

Computer Integrated Manufacturing Issues Related to the Hardwood Log Sawmill

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ABSTRACT

This paper evaluates the issues associated with the computer integration of the various technologies now available to hardwood log sawmills, so that these technologies will cooperate in helping the sawmill achieve better lumber yield. The concept of computer integration, and the current sawmill setup, are reviewed. A model of a computer-integrated hardwood sawmill is described. Issues concerning the integration of both hardware and software are also discussed.

Keywords: *Computer integrated manufacturing, hardwood log sawmill, integration issues, technology review.*

INTRODUCTION

The hardwood log sawmill, traditionally operated by small private owners using long-time manufacturing methods, has undergone a gradual yet major change in the last ten years. A modern hardwood sawmill today may be equipped with a computer numerically controlled (or CNC) headrig that allows for precise positioning of the log relative to the band saw, as well as low-powered laser emitters that provide fine-beam reference lines for alignment purposes. The sawmill may also have microcomputers that provide an off-line estimation of the eventual log yield given the gross dimensions of the log.

These new equipment, however, usually exist as islands of automation, i.e., powerful in their own right, but merely co-existing, not cooperating. The ultimate determinant in the breakdown of the hardwood log, and consequently in its yield, is the human sawyer. The sawyer must decide with the assistance

of all these separate equipment how to break the log into useable sections. There are more new equipment on the way. Studies in several universities, private and government institutions are looking at the feasibility of using non-invasive log scanning equipment to provide images of the internal condition of the log [2,3]. Eventually, the advent of such technological developments, if allowed to merely co-exist without integration of the information involved, will result in data overload for the human sawyer. Data overload will cause the sawyer to either misinterpret the information, or simply to ignore the information in the sawing decision.

This paper evaluates the issues associated with the computer integration of the various technologies now available to hardwood log sawmills, so that these technologies will cooperate in helping the sawmill achieve better lumber yield. The concept of computer integration, and the status quo in a typical hardwood log sawmill will be reviewed. A model of a computer-integrated hardwood sawmill will be described. Integration issues affecting hardware and software will be discussed.

CIM — COMPUTER INTEGRATED MANUFACTURING

Computer integrated manufacturing (CIM) has been a buzz word in the manufacturing industry within the last decade. What exactly is CIM? Is it a new technology? Is it a set of techniques for gaining manufacturing productivity?

CIM is neither a type of technology, nor a set of techniques. Rather it is a way of thinking, an approach to structuring information that is necessary in running a system of people, machines, and materials. Central to CIM is of course the computer, without which such an approach would be difficult to achieve. The basic premise of CIM is that some decisions are interrelated, and thus these decisions should not be made separately in isolation. This premise holds true, regardless of the application area.

Examples of CIM abound in fabrication industries where the importance of the link between product design and product manufacturing have only of late been finally recognized. Some examples will now be considered. In 1981, John Deere Tractor Works of Waterloo, IA won a LEAD (Leadership and Excellence in Applications and Development) award from the Society of Manufacturing Engineers in

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Table 1. Comparison of Marine Gear Development Stages (Schlie & Goldhar, 1989).

Development Stage	Western Company (approx. months)	Japanese Company (approx. months)
Conceptualize Design	3	1.5
Complete Design	3	1.5
Review Design	0.5	1.3
Detail Design	4.5	1.3
Build Prototype	7	2.3
Do Pilot Test	3	1.5
Do Field Test	10	4.6
Manufacture First Product	7	4.5
TOTAL	38	18.5

recognition of their CIM application [11]. With objectives of producing top quality products, performing work in the most efficient way, and providing employees with a supervisory work environment, John Deere reorganized functional manufacturing activities in a cellular arrangement. Cellular arrangement groups together machines, tooling, and information required to produce families of products with similar process and routing needs. The end result are complete production cells that can perform the major operations to produce a family of products from beginning to end. As a result of the reorganization, John Deere achieved a 25% reduction in the number of machines required, a 70% reduction in the number of departments, a 56% reduction in job changes and material handling, an 8-to-1 reduction in required lead times and corresponding reduction of inventory, and a clearer delineation of responsibility among shop supervisors [11].

Schlie and Goldhar [9] reported the findings of the Boston Consulting Group that through CIM and concurrent activities, Japanese companies now develop projection TV systems in one-third the time required by U.S. firms; plastic injection moulds in one-third the time required by U.S. firms with 30 percent lower cost; and new cars in half the time required by U.S. firms, with half as many people. Table 1 illustrates an example of completion times for different stages in the development of marine gears, as reported by the Boston Consulting Group [9].

