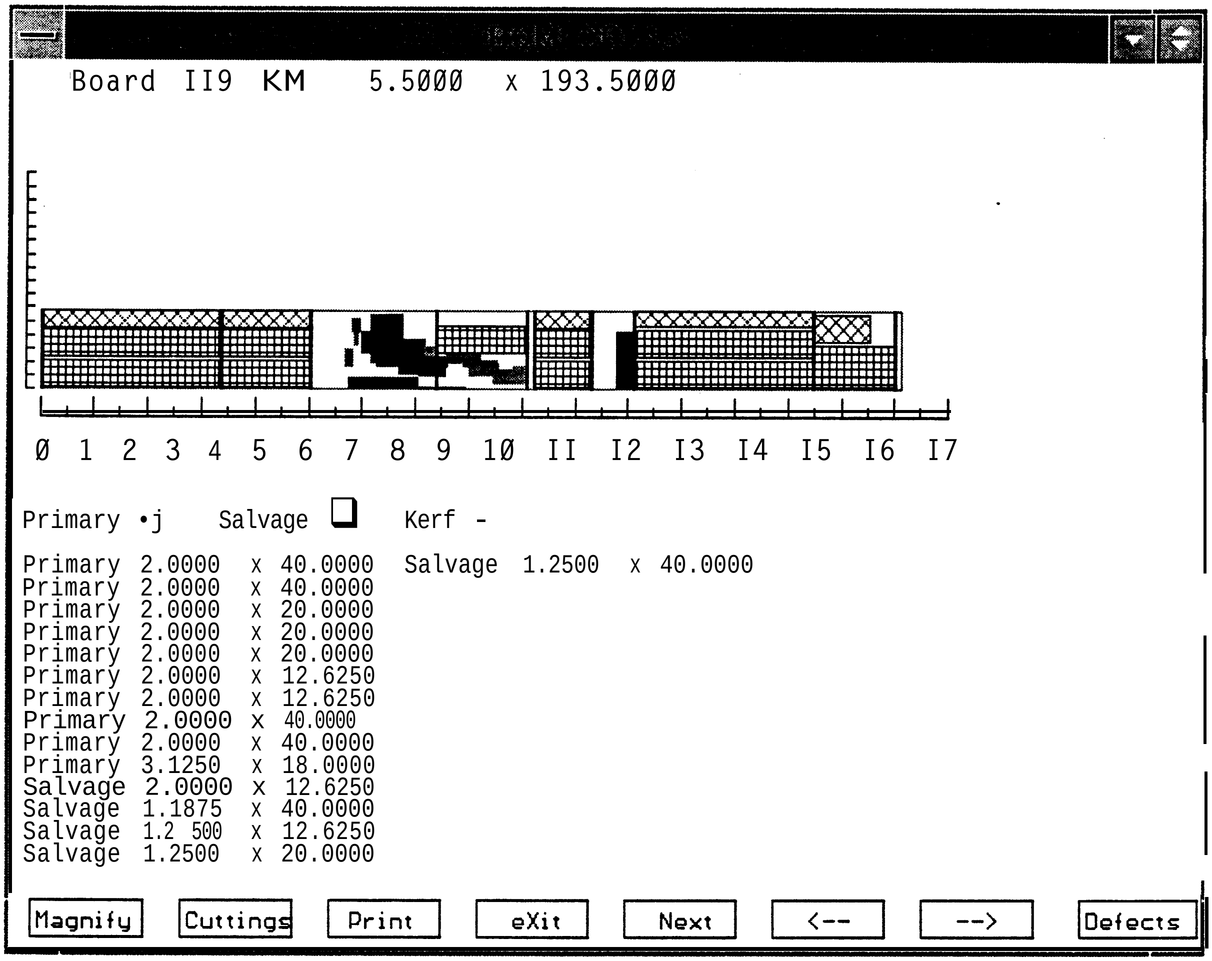

Figure 1: Board Plot Showing the Placement of Cuttings and Defects on a Sample Board

Fri Jun 20 12:20:43 1997
ROMI-CROSS Ver I .O l

Cutting Bill Processed: cutl-a6
Cutting Bill Overall Part Quantity Obtained Report

Weighting Method: COMPLEX DYNAMIC EXPONENT. (CDE)
(Glue-Up parts prioritized at 30.0 percent of solid parts

Length		Width	Level	Glue Up	Required Quantity	Obtained Quantity	Salvage Quantity
12.0000	x	2.2500	1		200	245	65
15.0000	x	2.2500	2		160	175	7
18.0000	x	2.2500	2		133	147	18
21.0000	x	2.2500	1		114	114	29
25.0000	x	2.2500	2		96	98	0
29.0000	x	2.2500	2		83	84	15
33.0000	x	2.2500	1		73	73	13
38.0000	x	2.2500	2		63	64	9
45.0000	x	2.2500	1		53	53	4
52.0000	x	2.2500	2		46	47	0
61.0000	x	2.2500	2		39	40	0
67.0000	x	2.2500	1		36	38	4
75.0000	x	2.2500	2		32	32	0
91.0000	x	2.2500	2		26	27	0
100.0000	x	2.2500	1		24	24	0

