ADVANCES IN SAWING FROM FOREST TO SHOP

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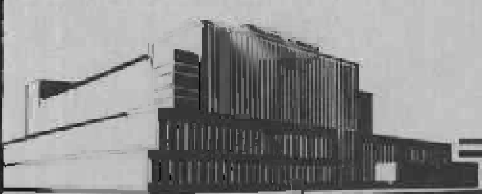

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Foreword

The author has had the opportunity, as a Fulbright research scholar, to study sawing and sawing techniques in Europe to supplement the background of his own research at the U. S. Forest Products Laboratory. The purpose of this paper is to present a broad review of the various functions for which saws are used in the numerous forest management operations such as clearing, thinning, and pruning, and in the harvesting and conversion of the forest crop. Also presented is an overall report on advances in saws and sawing techniques as employed in various operations and on the trends and opportunities for further research on this important problem.

The paper has been prepared as a contribution to the program of the Working Party on Sawing and Machining, of the FAO Conference on Wood Technology.

--L. J. Markwardt
Member, FAO Working Party
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ADVANCES IN SAWING FROM FOREST TO SHOP[1]

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Introduction

The rapid development of machinery in general during the last century has changed the appearance and processes of many industries quite radically, but it has not been able to relegate the saw to a minor position in the wood industries. Regardless of other developments, the saw remains as the primary tool in the long process of converting standing timber into the useful wood products of commerce including pulp production. Indeed, it even has a part in the culture of the young forests that grow into the timber used by the wood industries.

Saws Used in the Forest

Saws in the young forests are not the spectacular tools of the big sawmills, but they contribute to the eventual operation of those mills. Where intensive silviculture is practiced, other tools, such as the ax, brush hook, machete, clippers, or even scythes, are commonly used instead of saws in preparation of planting areas, in release cuttings on plantations, in weeding, and in hardwood regeneration by mowing.

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[1] Included as part of the report of the Working Party on Sawing and Machining to the United Nations Food and Agriculture Organization Conference, April 1958 in Madrid, Spain.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Saws for Pruning

Saws come into use, however, in the subsequent early pruning, sometimes done with a hand saw, or with a pole saw blade mounted on an ax helve (33),[3] followed later by pole saws as the height of pruning rises. This field of hand tools has been invaded in recent years, both in North America and Europe, by the "Brushmaster" type of powered saw. This circular saw is mounted obliquely at the end of a long drive shaft that extends from a small light gasoline motor. The entire assembly is carried by means of a shoulder sling, and the operator is free to move the blade for use in any position at any height, for pruning, weeding, lopping, and other types of work.

For pruning at greater heights than can be reached with this small brush saw, and for removing large branches in older stands not previously under a pruning regime, sporadic attempts have been made in North America to develop a power pruning saw of large cutting capacity and extensive reach. One such attempt made use of a small gasoline motor with a circular saw. The unit was raised and lowered by a rope passing through a pulley hooked to a high branch by use of a jointed pole. This pole was subsequently attached to the base of the saw unit to guide it during sawing. Other attempts have involved a circular blade mounted on a short shaft extending at right angles to the main drive shaft housed in a long hollow pole. A flexible shaft coupled the drive shaft to a motor carried on the operator's back or mounted on a dolly with wheels or runners.

The problems of adequate power at the saw, light weight aloft, and great maneuverability for positioning the cutting blade and avoiding damage by falling branches call for an intensive development program rather than the sporadic attention so far given to power pruning. This lack of powered high-pruning equipment leaves the operation to the impact chisel pruner (for small branches) and to hand or pole types of pruning saws for continuing the pruning of young stands or initiating pruning in older stands.

Saws for Thinning

As the immature stands continue their growth to the harvesting stage, the saw continues to have a part in their development. The thinnings and the improvement and sanitation cuttings that help to produce a better final crop are made with the saw, usually of the hand-operated Swedish bow-saw type or the motor-driven saw.

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[3] Underlined numbers in parentheses refer to Literature Cited at the end of this report.

Of the motor-driven saws, the chain saw and the portable oscillating blade types are most adaptable to use in thinning or other intermediate cuttings. The drag saw type is almost obsolete for tree felling, and the wheel or tractor-mounted circular saw, or the spearhead type of saw mounted on a tractor bulldozer blade, (18) is better suited to the final harvesting cuttings or to land clearing.

Saws for Harvesting

It is at the harvest cutting that the saw becomes the indispensable tool. The straight thin cut made by a saw wastes a minimum of material and energy in comparison with an ax cut, both in felling and in bucking the trunk into logs, and even in the limbing of large-branched tops. The 1- and 2-man manual crosscut saws have been largely displaced by motorized saws on commercial logging operations, and many owners of small forest areas own power saws jointly with similar forest owners. The power saw has advantages when the timber is large or hard, but for small-diameter trees of pulpwood species, the Swedish bow saw is fully capable of matching the output of motorized saws in pulpwood stands, and maintenance of bow saw blades can be eliminated by use of the recently developed disposable blade, hardened for maximum sharpness life. Since their sharpness life is several times that of the conventional blade, it is more economical to discard these blades when dull than resharpen, as they are too hard to file.