Schlie and Goldhar [9] also cited the case of Allen-Bradley, a division of Rockwell International that makes programmable controllers and other electronic devices, which built a CIM facility to make

motor contactors and control relays. The facility could produce 600 different versions of these products in lot sizes as small as one, with zero defects, and with lead times as short as 24 hours or less. The interesting thing was that the facility was built, not for cost-payback reasons, but for strategic purposes of competing in world markets where different design standards prevailed, and for countering foreign imports.

Technology itself does not bring about CIM. Thomson and Graeffe [11] reported how a Canadian mission to Japan quickly realized that automation itself in a variety of forms, e.g., numerical controlled machines, robots, etc., was not the key to streamlined production, because each only improved an area of specialization. Neither is CIM to be attributed to the inter-connection of these automated machineries, because inter-connection only achieves an "interfacing of the islands of automation", which allows for communication between machines, but does not constitute true integration. Neither is CIM to be achieved by increasing the efficiency in each step of production, from sales order to packing slip, because direct production costs today account for only a small fraction of the total product cost.

The key to CIM can be found in improving the coordination and control between the steps in the process, especially for support systems, such as in-process inventories, excessive management structures, and equipment, which now account for the largest share of total product cost. This perspective is consistent with the basic premise in CIM of unified decision-making, broached at the beginning of this section. CIM will require a team approach, an opening of communication between the various hierar-

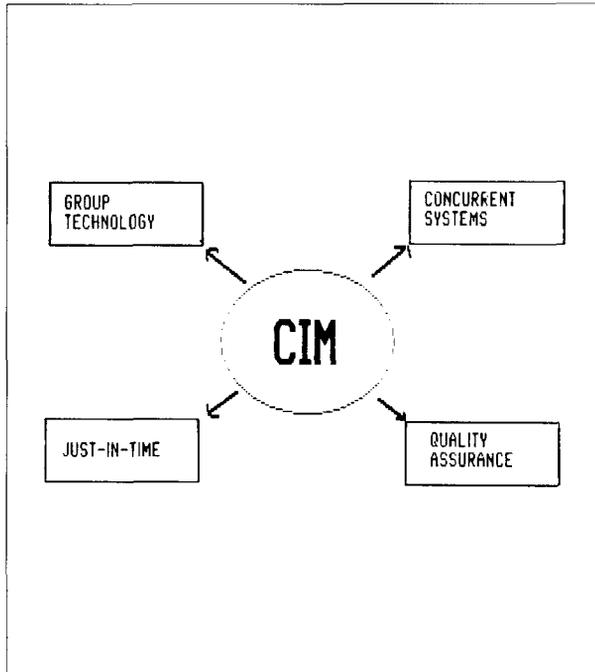


Figure 1. Central role of CIM.

chical levels and departmental structures in the manufacturing system, even perhaps the re-definition of these levels and structures if necessary. Foremost in the realization of CIM is the concept of information integration. All else, i.e., the application of group technology and the flexible manufacturing cell concept, just-in-time, inventory reduction, quality assurance, concurrent engineering, etc., proceed from information integration. Without information integration, all these production strategies and philosophies will flounder. Information integration gives CIM a central role as reflected by Figure 1. Group technology in Figure 1 refers to the concept of forming production cells, just-in-time refers to the concept of keeping operations simple by maintaining only what is necessary, quality assurance refers to the concept of incorporating quality-mindedness as early in the production process as possible, and concurrent systems refers to the concept of a simultaneous execution of process planning steps. More on these individual topics can be found in production planning and control literature.

CIM has been perceived in a number of ways. Thomson and Graefe [11] perceived CIM as a paradigm that promotes the integration of organization, planning and control as a solution to improved productivity by the maintenance of a single, information record. Others hold the a common perception that CIM is a machine-driven development

brought about by the advent of computer-aided systems such as computer-aided design (CAD), computer-aided process planning (CAPP), computer-aided manufacturing (CAM) employing numerical control and robotics, and the need to integrate these technologies together. Symon [10] and Havn [6] reported a more humanistic view of CIM as a human-centered endeavour, arising from their work with the European ESPRIT project.

These different perceptions can be reconciled by the common thread of information integration that runs in all of them. The machine-driven CIM perception relies on the availability of mathematical models, i.e., algorithms and heuristics, which provide a "predictive" capability of system behaviour. Human-centered CIM emphasizes the presence of a "non-predictive" capability which only humans can fulfill. Support systems, such as computer simulation tools provide a middle-ground between predictive and non-predictive capabilities through the use of statistical analyses. All of these involve information requiring integrated processing and presentation.

