Three configurations of chipping headrig and resulting chips

(See page under Koch, 864

WOOD MACHINING REV EW

963 through 965

and
THE PURPOSE OF THIS PAPER is to review significant research that has not previously been digested in recent English-language texts and bibliographies. In general, only findings published during 1963, 1964, and 1965 are considered. The reviewers' principal sources were the major world journals in wood science and technology, Forestry Abstracts, and personal communication with researchers known to be active. Only papers of research nature were reviewed. The reviewers recognize and regret that limits of time and linguistic ability have probably resulted in omissions and misinterpretations.

After some debate, it was decided to proceed by abstracting individual papers and arranging the abstracts under subject-matter categories. This procedure gives the reader more information about individual studies than would be possible in a narrative account and hence should aid him in identifying contributions of special interest. The subject-matter heads are listed in the box on this page.

While any general appraisal must reflect individual biases, their survey left the authors with some strong impressions.

For one thing, the total research effort seems to be accelerating, with increased numbers of workers active. The 198 references attest the fact.

For another, a substantial amount of recent research is being put into application. Thus the work of Plough (1962), McKenzie and Franz (1964), and St. Laurent (1965) on the principle of inclined cutting has seen application in 1966 through the development and installation of an oscillating-knife veneer lathe by a major forest products manufacturer in the United States.

Abrasive belt machining, while meagerly reported in English-language archival journals, has made striking progress in recent years, with applications primarily in the particleboard and plywood industries. Some trials on solid wood have been reported by Ward (1965).


rops and Addo-Ashong (1965) on anatomy in relation to mechanical failure was particularly illuminating. Knowledge of the disk defibration process has been furthered in work by Atack and May (1962, 1963), Dorland (1962), and Holzer (1962). Phenomena related to the dulling of cutting edges have been studied by Englesson (1964), Hillis and McKenzie (1964), Nosovskii (1963), and Pahlitzsch and Dziobek (1961). Stability of saws has received detailed analysis by Jones (1965) and Pahlitzsch and Dziobek (1961). Stability of saws has received detailed analysis by Jones (1965), Mote (1964, 1965), and Thunell (1962, 1963, 1964).

Background

History and General Texts


Invention was active in three periods: Roman times, between 1400 and 1500 AD, and finally, in the 18th century, which the author considers the golden age of hand woodwork. Contains a 42-entry bibliography, a list of British museums with tool displays, and a 3-page index.


An elementary text with introductory comments on the structure of the lumber industry in Britain. Considers (but does not discuss in depth) types of sawmills, workshop practice, tools and maintenance (including planers), sawmill organization, wood anatomy, and the future of sawmilling in Britain. A 4-page appendix outlines statutory requirements applicable to British woodworking factories.


This third volume in Vorreiter's series of wood technology handbooks is concerned with all aspects of wood machining. The first section discusses fundamentals of mechanical wood conversion, the second and major section describes individual machines and methods according to function, and the short final section is concerned with safety. The text contains 84 tables and 633 good illustrations. The 7-page list of references omits mention of such well-known English-speaking researchers as Franz, Goodspeed, Leney, Lubkin, and McKenzie. Generally speaking, the machines illustrated are of European manufacture. The principles elucidated are, or course, universal. Text in German.

Properties of Wood


Summarizes the structure of hardwoods and softwoods (initial 14 pages). In the light of this structure examines the changes in anatomy and fine structure of wood resulting from mechanical failure. Concludes that, in compression parallel to the grain, the initial zone of failure lies between the secondary wall layers S5 and S6 within the fibers, thus causing increasing stress on adjacent fibers and deformation within them as well. With further increase in load, the number of cell wall deformations is increased, and stress concentration buckles the fiber walls, with consequent failure between fibers or between ray parenchyma cells; buckling lines are recognizable under the microscope. When wood is compressed perpendicular to the grain, the low modulus of elasticity results from a change in the cross-sectional form of the cells and does not involve the properties of the cell wall constituents in a direct way; that is, with slight forces the cell walls bend inward or are distorted sideways. As with compression parallel to the fiber length, layer S6 separates from S5 when failure occurs. Individual fibers exhibit greater wet strength in tension than do dry fibers, whereas with whole wood, the opposite is true. The increase in strength of whole wood on drying can be attributed to the formation of additional bonds between the lignin, matrix (hexosans, pentosans, substituted pentosans, and polyruhomic acids), and the cellulose framework. Short fibers with large microfibril angles break under a smaller load than do long fibers with small angles. Therefore, long fibers require a larger area of overlap with adjacent cells to develop their intrinsic strength. Tension failures, in common with compression failures, usually occur within the fiber between the S5 and S6 layers. In wood subjected to radial shear forces, lines of failure generally follow the rays but also involve some rupture of the fiber walls. In some specimens, tangential shear causes fracture at the junction of earlywood and latewood and is further affected by rays and vertical parenchyma, but fracture of fiber walls also occurs. These fractures lie between the layers S5 and S6.