Different types of motorized saws are available. These include the large circular saw type, the hubless circular saw, the oscillating or reciprocating straight saw, and the chain saw type. The motorized large circular saw unit is mounted on wheels, and the blade is located at the end of a gooseneck or right-angle support. This support can be turned to place the saw in proper position for either felling or bucking. The hubless circular and the reciprocating straight-bladed saws are of the portable 1-man type, while the chain saws may be of the 1-man or 2-man type for woods use. The saw chain may run over a beavertail or a bow-shaped guide bar in the 1-man types, or over a long guide bar, running up to 14 feet in length, with a detachable handle at the end away from the drive motor. The saw chain that operates over the guide bar may be equipped with any of three styles of toothing, the chisel tooth, the side-cutter-and-raker combination, or the chipper type.

The effectiveness of the different types of saw chains and of complete chain saw units as logging tools has been the subject of studies in various countries. Cutting characteristics of saw chains of various types and tooth angles have been studied in the United States by Randel (54); in Australia, by Turnbull

(71), Hebblethwaite and Turnbull (42), and McKenzie (51); in Japan, by Hasuo (41); in Sweden, by Troëng (70) and Backman and Winnlert (24); and in Russia, by Uspenskiĭ (72) and by Kuosman and Drekhsler (49). Vil'ke (73), also in Russia, has analyzed the design of beavertail cutter bars and determined the conditions for minimum wear of the bar.

Since the advent of the "chipper-tooth" or "hooded-tooth" saw chain, there have been no major innovations in the chains other than the laminated teeth made of a high-alloy layer for the cutting edge and a thicker soft and tough layer for the tooth body, as described by Vil'ke (73). Saw chain bars have been improved by hard facing of the areas of severest wear, and one United States maker has announced a 1-man-saw bar with a rotating nose section, running on ball bearings, to eliminate the heavy wear at the nose end of the bar. Motors, naturally, have been improved too, and chain drive at high speed direct from the motor shaft has been introduced. Motors have become lighter and more dependable and the gasoline type has been supplemented by Diesel and low-pressure (propane-butane) gas types.

Russia is reported to be using electric chain saws in the woods, supplied from generators operated by motors using gas made in wood-burning gas producer units. Interest in electric motor chain saws is generally centered around the use of alternating current frequencies considerably higher (by a factor of 2 to 5 or more) than normal domestic current. Although a portable generator will produce some noise and may entail some residual risk of fire, especially if operated on wood-producer gas, the fire-risk zone is comparatively stationary, and the reduced noise at the saw will decrease the saw operator's hazards from unheard falling debris. Several saws may be operated from one generator, and the light weight of the sawing unit will facilitate its handling during felling. Handling of the cable from the generator during limbing and moving from tree to tree, however, may offset the savings from instant saw starting and easier operation during felling. Also, skidding operations must be planned to avoid any entanglement with the power cables. The power cables must of necessity be tough and durable to withstand the severe service and to avoid internal breaks or external exposure of live wires. Such disadvantages, however, may be fully compensated by the reliability of a system in which a Diesel-powered generator and electric saw motors are used or by the freedom of a producer-gas-powered system from the problems of oil or gasoline supply.

The modern chain or other type of motorized saw is preeminently a forest machine, but the forest is by no means the limit of its activities. At yarding sites within or near the forest, the motorized saw may be used in the normal way for bucking of tree lengths into logs, for trimming, or for fuel or pulpwood cutting. Alternatively the chain and bar may be so mounted that it can be moved in a vertical plane. The mount may be a permanent one beside a conveyor or log pond, or it may be a platform on wheels. The swinging motion may be obtained by tilting the platform or by mounting the bar on a pivot on a nontilting platform. A separate motor is used when the bar is pivoted. The type of saw and the sawing techniques in use are, to some extent, related to the steps and means of transportation of the wood from stump to mill.

Forest to Mill Transport

As the harvested forest products move to the mills, normal modes of transportation are employed -- rail, truck, and water -- and the general practices in such transportation are essentially the same in the United States and Europe. One recent innovation in Canada is the use of self-dumping barges (5). Water transporation -- river driving -- is the principal method used for softwoods in Norway and Sweden, whereas this method is no longer common in the United States. In Scandinavia, where much of the saw log residues go into pulp, the question of bark removal before or after driving is related to pulp use, since bark protects the timber during driving and storage, yet the migration of bark extractives into the wood is objectionable for some types of pulp processing and uses.

In the United States, river driving is limited to a portion of the Northeast, primarily Maine, and to the Pacific Northwest. In the Puget Sound region of the Northwest, logs are frequently made up into large rafts and towed to the mill, but some river driving may precede the rafting, or logs may be driven directly to the mill. In one case of extremely rough terrain and river turbulence, logs are strapped into bundles that are dropped 93 feet to the river (8). The bundling minimizes damage resulting from the initial fall into the river and subsequent passage through the river's turbulent canyon portion.

Bundling of logs for river driving might be of value under conditions in Scandinavia, where sorting and handling by ownership in the sorting basins would be simplified, and simplification of the further sorting into diameter classes might be effected if each bundle were made up of logs of the same diameter class.