STATE OF THE HARDWOOD LOG SAWMILL

Hardwood log processing can be viewed as having three stages. Stage 1 involves the harvesting of the log from the forest, where a tree is felled, delimbed, bucked and topped into a log, then scaled, graded, and finally hauled to the sawmill. Stage 2 involves the sawing of the log into flitches, followed by edging and trimming of the flitches into green lumber, grading, and drying. Veneer production is a variation in that the log is quartered into sections for veneer slicing. Stage 3 involves the cross-cutting or ripping of dried lumber into defect-free dimensions for final use, such as in furniture-making. The focus of this paper is the second stage, which takes place in the hardwood sawmill. The first and third stages, however, will be alluded to later in the paper.

Hardwood sawmill processing consists of at least seven basic operations: debarking, loading on dock, positioning on carriage, sawing, edging, trimming, and grading. Debarking of the log, or bark-removal, is a pre-processing activity done to help maintain the saw blade and to upgrade the quality of bark chips that may be salvaged for other uses. When sawing is about to be performed, the debarked logs are loaded onto a log deck, a sloped platform with a log-stop at the end, where logs await processing.

As the log-stop is lowered, the log rolls down and is caught by a loader mechanism which loads the log on to the carriage. The log is held on the carriage by two claw-like fixtures, or dogs. The carriage is a heavy-duty trolley that runs on tracks and is used to feed the log into the saw in several passes. The log is turned over in the log-carriage so the sawyer can decide the best-face to saw. Turning is done by a log-turner mechanism which thrusts up at the log as it rolls outward from the carriage when released by the dogs, thereby rotating the log along its longitudinal axis.

Log sawing is accomplished by passing the log, held by the dogs and the carriage knee, past a belt-driven saw. The carriage is indexed towards the saw by the thickness of the flitches to be removed. The saw, which can be a band or circular blade, is housed in a frame known as the headrig. As the carriage passes by the headrig, a slab or flitch is sawn from the log. The slab or flitch drops onto a powered conveyor which takes the slab or flitch to the next operation. The carriage then retracts to the feed position. After a log face is chosen, the carriage indexes outward for the next pass.

The sawyer operates the carriage control, and judges how the log is to be sawn. The sawyer sits in a control station with an end-view or a side-view of the log and the saw. The sawyer may be aided by numerical controller for the carriage, a video monitor hooked up to perimeter video-cameras, and a low-energy laser-generated beam for sight alignment of log and saw.

With hardwoods, the log is usually sawn on the same face, until a degrading defect, i.e., knot, split, etc., is detected on the face. The log is then turned 90 degrees for an orthogonal cut, intended to prevent distribution of the detected defects in the subsequent flitches. The log is turned again whenever defects are detected on the current sawing face. This log breakdown pattern, known as sawing-for-grade or around-sawing, attempts to box in the center of the log where most defects are found. A number of other log breakdown patterns exist.

Edging immediately follows sawing. The task is performed by an edgerman who retrieves the flitch from the conveyor and positions twin saws at the flitch edges, i.e., parallel to the longitudinal axis of the flitch. Edging is done to remove wane and other edge defects, and to produce a parallel-edged lumber piece. Whereas before, light-generated "shadow

lines" were used as guides in positioning the twin saws, today, alignment can be done with the help of low-energy laser beams.

The board then goes to the trimmer saws, where wane and other defects are removed from the ends and the lumber piece may be cross-cut to desired length. This task is done by a trimmerman, who like the edgerman, judges the amount of wane and wood to remove. The end result is green lumber. After being sorted by size and species, the lumber is then evaluated by a professional grader. The grade is based on estimates of the orthogonal dimensions, percent of defect area, and the proportion of clear cuttings that can be extracted from the poorer of the two lumber faces. Lumber grading rules in the United States have been defined by the National Hardwood Lumber Association.

Recent developments report studies on the application of non-invasive imaging technologies, such as computed axial tomography (CAT) [3,4] and nuclear magnetic resonance (NMR) [2], to the detection of internal log defects. This capability, when finally implemented, will enable proactive in lieu of reactive sawing decisions, on the part of the sawyer. There is also increasing use of programmable logic controllers, which can activate devices and switches as outputs in response to the conditions of input sensors, in automatically sequencing functions. There have also been studies involving the utilization of log and internal defect information in automatically generating log breakdown instructions [7,8].

While providing sophisticated control of certain aspects of log processing, these technological developments are usually specialized and not integrated. They therefore reflect the islands of automation symptoms described earlier. Each development also generates additional information that has to be mentally processed and assimilated by the sawyer in arriving at a sawing decision. Granted that the human mind is adaptive and highly capable of processing vast amounts of information at lightning speed, there are known limits.