Analysis of Cutting Process

Orthogonal Cutting


Brittle-lacquer techniques were used to study stress distributions in the workpiece ahead of the cutter along the three principal wood axes. Stresses
were not significantly related to cutter geometry but were determined by the microgeometry of the cutting edge.


A detailed mathematical analysis of vibrational cutting for the special case of uniform feed, linear vibrations in the feed direction, and a cutter assumed to be a flat knife without teeth.

**Inclined Cutting**


Inclined cutting perpendicular to the fiber direction, accompanied by a rotating disk, has considerable benefits related to the velocities parallel and perpendicular to the cutting edge. Cutting force decreases as the tangent of inclination increases, stabilizing at a minimum of half that observed at zero inclination. Reduced cutting forces and improved surface quality are initially attained with less input energy (higher cutting efficiency), but input increases at the higher inclination angles necessary for maximum surface quality. The benefits of inclination are primarily due to minimizing the spread of stresses and deflections as the cutting edge advances into the cell structure. At low rake and high inclination angles, forces are transferred to a direction where the shear strength of wood is less. Edge bluntness, abrasion, and heat also importantly affect the incision of fibers.

_McKenzie, W. M._ 1965. The effects of edge bluntness in the cutting of wood. IUFRO, Sec. 41, October Meeting, Melbourne.

Hypothesizes that, when chip formation causes a tensile stress across the cutting plane, the ratio of severance force to chip-deflection force will depend on the ratio of the square root of the edge radius to the chip thickness, and will be independent of rake angle, wood properties, moisture content, and grain direction. Since the severance force and energy are greatest for cutting in the transverse planes, any cutting device must concentrate extreme energy to be efficient and produce quality transverse surfaces.


When plywood of refractory species is saw-trimmed, the edges splinter to some degree. With inclined cutting it may be practical to rettrim such panels to eliminate breakout. Tests were made with a toothless disk 11-1/2 inches in diameter and with rake angle of 50°, clearance angle of 5°, and cutting-edge radius of 6 microns. At a rim speed of 600 feet per minute and feed speed of 1-1/2 feet per minute (v = v = 400), the disk satisfactorily trimmed 3/8-inch, 3-ply plywood made from mountain ash (Eucalyptus regnans) if the plane of the plywood were 2-1/2 to 4-1/2 inches from the center of the disk. Thus the angle between the tangent to the disk periphery and plane of the sheet was 23° to 38°, and the resultant cutting force component lay within the plywood, that is, with no outward component.


A vibrating knife produced a superior end-grain surface, presumably by kinematic reduction in rake angle. Proposes a rotating conical knife to achieve continuous inclined cutting.


Parallel cutting force exerted on a single swaged tooth (1/4-inch wide inserted-type for circular saw), having 35° rake angle and 10° clearance angle, was measured when cutting a 0.01-inch-thick chip from the end grain of a 0.15-inch-wide piece of hardwood at 4-percent moisture content. The tooth was subjected to lateral vibration. At cutting speeds below 3-1/2 feet per minute, double vibrational amplitude of 0.10 to 0.015 inch, and vibrational frequencies of 50 to 200 cycles per second, parallel cutting force was substantially less than when the tooth was not vibrated. Force was decreased 50 to 70 percent if cutting speed was reduced to 2-1/2 feet per minute. Surface quality was increased in inverse proportion to parallel cutting force. No reduction in parallel cutting force was observed when: 1) cutting speed was increased above 3-1/2 feet per minute, or 2) chip thickness was increased above 0.016 inch, or 3) vibrational frequency was more than 300 cycles per second, or 4) vibrational double amplitude was less than 0.04 inch, or 5) the wood was wider than the tooth.

**Peripheral Milling**

In planing particleboard and end-grain beech, cutting force increased 300 percent between sharpening and removal for resharpening. As blunting proceeded, power requirement increased more rapidly at slow than at high feed speeds.


A transducer is described that permitted profile determination of a rotary-planed surface. Measured depth of knife traces agreed with calculated values. Profiles differed somewhat by species. Heavy hold-down pressures reduced depth of knife traces.


The relationship of the radial and tangential cutting forces to chip thickness is graphed for five cutting-schedule factors. Power consumption was at minimum with the following schedule: clearance plus sharpness angle 40° to 45°; clearance 5° to 7°; cutting speed 30 to 40 meters per second; nominal chip thickness 0.3 to 0.5 millimeter; moisture content 10 to 12 percent; edge radius 4 to 10 microns.