Logs are also being bundled in America for shipment by rail or truck (1, 2) and special jigs are in use for making up the bundles (3, 6). Movement of logs from woods to mill is also being expedited by the preloading of semitrailers to enable the tractor unit to unhitch its empty trailer on arrival at the loading area and immediately pick up a loaded trailer for hauling to the mill. Other systems include the "piggy-back" trailer method in which the pole and tandem-axle trailer wheel assembly is lifted, after unloading, on to the tractor unit for the return trip to the woods. In the steerable 4-wheel trailer bunk system for poles and tree-length logs, the load itself serves as the reach pole, and a second driver steers the trailer unit -- a method that permits very long loads to be transported over winding roads. Articulated trailers, in which the wheels are pivoted and follow exactly in the tracks of the tractor unit, are used in a few instances in the United States, normally with only 2 trailer units in the train, whereas trains of 4 or more trailers may be used in Europe.

Transportation of logs by truck is far less common in the softwood areas of Europe than in the United States, but trucks are coming into greater use to provide winter supplies of logs and to reach timber not adjacent to drivable waterways. Use of trucks in Europe has not developed to the stage found in northwestern United States, where extensive holdings are provided with all-weather private logging roads on which equipment is operated that is far above the size and weight legally permitted on public highways. Newer United States trucking equipment includes such developments as propane fuel, torque-converters, and hydraulic retarders for down-grade speed control, while gas turbines are under test as truck power units.

Transportation is almost universally an operation that is distinctly separated in time from although coordinated with the process of sawing involved in felling and bucking operations. There is, however, one system being tested in the United States in which trees of pulpwood size are felled by powerful shears, cut into pulpwood lengths by the same shears, and loaded on to a trailer unit pulled by the shearing and loading unit. When loaded, the trailer is exchanged for an empty, and loaded trailer units are hauled to the mill by standard trailer tractors. Since the trees are cut off at ground level, there are no stumps to interfere with hauling. The loader can, therefore, leave a filled trailer almost anywhere. Thus the skidding operation is eliminated, and there is no diversion from primary felling and bucking functions. Such a system is best adapted to rather flat regions where pulpwood tracts are managed on a system using very heavy or clear cutting in strips or patches.

An intimate association between saw and truck exists in the case of one new mill in the United States cutting pulpwood. It is a mobile mill (4), consisting basically of a circular cutoff saw and a power plant mounted on a truck, with a log deck and a loader on opposite sides of the body. At the landing in the forest, this mobile mill is supplied with tree-length logs, on the deck side, which are fed against a stop and cut into 96-inch pulpwood lengths. These bolts cross to the loader, and are deposited on a trailer alongside the mill.

In most operations, the tie between transportation and sawing is not so close, but the choice of transportation methods and sawing equipment is governed by the locale of each sawing operation and the nature of the sawed products to be moved to the next stage.

Preparatory Operations at the Mill

With the arrival of the logs at the mill, some preliminary manipulation may be required before mill saws can begin operation upon the wood. Tree-length logs may be bucked into log lengths before going into water or dry-land storage, but in most instances the stock delivered to the mill goes immediately into short- or long-term storage before further processing begins. Logs delivered by truck or rail may go into a pond or be decked on land, but logs delivered by driving, floating, or rafting usually remain in the water. At frame-saw mills in Sweden or Finland, the water-borne logs are scaled and marked by diameter class, then floated into sorting bays, one for each diameter class.

A dry-land sorter is used at some mills in Sweden. This sorter consists of a log haul that takes the logs from the water, conveys them through metal detectors and debarkers, if desired, to a cross conveyor passing a control hut, where the log is measured for diameter and scale. On the control panel within the hut a button corresponding to the log diameter is pressed, and a small hole is thereby punched in a wide paper tape. The diameter class determines the distance of the hole from the edge of the tape. The cross conveyor drops the log on to a distributing chain parallel to the log haul and extending in both directions from the cross conveyor. The movement of the distributor chain imparts a proportionate movement to the paper tape. A series of sorting bays in water or log decks on land flank the distributor chain, and as the log reaches a position abreast of the bay or deck assigned to its particular diameter class, the hole in the paper control tape simultaneously reaches a contact mechanism in the control instrument and actuates the logkicker for that sorting bay or deck, and the log is ejected from the distributor chain.

In North American practice, logs are seldom sorted before they enter the mill. In the rare case, logs may be selected for special products or orders, on the basis of species, quality, or above-standard lengths. The extra-large diameter logs and the tree-length logs brought to some mills require exceptional treatment. Redwood and Douglas-fir logs in the United States occasionally are too large for the headsaw, and the same is true of some other native species. This is particularly true in European countries that import logs of tropical species.

Splitting Large Logs

These logs that exceed the saw capacity must be split lengthwise into halves or even quarters to permit handling on the headsaw. They have been reduced by splitting with wedges, but the labor and the loss of material involved have inspired the use of special sawing equipment for preliminary breakdown of the logs. Single-bladed horizontal frame saws have been developed in Europe in which the log is carried on a low carriage under a reciprocating saw. This saw, mounted on a framework that straddles the track, is vertically adjustable for cutting height. Horizontal bandsaws are also used, with the saw unit either traveling past a stationary log or a moving log passing a fixed-position saw.

In the United States, the chain saw has been adapted to log splitting in several ways. In some instances, a 2-man saw is used with no guide other than a line marked along the log. The cutting proceeds in a horizontal plane. In other cases, the saw is supported at both ends on horizontal guide rails on a framework straddling the log. In a third method, the cutting plane is vertical, and one man stands on the log and operates and guides the chain saw along a line marked on the log. After the cut is completed, braces against the log are removed, the two halves roll outward ready for vertical quartering cuts or for sending to the headsaw. This vertical cutting system eliminates both the need for wedging to prevent pinching the saw and lifting of the top half of the log off the bottom half after the cut is completed. Little special equipment is needed for the vertical cutting system, and the weight of the saw is carried by the log. Even simpler is the splitting of logs in water. For this, a chain saw is mounted vertically on a platform extending over the water or on a catamaran type of raft, and the log to be split is floated through the water as it is being sawed.

