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DESIM: A System for Designing and Simulating Hardwood Sawmill Systems

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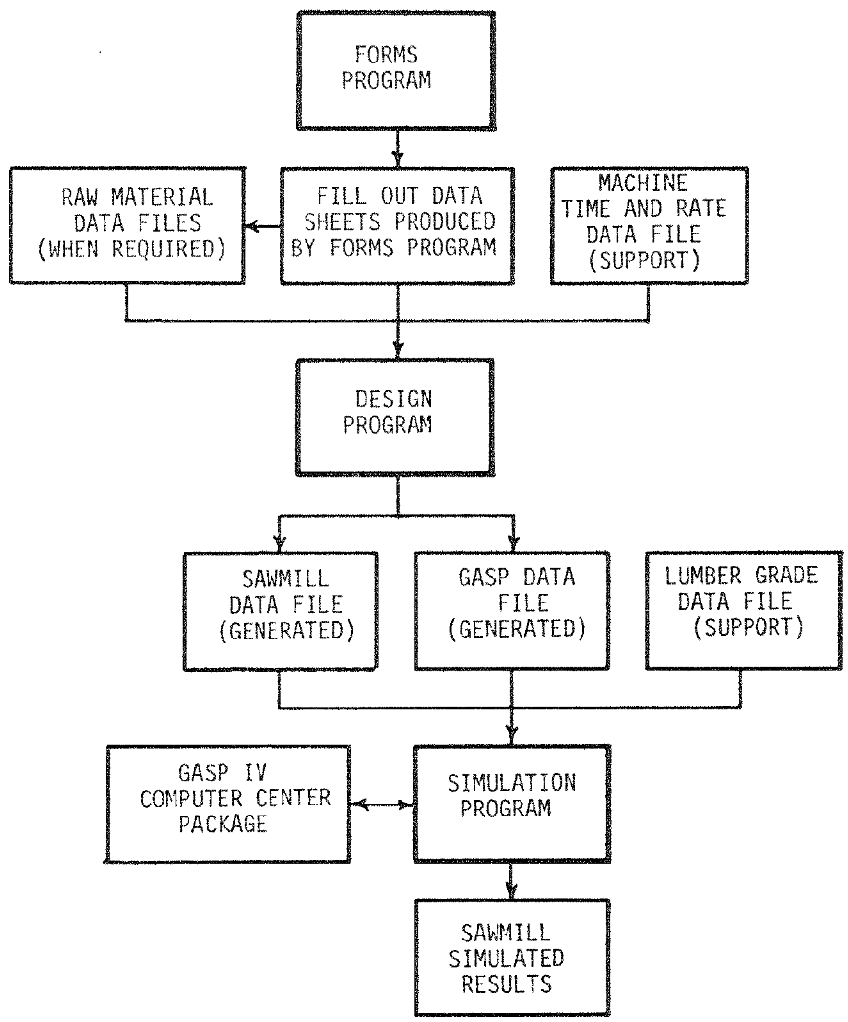

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Abstract

DESIM is a comprehensive tool for designing and simulating hardwood sawmill systems. Developed to handle complex sawmill designs and many possible raw material/product mixes, it provides a valuable analytical tool for sawmill managers and designers. It is a user-oriented system that makes it easy to change many factors including the design itself to analyze the operation of new or modified mills before they are built.

Introduction

Sawmill analysts have found that many hardwood mills in the Northeast are not set up to process available raw materials efficiently. The problem has been compounded by changing market conditions that have forced mills to produce products other than those they were originally designed for. New mills must be built and existing mills modified to handle the changing raw material and product mixes efficiently. A new system called DESIM[1] (DEsign SIMulator) can help in the design of new mills and the modification of existing mills to achieve this efficiency.

DESIM is the only system of its kind available for designing and simulating hardwood sawmill systems, a valuable analytical tool for sawmill managers and designers. With the present high costs of construction and equipment, new or modified mills must do the job for which they are built. Even minor modifications are costly afterward. DESIM allows a thorough look at the operation of a mill before it is built or modified, providing answers to important questions such as:

- Are the conveyor and surge deck systems adequate?
- Are there any bottlenecks?
- What happens if raw material size and/or grade distributions change?
- What happens if the product mix changes?
- How will an increase in downtime affect production?
- How will adding a piece of equipment affect production?