As early as 1970, Hallock [5] reported studies [12] which showed that human operators can evaluate information and make correct decisions at a maximum rate of five bits per second. More recent studies by ergonomists have shown, not only that the rate at which human workers can process sensory inputs and generate information outputs is biologically limited, but that the human error-rate, i.e., the frac-

Table 2. Outline of Operations, Technologies, and Information in the Sawmill.

Operations	Technologies/Activities	Information
Log Scanning	non-invasive scanning and imaging	log and defect profiles
Setworks	numerical control; programmable logic control; laser alignment; data acquisition	positioning; operational control parameters
Sawing	video-monitoring; feedback control; computer	sawing decisions; yield estimates
Edging	laser alignment, numerical saw	positioning; edging decisions
Trimming	laser alignment, numerical saw	positioning; trimming decisions
Grading	computer	grading decisions

tion of information output that is garbage, tends to rise sharply as the worker approaches maximum output [1].

Thus, unless the information made available by technological advances is integrated and then presented in an organized manner, the sawyer under duress of information overload may choose to simply ignore the information, or interpret it incorrectly. There can be no more compelling reason for consideration of CIM than the improper use of costly capital investments. There is also the untapped potential for productivity improvements that will result from the integrated control of existing equipment that may currently as islands of automation.

CIM AND THE HARDWOOD LOG SAWMILL

So where does one begin in relating CIM and the hardwood log sawmill? Begin by looking at the types of technological applications, activities, and corresponding information currently active in a sawmill system. Table 2 gives a sample outline of some pertinent types. For example, the internal imaging operation involves non-destructive imaging technology and provides information on log and defect profiles. The sawing operation involves numerical control, programmable control, laser alignment, and data acquisition technologies, from which provide information on log positioning, and operational control parameters.

The information provided by the different operations can then be examined for interrelationships which may signify candidate information for integration. It is possible to visualize, for instance, the interrelationship between sawing, edging, and trimming. While they are separate operations performed by three different people, it is not unreasonable to think that when the sawyer examines a log face and decides to saw a flitch, the sawyer estimates a possible lumber grade with a particular edging and trimming pattern in mind. Without communication and without the integration of information, the edgerman and trimmerman downstream will have no way of knowing the edging and trimming intentions of the sawyer, which could result in different cuts. Message passing between remote workstations under computer control is now possible through local area computer networks that can convey multi-media information.

Following this line of thinking, it becomes apparent that while intermediate activities exist which provide boundaries, such as log grading and lumber grading, there are inter-relationships which cross boundaries, even across the three stages of hardwood processing. As Figure 2 illustrates, the result of bucking and topping in stage 1 constrains the lumber that can be sawn from the log in stage 2, whereas the sawing operation in stage 2 constrains the dimension stock that may be extracted during rough-milling in stage 3. From a computer integration

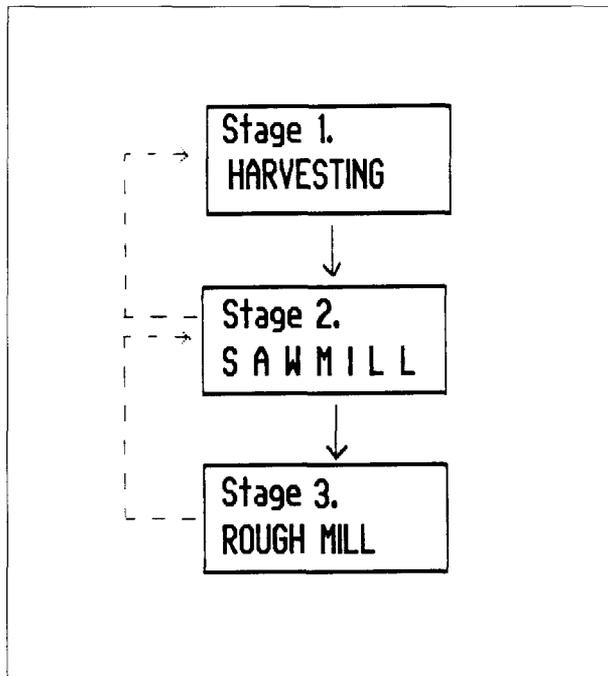


Figure 2. Cross-stage dependencies.

perspective, there ought to be a feedback loop between these stages, as denoted by the dashed lines in Figure 3, to integrate information about end-use to the earlier stages. It is interesting to note with the prevailing emphasis today in just-in-time and pull systems, that the early sawmills actually operated in a "pull" system environment, i.e., lumber was only cut based on customer demand and orders.