The accumulation of sawdust in the pond is a minor disadvantage that is readily handled (9) when splitting by saw in the pond. The same problem occurs when logs are received in tree or multiple lengths. Chain saws are used for bucking before the logs go to the log haul eliminating difficulties that may arise when bucking at the top of the log haul just ahead of the log deck. Chain saws used in fixed locations at permanent mills often are powered by electricity, often from the mill's own power plant.

Bark Removal

In the sawmill, the main process of breaking down the log into boards and cants has undergone a major change in the last few years through the wide use of barkers to permit the conversion of residues into bark-free pulp chips. Although not primarily intended as an aid to sawing, removal of bark from the log before sawing has been found beneficial in reducing sawing energy (no bark to cut), in obtaining better sawing with species in which the bark causes sawing difficulties, and in increasing sharpness life of the blade because of the removal of grit and stones carried by the bark. Absence of bark also makes it possible for the sawyer to see knots or other surface defects more readily. This allows him to minimize their effects and thus improve the grade of the lumber produced. With band or circular headrigs, this benefit is greater than when gang saws are used, as the band or circular mill sawyer is free to turn the log between successive cuts and to vary the dimensions of the boards to take full advantage of higher quality portions of the log.

Removal of bark by saws may not be a typical procedure, but a bark-slitting saw (7) consisting of a 3-inch-diameter circular saw, with a depth-regulating rubber disk, driven from a portable motor through a 5-foot extension tube, was recently introduced for making a single longitudinal slit through the bark of a log. After weathering for 1 to 2 months, the bark falls off in handling or can be readily removed in a drum or by hand. Another type of bark saw is the so-called "rock" saw, merely a small, thick circular saw arranged to remove the bark and associated dirt and stones along the path of the main circular or bandsaw. It is used only on the top of the log ahead of the main saw, and is mounted on an arm that is adjustable to cope with log irregularities and differences in size.

Types of Saws Employed in the Mill

The headsaw in most mills in the United States is either a bandsaw or a circular saw. Where logs are of large diameter, a second circular saw called a top saw may be placed above the first, cutting in the same plane. Occasionally bandsaws are toothed on both edges, to cut on both the forward and return movements of the log carriage. This eliminates the need for a carriage offset to draw the log back from the blade to provide clearance on the return trip. This offset mechanism is also eliminated on some bandsaws in which cutting is done only on the forward movement, but the back edge of the saw blade is then provided with shallow teeth, not set or swaged, called "sliver" teeth. During the return travel of the log these teeth remove any splinters or slivers that might catch the blade and tend to pull it off the wheels.

Saw bands with holes in the central part of the blade have been used in the United States for quite a few years, but the primary purpose of using them has been to remove fuzzy or woolly fibers and any sawdust that may have escaped from the saw tooth gullets. More recently, in England, bandsaw blades have been perforated with round holes or diagonal slots or have been grooved lengthwise with the objective of controlling "tension" in the blade and securing greater stability during cutting. This followed the introduction in the United States of "stabilizing" holes in circular blades, but with saw bands, the perforations seem to influence the cutting accuracy adversely (28), although the accuracy of the saws longitudinally grooved equalled that of conventional solid bandsaws.

Saw Maintenance Problems and Techniques

One of the problems in the use of bandsaws is the repair of damage caused by foreign objects in the logs (iron, stones, or grit in the bark), by normal wear, or by unusual abrasiveness of the wood itself resulting from a high silica content. Because of the thinness of the saw band and its repeated flexing as it travels over the band wheels, no system of teeth that are not integral with the saw band has been developed as yet. Consequently, the advantages of inserted teeth, as used with circular saws, are not available for bandsaws, and badly damaged or broken teeth can be replaced only by welding.

Excessive wear or dulling, due to abrasive wood or dirt, is being minimized by application of stellite to the faces of bandsaw teeth (29, 10). The toughness of the stellite and its ease of grinding without special equipment make this method of increasing resistance to wear more practical than tipping the teeth with tungsten carbide.

Hardening of Saws

A simpler method of increasing wear resistance is to use hardened disposable blades, in which the tooth points are made extremely hard and nonfilable with the intent of discarding the blade when the teeth become dull. This system is practical, however, only with narrow bandsaws, small circular saws, and bow saws, and would not be economically feasible for log saws. Hardening of log saw teeth would be desirable under some conditions provided they could be serviced repeatedly as with the usual steel blade. Electrical heating by induction, using high frequencies, permits good control of the location and distribution of heating effect making it possible to harden and anneal the tooth points as desired, without heating the body of the blade. Birikov and Chernyshev (27) describe the use of high-frequency current in hardening the teeth of frame-saw blades, and Lyanguzov (50) gives specific directions for the process. An induction-heating method of automatically swaging and hardening saws of all types -- band, circular, or frame -- on a machine of grinder-like construction has been under development for some years by Raymond Antoine at Laboratoire Forestier (Université Catholique de Louvain, Belgium).