This is a user-oriented system that makes it easy to test the effect of changes in many factors, including the design itself, on answers to these and many other questions.

Because DESIM was developed to handle complex sawmill designs and many possible raw material/product mixes, it requires a large mainframe computer such as those available at most universities. An IBM 370/158[2] was used to develop and test it. And, because the system uses the GASP IV FORTRAN-based simulation language, users must have the GASP IV package available (Pritsker 1974, 1977). A conversational monitor system (CMS) computer terminal is also required to handle the question and answer technique used to set up and/or change mill designs. To many potential users, these requirements may seem unreasonable, however, with a CMS computer terminal and a telephone hookup (modem), adequate computer facilities are only a telephone call away.

Although the system requires the use of a large computer, it is relatively inexpensive to use. The cost will depend on (1) the size and complexity of the mill being designed; (2) the length of operating time being simulated; and (3) the various changes required by the computer center. However, it should not cost more than $25 to set up a design and simulate an 8-hour operating shift for a complex mill with a large raw material/product mix.

The following discussion is divided into three parts: (1) the DESIM system, (2) the required inputs, and (3) the resulting output. This paper will give the reader a general understanding of the system; greater detail can be found in the DESIM user's manual.[3]

[1]The computer programs described in this publication are available on request with the understanding that the U.S. Department of Agriculture cannot assure their accuracy, completeness, reliability, or suitability for any other purpose than that reported. The recipient may not assert any proprietary rights thereto nor represent them to anyone as other than Government-produced computer programs.

[2]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

[3]Adams, Edward L. DESIM user's manual. (In preparation for publication, Northeastern Forest Experiment Station, USDA Forest Service, Princeton, WV.)

DESIM System

A great deal of effort has gone into making the DESIM system easy to use. To this end, the system has been divided into the following parts: (1) a FORMS program, (2) a DESIGN program, (3) a SIMULATION program, (4) two support data files, and (5) several generated data files. The two support files include standard machine times and rates for different types of sawmill equipment and lumber grade information (Hanks 1973; Hanks et al. 1980) used to assign lumber grades to the boards produced. The generated files include up to five raw material data files that are supplied by the user if actual log and/or bolt information is used as input. The generated data files also include a sawmill data file and a GASP data file produced by the design program. Figure 1 shows the interaction of these various parts.

To illustrate how the DESIM system works, each program and its relationship to the different data files will now be discussed.

FORMS Program

The FORMS program produces the data sheets necessary to set up an entire milling situation. Of the 22 different types of data sheets available, the user can specify the ones wanted and the quantity of each. This is much more efficient than providing blank forms that must be filed and then copied when needed. The program provides data sheets for: (1) raw material inputs, (2) machine center information, (3) conveyor and surge deck (buffer) systems, (4) material processing instructions, and (5) material routing instructions. A user's manual provides instructions for filling out these data sheets. The systematic approach used in the data sheets and the user's manual reduces the difficulty of setting up a sawmill system, even for a very complex situation. Once the data sheets have been filled out and the raw material data files created (if needed), then the DESIGN program is run.