Figure 2: Cutting Bill Report Showing Part Sizes, Quantity, Panel and Scheduling Specifications

4 FLOW SIMULATION

The key to good plant engineering is the ability to have a good idea of the consequences of any changes to the current manufacturing process. If there is no clear end result to making a change, there is no reason to make the change in the first place. The lumber processing industry is at a major turning point. More and more companies are building high-tech machinery for the industry. The move to more advanced equipment has been slow. This is due partly to the fact that this industry is highly fragmented into small companies that have little or no research and development budget. In other words, the only tools for evaluating changes in rough mill layout and design are external to the company. The MaxSIMizer Pro, rough mill flow simulation service, gives managers and plant engineers the chance to examine the benefits of simulation without the high costs associated with simulation and a large time constraint.

4.1 Example of a Flow Simulator for the Wood Industry

MaxSIMizer Pro is a stochastic rough mill flow simulation that models the complete flow and processing of materials on the rough mill floor. The distance and speed of conveyors between machines, as well as the throughput of operators and machines are all modeled in MaxSIMizer Pro. Although there can be large differences among rough mills in their end products, they are all very similar in the types of machinery they use and the way material flows between machinery. To speed development generic simulation coding blocks are used to define rough mill equipment. For the simulation definition, these blocks are further defined and linked together according to the rough mill's specification. By using these coding blocks, it is very simple to recreate a rough mill in the computer.

Obviously, data collection is very important and impacts the time and cost of the simulation. To start a simulation project without any data will take a large amount of time in order to obtain the necessary input to the simulation code. With rough mills there are two types of data necessary in running a simulation. The first is timing data which is not very difficult to obtain since most rough mills have only two types of machinery and one or two operators each. The other type of data is material data, which is almost impossible to obtain in a rough mill due to the variability of the raw material.

The material data information that was once impossible to obtain is now simply obtained. The process simulation programs described earlier use a database of digitized lumber of many different sizes and grades. It is possible to choose the lumber within this database that best resembles that being used by the rough mill under examination. In addition, the process simulation cuts up the digitized lumber based on a cutting bill and other manufacturing limitations. Thus all of the material data for the flow simulation can be created by the process simulation.

Another problem that has hindered the use of simulation by the wood processing industry is the reluctance of managers and plant engineers to trust output from computer programs. One of the most important features of the new simulation packages is animation. This feature can relieve some of the apprehension that managers or plant engineers may have about trusting the results from the simulation. With the ability to show a customer how the material flows both through a new plant layout and the simulation program, they are more likely to view the results as more realistic.

4.2 Uses of Flow Simulator

Flow simulation has been and can be used for numerous applications within a rough mill. Some examples of these follow.

- Crosscut-First vs. Rip-First Rough Mills - Companies that are building new rough mills or who have thought about changing their plant layouts cannot decide whether a crosscut-first or a rip-first rough mill is best. There are only a few cases in which a company can make that decision with surety. However, it is easy for them to make this decision because of the fact that their end product is geared more towards one type of rough mill over the other. The rest of the companies have products that fall within the gray between these two types of rough mills. Flow simulations can be developed for both types of rough mills under the specifications of the new mills. The simulation results will then demonstrate which type is best for a particular company.
- Lumber Grade - Lumber is the largest expense for most wood companies, yet little time is spent on determining whether the lumber that is being bought yields the most capital. Lumber grades range from a large high grade boards with very little defect to smaller low grade boards with more defects. As would be expected, costs of lumber within these grades can fluctuate greatly. Thus, using a lower lumber grade could lower the cost significantly. Simulation can be used to determine the effects of adding lower grade lumber to high grade lumber or reducing all of the lumber to a lower grade.
- New Machinery - For many in the wood industry it is easier to justify building a new rough mill than it is to buy one new piece of machinery. Like the other examples, it is simply the fact. that it is next to impossible to know what the end results of such a change will be. In addition, because there are really only two processes within a rough mill, by changing one machine or machine group the entire mill changes by about 50 percent. This has been one of the most popular uses for simulation in these mills since it gives quick answers for a difficult decisions.

4.3 Results from Flow Simulators

The results for the MaxSIMizer Pro are consistent for all rough mills being simulated. There are three outputs that are looked at by managers and plant engineers: (1) Yield, (2) Throughput, and (3) Resource Utilization. Yield is the amount of useable parts in volume that are obtained from the amount of lumber used to create those parts (also a volume). Throughput is the amount of parts of value are produced in a day. Finally, resource utilization is the amount of time that high dollar machinery or labor is used in a day. From these three, the cost of manufacturing and the relative loss due to resources not in use can be determined.