The hardening of teeth of wood-cutting circular saws has been introduced chiefly on thin blades of small diameter to be discarded when dull. The carbide tip is the usual means for supplying tooth hardness on shop and factory saws, but in the primary conversion from logs to lumber, the carbide tip is not in use. Where solid-tooth circular saws are used for log breakdown, the ordinary saw steel must be used, unless hard-facing is justified by the sawing conditions. A suitable technique for the hard-facing of circular saws has been developed, for spring-set saws, in Australia (11).

Modified Metals for Saws

In the United States, Canada, and elsewhere where the inserted-tooth circular saw is used, the ordinary steel teeth can be replaced by insert teeth or bits of "high speed" steel, chrome-plated bits, or bits "inlaid" with a hard facing material. Endersby (35) has found much better performance with hard-faced insert bits than with ordinary bits in the sawing of makore. Although inserted teeth with carbide tips are not used for log breakdown saws, one manufacturer in Germany has developed an inserted-carbide-tooth saw for factory saws.

Developments in inserted teeth metals have been accompanied by developments in specialized forms of inserted teeth for sawing of frozen woods. Two manufacturers in the United States have brought out bits of special shape to control the breaking up of the chips and the direction of sawdust flow. Another manufacturer in the United States uses the standard form of bit, but modifies the holder or shank by adding a small half-cylindrical projection to it near the bit end. This projection serves to break up the chip and control the direction of sawdust flow.

Modified materials for saws are not limited to inserted teeth. Stellite has been applied to the teeth of band, frame, and solid-tooth circular saws. Complete chrome plating of circular, band, and frame saw blades, or partial plating over the tooth portion has been used in Europe for some time to improve saw performance, but is less often used in the United States. One United States development, however, combines the hardness and resistance to gum accumulation of chromium surfaces with the high heat conductance of copper in multiple-plating of circular saws, using a specific plating design to control heat distribution. Heat control and elimination of gum accumulations permit a reduction of several gages in the thickness of saws over unplated saws of the same diameter.

Frame saw blades have followed some of the trends in saw modifications, such as stelliting, chrome-plating, perforating, and induction hardening. The swaged teeth commonly used in North America have not been generally accepted in Europe, where the spring-set tooth is used almost exclusively for all types of saws. Russia, however, seems more disposed to use the swaged form of teeth on frame saws. An attempt to introduce swaged-tooth saws in Sweden some years ago did not result in any lasting interest in such saws. In Norway, a comparative study of swaged and spring-set teeth is under way.

Saw Maintenance Equipment

Much of the successful use of a given type of saw tooth depends not only on the tooth design and quality of the steel, but on the equipment used for producing and maintaining the tooth form. Tools for swaging and shaping, both hand and air-operated, have been highly perfected in the United States, but automatic machines have not been developed here. An automatic swaging and shaping machine has been developed in Germany, and is adapatable to circular, band, and frame saw blades of the gages in common use in Europe, but is somewhat light for the heavier gages used in the United States. A slight modification of the faces of the clamping jaws appears to be desirable for adaptation to the single- or double-conical circular blades common in the Scandinavian countries.

For spring-set saws, a number of setting machines and hand-operated setting devices have been developed in Europe with built-in indicators to measure the amount of set given each tooth. Grinders have been improved in accuracy and durability through ordinary developments in machinery construction; the major innovation is the incorporation of several sets of cams for various combinations of tooth form and pitch. Knobs or levers permit selection of the desired set of cams. One grinder made in Germany is equipped with two grinding wheels properly spaced on the single spindle to provide both grinding and stropping action simultaneously on adjacent teeth.

For the straightening or "leveling" of saws, the hammer remains the principal tool. Tensioning of saws by hammering is still largely used for circular saws, but roller-tensioning, commonly used for band and gang saws, is coming into use for circular saws as well. Rollers for tensioning of band and gang saws have long been used, but the adjustable roller alinement of one French make permits the axis of one roller to be swung horizontally to simplify the removal of twist in the blade. As a tensioning device, the roll machine is being displaced in many North American mills by flame-tensioning devices, in which heat is applied by torches at a controlled rate along the saw edges to shrink the metal enough to establish the desired "tension."

Improvements in Sawing

Sash gang or frame saws have shown a number of notable improvements in recent years. Adjustable overhang has made possible the substitution of continuous feed for the intermittent feed, and the stroke-per-minute rates have increased. Hydraulic saw tighteners have been developed to provide uniform tightness for all saws, although this has added some weight to the highly stressed oscillating parts of the machine and requires the use of saws of uniform width within a given setup. In Scandinavian practice, the outer saws often are narrower than the central saws, and tighteners that produce a uniform unit stress rather than a uniform total stress are necessary. The ordinary screw and cam types of saw hangers permit such selective tightening but are troublesome to adjust. Elastic wedges, developed in Germany, provide easier and more stable adjustment, reduce shock loads, and do not increase the moving mass (44, 45, 65, 66). The problem of spacing and alinement of blades may be eased by a gage being developed in Norway. Automatic adjustment of spacing is also available (43).

Log gangsaw carriages have been much improved by hydraulic and pneumatic controls for gripping, turning, and vertical or horizontal shifting of the rear end of the log, while self-centering devices for the front end of the log increase the facility of feeding logs to the saw.