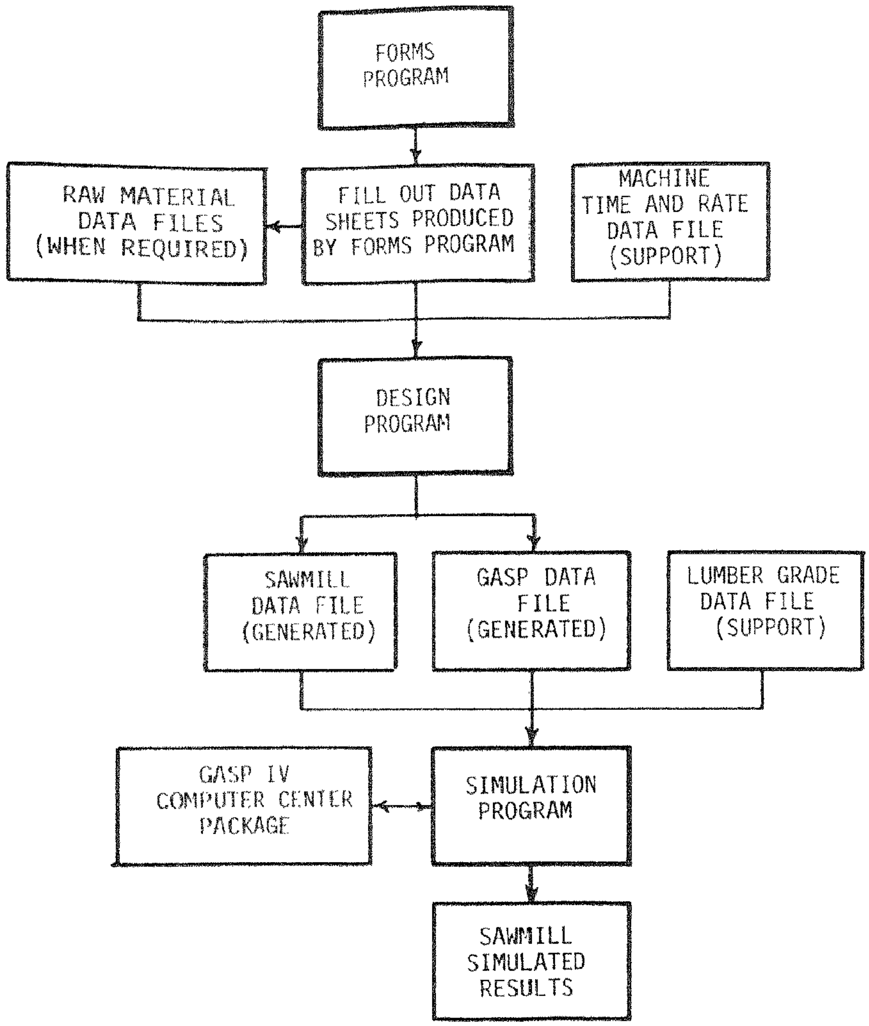

Figure 1.—Flow diagram of DESIM systems.

DESIGN Program

The DESIGN program is used to get the information from: (1) data sheets, (2) machine times and rates data file, and (3) raw material data files, when used, into the form required by the SIMULATION program. DESIGN is an interactive program that asks the user questions and solicits the answers. Most of the answers come directly from the data sheets produced by the FORMS program and filled out by the user. The user is shown the standard values in the machine times and rates file, and asked whether any of them should be changed. If the user answers yes, the system asks for the new values. This question and answer procedure is used both for setting up and for changing a sawmill system. When the user has answered all of the questions, the program produces the sawmill data file and the GASP data file needed by the SIMULATION program. The GASP data file contains the control information needed by the GASP IV simulation package.

SIMULATION Program

Finally, the SIMULATION program is used to simulate the actual operation of the proposed sawmill system. Inputs to the program include: (1) the sawmill data file, (2) the GASP data file, and (3) the lumber grade data file. Using this information, the logs and/or bolts are "processed" into the various end products at the specified processing times and rates. The individual pieces are routed from machine center to machine center according to the lengths and speeds of the conveyors and buffers involved, and the machine is shut down as in the specified downtime information. In this way the simulated run reflects the material slacks, surges, and backups that would occur in the actual mill operation, and provides estimates of the busy, idle, blocked, down, and purge times that might be expected for different machine centers. Purge time as used here is that nonproductive time caused when the headrig is shut down early to allow material to clear the mill system by the end of the shift.

If, after evaluating the output for the simulated operation of a proposed sawmill system, the user wishes to change any aspect of it, it is only necessary to rerun the DESIGN program. The program will ask questions and prompt the answers needed to make the changes. Once the changes are made, the DESIGN program provides a new sawmill data file. This new data file is then processed by the SIMULATION program to provide a new set of results. This makes it possible for the user to try many different situations in the search for the best mill for a given raw material/product mix.