Flow simulations like MaxSIMizer Pro are an important tool for managers of rough mills. They give results that can easily be translated into dollar figures. It is ‘these figures that will give managers the justification needed for making large changes to their rough mill.

5 ROUGH MILL SIMULATION: A CASE STUDY

In a conventional rough mill cutting bill, there are usually more part sizes in the cutting bill than the mill can process at once. This can be due to several factors, such as limited area or personnel for sorting out and stacking the different part sizes. In addition, if the rough **mill** is using manually operated chop saws, the operators can typically keep track of only five to six part lengths at one time. The remaining part lengths in the cutting bill are assigned to the operator one a time to replace part lengths whose part requirements have been met. The inability to consider more lengths can have a considerable impact on yield. This case study will look at the potential yield increase that can be realized by increasing the number of lengths that are processed at a time. By cutting more lengths at time it is possible to find better optimization solutions than when only a few lengths are being cut.

For processing simulation we will use ROMI-CROSS. ROMI-CROSS can simulate the scheduling of parts to the chopsaw as described above. We will process a cutting bill with 15 part lengths and a single width using a 1 Common lumber sample. The cutting bill processed is shown in Table 1. In this sample cutting bill the total part area required for each part size is equal to every other part size. Although this is not a common cutting bill, it does well for this example.

Table 1. Sample ROMI-CROSS Cutting Bill

Part Width	Part Length	Quantity	6 Part Schedule	9 Part Schedule	12 Part Schedule
2.25	12.00	200	1	1	1
2.25	15.00	160	2	2	1
2.25	18.00	133	2	1	2
2.25	21.00	114	1	2	1
2.25	25.00	96	2	1	2
2.25	29.00	83	2	1	1
2.25	33.00	73	1	2	2
2.25	38.00	63	2	2	1
2.25	45.00	53	1	1	1
2.25	52.00	46	2	1	1
2.25	61.00	39	2	2	1
2.25	67.00	36	1	1	1
2.25	75.00	32	2	2	1
2.25	91.00	26	2	1	1
2.25	100.00	24	1	1	1

To simulate the yield impact due to the ability to cut more lengths at a time, we will examine cutting 6, 9, 12, and all 15 lengths at a time. The rightmost columns specify the order in which the parts are processed and replaced. All parts with a ' 1" in the specified length count column are processed first. Parts with a "2" in the specified length count column are scheduled for cutting as the first parts processed are obtained. The scheduler operates by replacing a completed part size with the part size that most closely matches the length of the completed part size.

The results from the processing simulation show that nearly a four percent primary yield gain can be realized by cutting all 15 lengths at the same time instead of only six. Table 2 shows the results for the sample analysis. There is a primary yield increase and a salvage yield decrease associated with increasing the number of lengths processed at one time. Since salvage is more expensive to produce, a decrease in salvage yield is good, as it indicates more efficient primary processing. More evidence of increased efficiency can be seen in the decreasing amounts of lumber needed to obtain required part amounts.

Table 2: Yields Using 1 Common Lumber for Different Number of Lengths Cut at Same Time

Part Lengths Cut at Once	Primary Yield	Salvage Yield	Board Feet Required
6	53.77	5.50	986.1
9	55.38	4.81	964.9
12	56.87	4.34	954.0
All	57.67	4.08	951.2

The next step is to determine if it is possible to implement the strategy of cutting more lengths at the chopsaws. First a timing study would have to be done for the entire rough mill, timing the flow of materials from station to station and the amount of processing time at each station. Next, one of the chopsaw stations could be assigned to cut more lengths. The operator could keep track of the extra lengths using an optimization device that reports the required lengths in the cutting bill. With a small timing study, flow simulation can be used to determined the overall changes in throughput and material flow for this particular station. This information would then be used to alter the timing and logic within the flow simulation model of the rough mill. Alternatively, the purchase of new equipment such as automated optimizing chopsaw could be examined. These chopsaws read marks on the lumber surface to determine the best chop solution. These saws can easily handle dozens of part lengths and consider many more optimization choices than human operators.

By running the new simulation model, the end result of the effects of the cutting strategy changes can be determined for the entire mill. One consequence could be that cutting more lengths on the chopsaws causes other stations to be overloaded and bottlenecks to form within the rough mill. Or it could be that the sorting system cannot handle the additional lengths. Thus, increasing the number of lengths on the chopsaws, can lead to required changes in the rest of the rough mill, including new personnel and/or new equipment. To be able to recognize these difficulties before they are encountered on the rough mill floor is a great aid in rough mill plant design and layout.

6 CONCLUSION

Simulation is a valuable tool for the lumber processing industry. Process simulations such as ROMI-RIP and ROMI-CROSS can assist in creating cutting bills or changing cutting strategies. Process simulations also help users answer the “what-if" questions concerning everyday operations. Flow simulations such as MaxSIMizer Pro can be utilized to make decisions on plant layout and lumber grades.

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