Several adaptations of frame-saws have been evolved for specific purposes. In one German innovation, a chain saw is incorporated with a frame-saw to reduce over-size logs to sizes that can be accommodated by the frame saw. This chain saw is mounted vertically on the side of the machine at sufficient distance to permit it to remove slabs and additional planks, as the log is moved along a track parallel to the frame-saw track. In an Austrian adaptation, the side-gate saw, the open-sided sash bearing 2 or 3 blades operates on one side of a wide vertical support, instead of between the two supports of the normal frame-saw, and cuts several planks simultaneously at each pass of the log carriage along the adjacent track.

Portable Saws and Equipment

Portability in frame-saws is not exactly an innovation, but more interest in this feature is developing. Several companies in Germany make portable gang mills, and one in Sweden is entering this field. In the United States, several companies make frame-saws mounted on trailer platforms or on skids for semiportable use (12, 13) unlike the European mill mounted on its own chassis. To avoid the pit required for the subfloor portion of some mills, one portable made in the United States has the driving mechanism mounted on top of the framework (14). In addition, this mill has two frames or sashes, each carrying half of the set of saws, with those in the rear frame staggered between those in the front frames. The 2 frames are 180 degrees out of phase in their movement, so that 1 frame is going up as the other is coming down. Vibration is thus balanced out.

Portability is a characteristic common to many small sawmills in North America, but only a few band mills (64) are fitted as portables. The vertical bandsaw is not well adapted to portability, but several French and German makers use a horizontal band on their portable bandsaw models.

Maximum portability is, of course, obtained with the circular saw, widely used in the United States. The older type of portable saw, which required dismounting and reassembly, is being succeeded by wheel-mounted units that can be trailed behind a truck. In some United States designs the end sections of the tracks for the carriage are hinged to permit shortening the overall length during moves. Supporting and leveling jacks are provided for rapid setting up of the mill at each new location. This operation requires only 15 minutes to an hour according to the type of mill being set up. Power may be supplied from a takeoff on the tow truck, or by belt from a diesel motor mounted on the tow truck. A diesel-electric drive may be used, especially when an edger is included as a separate unit. The sawyer may operate from the ground, from a position on the mill base, or he may ride a traveling-saw carriage, depending on mill design. Log carriages are of the riderless type, and dogging is usually manual.

The sawing accuracy of these mills is usually good in comparison with the older types of demountable mills and small permanent mills, although it does not approach that of permanent band or gang mills. Production rates are high, largely because of the light weight of log carriage used, the permanence of alinement provided by the rigid framework, and the use of adequate power.

Although portable circular sawmills in the United States are usually designed for sawing small logs (30 inches or less in diameter), a portable circular mill made in England has been designed for logs up to 45 inches in diameter. Logs of this diameter can be sawed by use of a top saw. The equipment, including the 120 horsepower diesel-electric generator, is mounted on 3 trailer units that can be coupled together for mill operation.

The lightweight characteristic of portable mill log carriages is a product of efficient design, compactness, and freedom from the slam-bang shock of mechanical loading and turning devices used in permanent mills. Excessive weight is, however, an undesirable feature even at permanent mills, as it merely adds a fixed set of forces and stresses to those directly related to the sawing operation. To eliminate the dead-weight effects, a manufacturer in Ohio has introduced an automatic log carriage weighing less than half as much as the conventional wood and steel carriage. This reduction in weight has been achieved by the use of aluminum for parts not subjected to heavy wear. Steel is used at all points of heavy wear.

Modern log carriages have been provided with automatic dogging and setting equipment operated by air, oil, or electric means controlled at will or automatically by the sawyer. The use of numerous combinations of remotely controlled forces eliminates the need for dogging and setting by men riding the carriage. Equally good dogging and setting results can be obtained in many ways. One manufacturer in France provides a remote-controlled carriage on which the log is hydraulically dogged at both top and bottom, then raised by the dogs until it clears the bolsters by several inches. The objective is to improve setting accuracy by eliminating the frictional drag of logs resting on the bolsters. Although the log weight is transferred to the knees, the resulting increase of friction between knee and bolster is based on a predictable weight instead of a drag on the bolster that varies with the presence or absence of bark, water, and grit.

Saw Types for Small Logs

Specialized types of mills broaden the field of log sawing. Small or low-grade logs require high-speed handling to be sawed profitably, and several types of machines have been designed to process such logs rapidly. The gang circular headrig with a top saw gang, the adjustable twin circular, the series of fixed-separation twin circulars, and the combination of circular splitter saw with a horizontal band resaw all have characteristics aimed at low-cost conversion of logs of small size (62).

The band resaw, used quite often in the United States, is far less common in Europe; the circular resaw is quite common in Scandinavia. A relatively new development is the use in Norway of the combination of an adjustable-spacing twin circular saw, a circular splitting saw, and a circular resaw. Logs passing through the twin circular saw are slabbed on both sides, turned down on one slabbed side and split, then each half is passed through the resaw, with the pith side of the flitch toward the fence, as often as required. For maximum recovery from logs with sweep, the log is passed through the twin circular with the sweep in the vertical plane, and then, in passing through the splitter, the cant is manually shifted during sawing to make the cut follow the curve of the log. Naturally, all subsequent cuts by the resaw follow the curve, since the cant is guided on the curved surface.