Required Inputs

As mentioned in the previous section, the required DESIM inputs include: (1) raw material information, (2) machine center information, (3) conveyor and buffer information, (4) material processing instructions, and (5) material routing instructions. In this section, the inputs will be discussed in greater detail.

Raw Material Information

The raw material inputs can be in the form of actual piece data, log size frequency distributions, and/or bolt size frequency distributions. Up to five separate sets of data can be used in each of these categories. The allowable species include northern red oak, black oak, scarlet oak, white oak, chestnut oak, yellow-poplar, hard maple, soft maple, basswood, black cherry, beech, and yellow birch. Other species can be used, but that would require minor modifications to both the DESIGN program and the SIMULATION program. It would also require changing the lumber grade information in the lumber grade data file.

The actual piece data include information such as piece number, species code, top diameter, butt diameter, and length. If the piece is a sawlog, the standard USDA Forest Service hardwood factory-lumber log grade is included. However, if the log is of subfactory class, Grade 4 is used. And, because there are no standard bolt grades, Grade 5 is used for all bolts. When the logs and/or bolts represent pieces to be processed from long-length material, a piece position code is also included in the data. The five data sets allowed in this input can be any or all of the following types:

- Long-length material to be bucked into sawlogs
- Long-length material to be bucked into bolts
- Long-length material to be bucked into both sawlogs and bolts
- Individual standard sawlogs
- Individual bolts

The sawlog frequency distribution data will accept a species frequency distribution (in percent) for up to five species in each of five data sets. For each species, it will accept a grade frequency distribution (in percent) for up to four log grades. Grades 1 through 3 are the standard USDA Forest Service log grades and Grade 4 is for subfactory-class logs. For each log grade included in the data, log-size frequency distributions (in percent) are required for both diameter classes and length classes.

The bolt frequency distribution data are the same as those for sawlogs, but bolt-grade frequency distributions are not used. Each of the five data sets will accept a species frequency distribution for up to five species. For each species included in a set, bolt size frequency distributions are required for both diameter classes and length classes.

Machine Centers Information

DESIM allows the user to work with sawmill systems having up to 29 machine centers, including up to five headrigs. Within these constraints the system can have any combination of the following machine centers:

- Raw material handler (forklift and crane)
- Bucksaw
- Debarker (all kinds)
- Headrig (circular, band, Scragg, and gang)
- Headrig w/vertical edger (circular and band)
- Edger (standard and combination)
- Resaw (gang, centerline, and line-bar
- Special products station
- Trimsaw
- Greenchain
- Chipper
- Transfer station (cross transfer chain from conveyor to conveyor)

The special product station listed above can be used to simulate any process that produces products by cutting boards or cants into shorter pieces, such as half-headers used in coal mines.

For each of the above machines used in a design, the appropriate time and/or rate information is required. This information includes:

- Material loading time
- Material turning time
- Material processing time or rate
- Machine downtime

Depending on the machine, these times are represented by lognormal frequency distributions, time per surface area, or fixed time. Processing rates are in feet or inches per minute. The machine time and rate data file has this information for many of the machines. However, if this information is not available in the data file for a given machine, or the user does not wish to use the available information, the user must provide it. The user's manual gives the necessary instructions.

Conveyor and Buffer Information

DESIM can handle almost any conveyor and buffer layout the user might want. A buffer, as mentioned earlier, is a surge deck used to store material just ahead of a machine center. Each buffer can receive material from any number of conveyors and/or machine centers. Up to four buffers can feed a given machine center. Each conveyor can receive material from any number of machine centers. Material can be cross transferred from one conveyor to another. And, a merry go-round conveyor-buffer system can return material for multiple passes through a given machine center.