From the types of information passed, a computer integrated sawmill system may be organized with two major activity phases: process planning and process control. The sawmill process planning phase, as depicted in Figure 3, involves a planning activity which can take place off-line, prior to sawing. It will have internal scanning information, rough-milling requirements, and grading requirements as inputs, and sawing, edging, and trimming decisions as outputs. The input information has to be considered concurrently, enabling an integrated decision to be reached. Information processing tools might include mathematical algorithms and heuristics (predictive), computer simulations and statistical analyses (quasi-predictive), and the essential dimension of human analysis and expertise (non-predictive).

The sawmill process control phase, depicted in Figure 4, represents the execution phase where the actual sawmill operations are carried out. It will therefore involve on-line monitoring, and adaptive

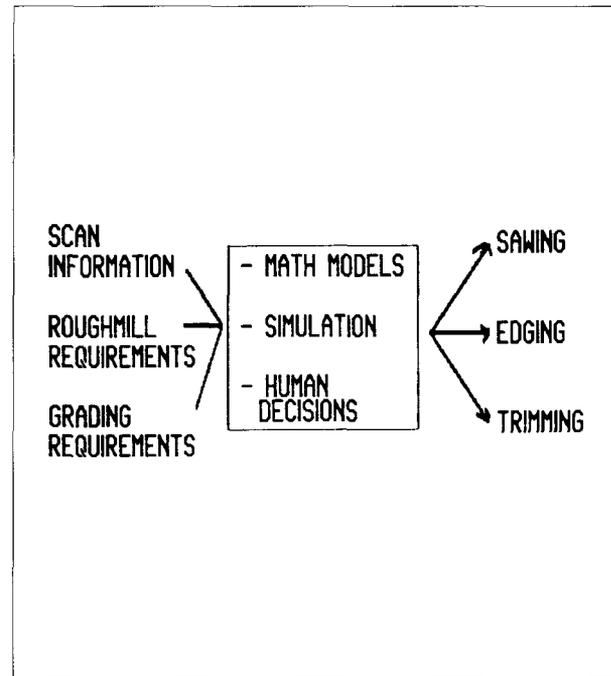


Figure 3. Sawmill process planning.

measures. For example, position monitors on the log carriage will supply feedback information on log position, while the sawing operation is ongoing so that sawing instructions can be fine-tuned and the log can be properly positioned. Sawing information, including intentions for edging and trimming for grade yield, will be passed on as instructions to the edging and trimming operations. Lumber grading can also feed back grade information to sawing, edging, and trimming operations as a baseline for performance evaluation.

Implied in all of the above procedural description is the integrated processing of information for automatic planning and control where possible, and for integrated presentation to the human operators where automation is not possible. It is not inconceivable that in a future human-centered computer integrated hardwood sawmill, the sawyer will be doing the "sawing" offline on a simulated image of the log, prior to the actual sawing. The sawyer will be equipped with "x-ray" views of internal defects to assist in planning for the best yield, of grade lumber or even dimension stock. At a later time the log can be brought to the headrig under automated control for the actual breakdown, then to the roughmill for dimension stock extraction also under automated control.

To the authors knowledge, no such computer integrated sawmill exists today. There are pockets of research work progressing in different universities, as well as industry and government laboratories, on the individual technological developments described earlier. If they evolve into computer integrated systems, this paper will have served its purpose.

CONCLUSIONS

This paper presented the computer integrated manufacturing issues related to the hardwood log sawmill. It covered a review of computer integrated manufacturing issues, a review of the status quo of hardwood log sawmills, and a description of an approach to the application of CIM concepts to the hardwood log sawmill. A human-centered CIM model is a viable option for the hardwood log sawmill, with associated integration of the information content found in the sawmill and the other two hardwood processing stages.

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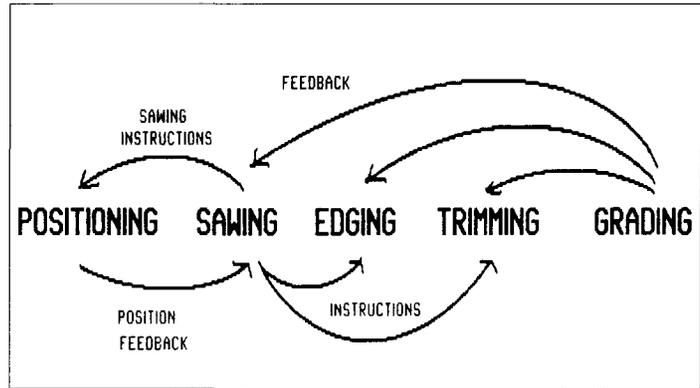


Figure 4. Sawmill process control.