Saws for Remanufacturing

Beyond the sawmill or primary conversion stage, remanufacturing saws come into play. Band resaws may be used in either the horizontal or vertical form, and in some boxboard mills in the United States as many as 5 vertical bandsaws may be arranged in series to cut thick billets progressively into 6 boards as the stock moves in a continuous stream along a channel guide past each saw in succession. When sawing resinous woods, the formation of gummy deposits on the saw band and wheels is prevented by use on both sides of the blade of a light spray or mist of air-atomized kerosene, called paraffin in Europe, and a continuous wiping of the band wheels by rope ends kept slightly moistened with kerosene drawn by wick action from a reservoir at the opposite end of the ropes.

Cross Cutting and Ripping

In remanufacture and fabrication, cross cutting and ripping become more equal in importance. Numerous types of cut-off saws are available, ranging from rolling or swing table to swing saws cutting from above or below with a vertical direction of cut, or swing saws with horizontal over-or-under cutting to horizontally cutting saws sliding on rigid arms or carried on sliding rams. The under-cutting saws are usually favored in Scandinavia, and the radial-arm saws are seldom seen in Europe and Scandinavia. Among the sliding ram saws in the United States, a rather new design operates hydraulically with foot pedal control for selective or automatic control of the stroke.

Many cross-cutting saws are used for purposes other than cutting stock to specific lengths for furniture, boxes, or other uses. Trimmers for boards, and slashers for reducing slabs, edgings, and other waste to short lengths are common uses. Various types of automatic slashers have been in use, but a new type (15) combines a cam-operated plunge-cut saw and a hold-down consisting of a double row of vertical rods free to move vertically. These rods adjust automatically to the contour of the waste near the cutting line.

Automatic control of ripping operations has been achieved by using the impact energy of the sawdust to control the feed rolls of a ripsaw bench (32). A self-feeding edger in Oregon, with no press or feed rolls (16) uses the forward pull of saws rotating in the feed direction. Four 20-inch inserted-tooth saws of the controlled-cut type are used.

The ripping of stock for manufacture of furniture and the like is often done on straight-line ripsaws, in which a moving metal link belt carries the stock past the saw in a true line regardless of any irregularities of the board edge, since the short fence used is really a width-gage and does no guiding during the actual sawing. This type of saw, with either an overhead or undercutting blade, has sufficient accuracy to produce surfaces straight enough to permit gluing directly from the saw; a practice now quite common in the United States. A new variant of this type of machine is the twin straight-line ripsaw (17), in which two saws and feedworks are combined as one unit with the second saw operating in the opposite direction. For multiple ripping of wide material, the stock passing through one saw is returned through the second, thus eliminating the need for a separate merry-go-round and conserving much of the space that would be required by the merry-go-round or by two single saws arranged in opposition. Since each saw requires an operator, the production rate must be high enough to keep both saws in operation continuously.

Reducing the Saw Kerf Loss

The ripping of wide material into narrow widths, or the sawing of thin boards or strips results in a relatively high ratio of saw kerf width to finished width or thickness. This loss of sawdust can amount to 30 or 40 percent in the production of thin laminations, slats for blinds, thin boxboards, ribs for canoes, and similar parts, unless saw kerf diminishes as strip width or thickness decreases. One way of reducing width of kerf is by reducing or eliminating the side clearance normally given by setting or swaging the teeth. Side clearance is completely eliminated in a new circular saw with abrasive side surfaces. This saw provides a smoothly cut surface requiring no further loss by dressing. This saw is being developed and field tested by its United States manufacturer, and if it performs satisfactorily it will be a further step toward the ideal of cutting without a kerf.

Cutting without a kerf has, of course, been achieved in veneer cutting, and slicing has been extended to the cutting of relatively thick stock, such as battery separators and boxboards, where only short lengths are involved. Both the guillotine and the rotating knife types of slicing have been used, but slicing usually requires heating of the stock before slicing, and always causes loss of strength resulting from checking on one surface as the sliced board is bent by the bevel of the knife.

Sharp bending of stock at the knife edge and limitations as to length of stock are eliminated in a kerf-less system of cutting based on the use of circular slitting knives (52). A gang of thin circular knives, spaced according to the thickness of strip to be cut, is mounted above the machine bed, with a similar gang mounted directly underneath and projecting above the machine bed by a small distance, about 1/8 inch. The distance between the two sets of knives is the thickness of stock to be cut minus twice the projecting distance of the lower knives. The knife arbors are rotated by power, and as a board is fed between the two sets of knives, the knives form shallow slits in the upper and lower faces of the board. Direction of rotation is such that the knives pull the board forward. This set of knives is followed closely by additional sets with each set tracking exactly in the slits made by the first. The vertical gap between the knives is reduced for each set, resulting in progressive deepening of the slits from both surfaces, until the slits meet to subdivide the stock into strips as wide as the stock was thick and as thick as the spacing between the knives on each arbor.

To ensure accurate superimposing of the slits made by each set of knives, provisions are made to prevent the stock from spreading as the slits are deepened. This necessarily subjects the cells along the surfaces to some compression, but even if some surface damage resulted it may not be important for many uses. Light planing or sanding may be necessary to finish the strips for some uses, but such finishing operations probably would be required with sawn strips also, and most of the gains from eliminating a saw kerf would be retained. The initial model of the machine was made to produce 1/4- by 1-inch boat ribs from 1-inch boards. Limitations as to maximum width of face (thickness of stock that can be slit) have not been established as yet.