Material Processing Information

To simulate the sawing of logs and bolts, DESIM uses a sawing subroutine, a modified version of a computer program developed by Airth and Calvert (1973). This subroutine makes a wide variety of different sawing patterns available to the user. Besides allowing for live sawing on a gang headrig, it allows the following sawing patterns to be simulated on circular, band, and Scragg headrigs:

Circular and band headrigs:

- Live saw
- Saw around (all)
- Saw around to timber
- Saw around to cant for resaw
- Saw around to 2-sided cant for resaw
- Saw around to 3-sided cant for resaw
- Slab around to timber (slabs to resaw)
- Slab around to timber (slabs to chipper)
- Slab around to cant for resaw (slabs to resaw)
- Slab around to cant for resaw (slabs to chipper)
- Slab around to 2-sided cant for resaw (slabs to resaw)
- Slab around to 2-sided cant for resaw (slabs to chipper)
- Slab around to 3-sided cant for resaw (slabs to resaw)
- Slab around to 3-sided cant for resaw (slabs to chipper)

Scragg headrig:

- Saw timber (slabs to resaw)
- Saw timber (slabs to chipper)
- Saw cant for resaw (slabs to resaw)
- Saw cant for resaw (slabs to chipper)
- Saw 2-sided cant for resaw (slabs to resaw)
- Saw 2-sided cant for resaw (slabs to chipper)

For each of these sawing patterns that will be used, the designer must enter such information as: (1) minimum allowable board length, (2) required saw kerfs, (3) rough board thicknesses, (4) nominal board thicknesses, (5) allowable board widths, (6) allowable cant or timber thicknesses, and (7) allowable cant or timber width.

Up to 100 sawing patterns can be specified for each headrig in the sawmill system. The simulator selects the proper sawing pattern for a given sawlog or bolt based on controls set up by the user. These controls are based on raw material species, grade, and size. Also, within a given species, grade, and size of raw material, the controls can select a sawing pattern on a sequential basis or a percentage basis. For example, three different sawing patterns can be set up for Grade 3 red oak logs greater than 16 inches in diameter. If a sequential basis is used, the simulator selects the first sawing pattern, then the second, then the third, and then back to the first as logs meeting the stated criteria are to be processed. If a percentage basis is used, the sawing patterns are based on the percentages entered by the user. There is enough flexibility in these instructions to allow for realistic simulation of many different processing procedures.

Material Routing Information

DESIM allows complex routing of material through the simulated sawmill system. The routing is controlled by criteria entered by the user during the design phase. These criteria include such factors as material type, species, grade, width (or diameter), thickness, and length. Material meeting given criteria can also be sent to one of as many as three separate machine centers on a: (1) priority basis, (2) sequential basis, or (3) percentage basis. An example of routing on a priority basis would be a 6- by 8-inch red oak cant sent to a gang resaw except when the resaw is down or its buffer is full. Then the cant is sent to the next designated machine center. Routing on a sequential or percentage basis would be similar to the process discussed above for picking sawing patterns.

This routing procedure allows for realistic passing of material from machine center to machine center. It also allows DESIM to simulate the decisions made in actual sawmill operations when material surges and blockages affect the flow of material through the system.

Resulting Output

If the input information accurately reflects the characteristics of an existing or proposed system, DESIM should realistically simulate its operation. In other words, the output will indicate what can be expected from the sawmill when it is processing given raw materials into specified products. There is enough information in this output to tell how well a new or modified mill can be expected to perform. Given the ease and relatively low cost of obtaining this output for different mill designs, the user can thoroughly investigate a wide range of possibilities before selecting the best one for a given situation.

The DESIM output can be divided into three categories: (1) raw material summary, (2) machine statistics, and (3) product yield summary. The following discussion provides a more detailed look at these outputs.

Raw Material Summary

For sawlogs processed through the design mill, this summary shows the percentage of each species. Within a species, it shows the percentages by log grade. And within each log grade, it shows the frequency distributions by both diameter and length classes. The summary is the same for bolts, but bolts are not graded. Table 1 shows an example of this summary for hard maple sawlogs.

This output serves two purposes: First, it allows the user to determine that the raw material processed during the simulation run reflects the raw material information entered as input; and second, when kept with the other results, it provides a record of the raw material used to obtain those results.

Machine Statistics

For each machine center used in the design, this output provides:

- Productivity in Mbf (thousand board feet) per hour, Mft^3 (thousand cubic feet) per hour, or tons per hour
- Products, by type, showing number of pieces and volume
- Busy, blocked, idle, down, and purge time by number of occurrences, amount, and percentage of total operating time
- Conveyor and buffer utilization by length and percent

Table 1.—An example of raw material input summary

Log Information

Percent Hard Maple = 100.0

Percent Grade 1 = 17.6																					
Diameter	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Logs	0	0	0	0	0	0	0	0	0	5	3	4	2	2	3	1	1	0	1	2	0
Percent	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.8	12.5	16.7	8.3	8.3	12.5	4.2	4.2	0.0	4.2	8.3	0.0
Length	8	9	10	11	12	13	14	15	16												
Logs	3	0	6	0	6	0	6	0	3												
Percent	12.5	0.0	25.0	0.0	25.0	0.0	25.0	0.0	12.5												
Percent Grade 2 = 37.5																					
Diameter	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Logs	0	0	0	0	0	0	3	6	12	6	10	3	4	3	1	2	1	0	0	0	0
Percent	0.0	0.0	0.0	0.0	0.0	0.0	5.9	11.8	23.5	11.8	19.6	5.9	7.8	5.9	2.0	3.9	2.0	0.0	0.0	0.0	0.0
Length	8	9	10	11	12	13	14	15	16												
Logs	6	0	17	0	11	0	8	0	9												
Percent	11.8	0.0	33.3	0.0	21.6	0.0	15.7	0.0	17.6												
Percent Grade 3 = 44.9																					
Diameter	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Logs	0	0	0	0	4	12	9	11	5	0	5	3	3	1	3	1	0	1	1	0	2
Percent	0.0	0.0	0.0	0.0	6.6	19.7	14.8	18.0	8.2	0.0	8.2	4.9	4.9	1.6	4.9	1.6	0.0	1.6	1.6	0.0	3.3
Length	8	9	10	11	12	13	14	15	16												
Logs	6	0	20	0	12	0	10	0	13												
Percent	9.8	0.0	32.8	0.0	19.7	0.0	16.4	0.0	21.3												

Table 2 shows an example of this output for a circular headsaw. Notice in the example that three different productivity values are given: (1) maximum, (2) no down time, and (3) in this system. The "maximum" productivity shows what could have been expected if the machine had produced during the total operating time. The "no down time" productivity shows what could have been expected if the machine had had its normal blocked, idle, and purge times but no down time during the total operating time. And the "in this system" productivity shows the actual productivity of the machine in the design system. This information not only shows the user how well the machine did in the system, it also indicates the possibility for improving productivity.

Also in the example (Table 2), you will notice a zero length and zero utilization for the conveyor. This shows that there was no conveyor between the headrig and the machine center sending logs to the headrig. In other words, that machine was sending the logs directly to the buffer.

Product Yield Summary

This output provides product yield tables related back to the primary breakdown machines. Each table provides the following information by log or bolt diameter class:

- Number of logs or bolts processed
- Scale volume (International ¼-inch)
- Tally volume
- Percent overrun
- Cubic volume
- Lumber recovery factor
- Percent yields by lumber grades, special products, and timbers

Table 2.—An example of machine statistics for a circular headsaw

Equipment Information

Equipment No. 4 (Circular Headsaw)

Productivity:

1.38 M bf/hour (maximum)
1.29 M bf/hour (no down time)
1.27 M bf/hour (in this system)

Products:

Number of pieces:		Volume:	
Lumber	1,194	Lumber	10,184 bf tally
Slabs	432		
Total	1,626		

Time:

	Number	Minutes	Percent
Busy	1,518	443.19	92
Blocked	0	0.0	0
Idle	1	1.99	0
Down	15	29.00	6
Purge	1	5.81	1
Total		480.00	100

Conveyor utilization:

	Type code	Length (ft)	Utilized (ft)	Utilized (%)
Conveyor (3, 4)	1	0.0	0.0	0.0

Buffer utilization:

	Type code	Length (ft)	Utilized (ft)	Utilized (%)
Buffer (3, 4)	1	20.0	21.6	108.0

For each primary breakdown machine, yield tables are presented by species, log grades, and bolts. A yield table is also presented for each primary breakdown machine with all species, log grades, and bolts combined. And finally, a summary yield table is presented for all logs and bolts processed through all primary breakdown machines. Table 3 shows an example of a yield table for Grade 3 hard maple sawlogs processed on a circular headsaw.