Kerf-less methods of dividing wood into boards of a thickness greater than the common thicknesses of veneer and without damage to the board have been the subject of speculation and thought, but no concrete progress in applying such methods has been made as yet. Ultrasonics, applied as vibration of a knife-edge tool, and ion streams are two means that may be worthy of exploration. Ultrasonic vibrations can be brought to a focus within a mass, much as light rays are focused, and it may be possible to focus ultrasonic vibrations to a line and sweep that line along a plane within a mass of wood. If sufficient power of the proper frequency could be concentrated along a fine enough line, cell rupture along the line may result, and a sweep over the length of the wood mass would divide it in the plane of sweep.

Advances in Saw Tooth Design

Until kerf-less methods of dividing wood are developed for reliable general use, the saw remains as the practical tool for such work. Numerous types and combinations of saw teeth have been devised to reduce power, increase cutting accuracy, improve smoothness of surface, or to cope with problems of grain direction, wood structure, wood condition, abrasiveness, depth and width of cut, or such special problems as curved saw cuts. Analysis of suitability usually has been based on empirical results and observations, but more and more testing under controlled conditions and with suitable measuring instruments has been done in recent years.

Several forms of swaged teeth for ripping have been tested in Canada (38) and the hollow-ground type was found to be superior in finish and lowest in power consumption. The normal, flat-faced type was equal in efficiency to the hollow-ground type, but required somewhat more power. The "diamond" tooth form was least efficient and required most power.

Studies by Reineke (55) have given an insight into the actions occurring during cutting with ripsaw teeth, and resulted in development of the Duo-Kerf saw, designed to cut more smoothly and with less power than present-day standard types of saws. Its use in modified form on bandsaws in France is presented by Boisseau (28).

Research in Wood Sawing

Other studies of cutting forces in wood, with reference to grain direction, knife angles, wood density, moisture content, or feed and speed rates have been made by Kivimaa in Finland (47), Thunell in Sweden (67), Balligand at Laboratorie Forestier de l'Etat, Institute Agronomique, Gembloux, and Antoine at Louvain, Belgium (22), Skoglund and Hvamb in Norway (60), Petitpas and Chardin in France (30, 53), Harris in England (40), Saito and others in Japan (58), and Telford in America (63). Kivimaa (48), Thunell (67), and Chardin have also studied the dulling of cutting edges, as have Endersby (36) in England, and Edamatsu and Ohira in Japan (34). The movements of sawdust in the gullets of the saw teeth have been studied by Thunell (69), and Chardin (31) has used color photography for this purpose. The escape of sawdust from bandsaw gullets has been studied by Reineke (57). Vibration of circular blades has been studied by Skoglund (61) in Sweden, Barz in Germany (25, 26), and is currently under joint study by Hvamb and Reineke.

Tooth forms have been developed with the assistance of laboratory equipment for specific purposes such as bow saws (24) and smooth-cutting circular saws (39). Parameters for existing types of saw teeth for use with specific wood species or specific working conditions have been instrumentally determined in England (37), by Antoine for Belgian Congo species (23), by Andrews and Bell in Canada (21), by Sergiev in Russia (59), and by Chardin and Sallenave in France, for French Equatorial species.

Various forms of unconventional saws have been introduced in recent years. Group and wavy setting of teeth have been introduced on narrow bandsaws. A practical inserted-bit type of carbide saw has been produced by a saw manufacturer in Germany (19), and a spring-set circular saw of Swedish design uses reverse setting with the high point of the tooth near the center of the blade (20). The controlled-cut circular saw originated in Germany has a small number of teeth projecting slightly beyond the circular shoulders. These shoulders prevent the teeth from taking an excessive bite. This feature prevents kickbacks, grabbing, or throwing of small wood trimmings, giving a high degree of relative safety (56), and making it possible to feed the stock in the cutting direction. Factors affecting such feeding with the saw, in contrast to the normal feed against the cutting direction, have been reported by Skoglund and Hvamb (60).

In the field of manual crosscut saws, use of the Austrian EHZ tooth form is reported to result in a 5 percent increase in production compared with the American type of crosscut saw. The gain may come from the thinner gage made possible by the shorter teeth of the Austrian type.

A wire type of blade with helical teeth has been introduced in America for manual use in scroll, coping, or hacksaws, and also for mechanical operation as a bandsaw. Because of its helical teeth, it can cut in any direction and the workpiece does not have to be turned, as in bandsawing, to keep the line of cut lined up with the blade. This freedom from turning the workpiece is valuable in sawing intricate patterns or large pieces, but the small diameter of the wire and the shallow teeth limit its resistance to the heavy cutting pressure in thick material or in high cutting rates in thin material.

The frequency with which new developments in sawing appear is indicative of the healthy attitude of the woodusing industries toward wood technology and conservation of wood through better techniques and tools. The increase in number and size of wood research centers promises an ever-increasing accumulation of data on sawing that will contribute to further technical progress in this field. The ultimate goal of kerf-less "sawing" in the offing, perhaps near, perhaps far away, is a constant stimulus to progress in sawing research. Even the noise problems of woodworking equipment are under investigation (46, 68), and in time both sawdust and the whine of the saw may no longer be the characteristic signs of a wood processing plant. Truly, the field of sawing is in a state of flux, and is marking up new advances at an ever-increasing rate.

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