The product yields were shown in this manner to allow the user to check them against published yields. In this way the user can be assured that the simulated results are within reason. In designing a new mill or planning modification of an existing mill, this comparison will make it easier to show that the simulated results for the mill are realistic.

Table 3.—An example of the product yield summary for a circular headsaw

Yield Information

Species = Hard Maple; Grade = 3

Primary Breakdown Unit No. 1 (Circular Headsaw)

Diameter	Number logs	Scale volume	Tally volume	Overrun	Cubic volume	LRF	FAS	SEL	Lumber 1C	2C	3C	Special products	Timbers
8	4	120	113	−5.83	22	5.05	0.0	0.0	6.19	1.77	92.04	0.0	0.0
9	11	385	353	−8.31	67	5.29	0.0	0.0	3.40	5.95	90.65	0.0	0.0
10	7	355	349	−1.69	59	5.89	0.0	2.58	15.76	9.74	71.92	0.0	0.0
11	9	560	559	−0.18	89	6.25	0.0	0.0	16.64	22.90	60.47	0.0	0.0
12	3	170	163	−4.12	26	6.22	0.0	0.0	3.07	43.56	53.37	0.0	0.0
14	3	350	347	−0.86	51	6.79	0.0	0.0	9.51	51.87	38.62	0.0	0.0
15	3	305	286	−6.23	43	6.66	0.0	1.40	16.08	31.12	51.40	0.0	0.0
16	2	220	214	−2.73	30	7.09	0.0	2.80	20.09	49.53	27.57	0.0	0.0
18	2	340	239	−29.71	46	5.17	3.77	6.28	33.05	43.10	13.81	0.0	0.0
19	1	260	248	−4.62	35	7.09	6.85	8.47	24.19	12.50	47.98	0.0	0.0
21	1	195	182	−6.67	26	7.13	0.0	9.89	18.68	21.43	50.00	0.0	0.0
22	1	260	249	−4.23	34	7.34	5.62	0.0	15.26	49.40	29.72	0.0	0.0
24	2	680	654	−3.82	87	7.48	2.75	2.60	22.63	34.56	37.46	0.0	0.0
Total	49	4,200	3,956	−5.81	615	6.42	1.47	2.28	16.51	29.15	50.61	0.0	0.0

Discussion

The best hardwood sawmill for a given location must be determined by the available raw materials and product markets. However, in this age of rapid changes, a manager may wish to build or modify a mill to handle a wider range of raw material and product mixes more efficiently. This makes designing or planning the modifications of a mill much more difficult. The DESIM system can be a valuable tool in this process.

DESIM can handle large complex sawmill situations. The many sawing decisions made by head sawyers can be simulated. And the material processing and routing decisions made by the other machine operators to produce and route a wide variety of different products are no problem for the system. In other words, the DESIM system can be used to design and simulate the operation of almost any hardwood sawmilling situation the user wishes to consider.

Although the system is complex, the procedure used to set up and simulate the operation of a sawmilling situation is relatively simple. This procedure also makes it easy to change the sawmilling situation and obtain new simulated results. Therefore, at a relatively low cost and with little time and effort, the user can look at many different situations and pick the sawmill design that best fits a given range of raw material/product mix situations. This not only guarantees an efficient mill for the money, but reduces the possibility that costly modifications will be needed in the future.

Copies of the program may be obtained from the Forestry Sciences Laboratory, Northeastern Forest Experiment Station, P.O. Box 152, Princeton, WV 24740.

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