Effects on surface roughness were established for: 1) feed per knife; 2) the minimum feed per knife visible to the naked eye (0.3 to 1.6 millimeter) for a group of 6 timbers; 3) setting precision of the knives in the cutterhead; and 4) progressing knife wear. Feed per knife, depth of cut, cutting angle (rake angle?), and distance between knife edge and chipbreaker (gib?) were studied. The most critical factors were feed per knife and cutting angle. Chipbreaker (gib?) settings are recommended for hardwoods and softwoods. Difficulties in planing each species are listed with frequency of each type of defect attributable to each factor.


Part III describes effectiveness, in a 4-knife cutterhead, of initially setting individual knives to less than 0.1 millimeter protrusion, grinding to 10 to 75 microns, preliminary jointing and final jointing to 10 to 50 and 5 to 10 microns, respectively. Cutting angles, feed speeds, and their effect on various species are discussed. Part IV concludes that a wide "land" caused by a heavy joint gave an inferior surface and short knife life; range of widths tested was 0.01 to 0.9 millimeter.


Energy consumption in cutting beech increased with clearance angle, being minimal at clearance of 5° to 15°. The greatest effects were observed with thick chips. Clearance had little effect in radial or tangential cutting perpendicular to the fibers but strongly affected energy required in cutting parallel to the fiber axis. In all cutting directions, energy consumption increased with chip thickness. It did not differ between radial and tangential cutting in a plane perpendicular to the fibers.


A test to determine the effects of sample shape, cutting direction, and knife material (carbon tool steel, chromium plated, and tungsten-carbide tipped) on energy consumption proved inconclusive. Energy consumption increased with cutting depth in all directions, but less in the radial than transverse direction. Consumptions for Fagus crenata, Chamaecyparis obtusa, and Shorea spp. are compared.


Rake angle was the major factor affecting energy consumption in cutting Fagus crenata, Chamaecyparis obtusa, Shorea philippinensis, and S. negrosensis. Energy consumption decreased with increasing rake angle, the rate of decrease depending more on cutting direction than species, moisture content, sharpness angle, or cutting depth. Energy consumption was proportional to specimen length in the cutting direction.


1) Specific cutting energy increases with moisture content up to approximately 20-percent moisture content (variable by species) and then decreases; 2) specific cutting energy is proportional to specimen length; 3) energy consumption is largest in transverse cutting. Tangential cutting in the peeling direction uses least energy. In the radial direction, the energy is the same whether cutting bark-to-pith or vice versa.

By means of very high-speed photographs (10,000 frames per second) chip formation in up- and down-milling was analyzed when cutting pine, beech, and poplar.


Energy consumption was minimized with a sharpness angle of 35° and increased with larger sharpness angles. High clearance in combination with high rake increased energy requirements. Cutting energy was inversely proportional to rake angle. It was minimized if the cutting edge was parallel to the grain and motion was perpendicular to the grain.


Laboratory tests on Fagus crenata, Chamaecyparis obtusa, and Lauan (Shorea spp.).


Describes the principles of magnetostriuctive measurement of cutting force and the test rig used to make such measurements in spindle-moulding beech, Finnish birch, and spruce under different conditions of grain angle, feed speed, depth of cut, and cutting speed. Cutting forces sometimes exceeded those reported in the literature. Mean chip thickness did not prove to be a suitable reference, particularly for thick chips. It was possible to calculate a specific cutting force from direction of cut and feed speed. Moulding machine power requirement could be calculated from cutting force and time.

Processes Directed Toward the Workpiece

Barking


Bond strength and bark thickness appeared to influence the performance of ring barkers.


A drum has been designed in 15-foot sections with inside diameter of 12 feet and discharge openings of 11 feet. Staves are of steel pipe. Standard 33-inch freight-car wheels support and drive against 100-pound railway track (bent to conform to drum circumference); a hydraulic motor achieves a drum speed of 8 rpm. For design purposes, a coefficient of friction between wheel and rail was conservatively assumed to be 0.12 under wood-room conditions (compared to railway experience of 0.22 for wet rail and 0.30 for dry rail). A 60-foot drum will clean 25 to 55 cords per hour. On frozen wood, tank sections are desirable, and when they are used, barking capacity is proportional to water temperature. The tank section requires some 2,000 gpm of water at a minimum of 60°F.


The equipment should be adjustable so that from 1 to 6 blades can be made to pass over each part of the log surface.


Investigates efficiency of a small drum Barker with a central driveshaft, and one with a basket-type rotor. Evaluates the parameter c in the equation: \( w = \frac{W}{1 + \frac{c}{w}} \), where \( w \) is weight (kilograms) of bark to be removed, \( W \) is weight of material (including bark) loaded into the drum, and \( t \) is the operating time (minutes). Types of material, number of drum revolutions, and apparent loading capacity are main factors affecting \( c \).


Sticks 8 to 14 millimeters in diameter coated with an artificial "bark" of sawdust glued in place with a fast-drying paint were processed in a bench-model barking drum 300 millimeters in diameter and 400 millimeters long, with glass ends and driven by a 1 horsepower motor. An index of bark...
removal was investigated. Effects of barking bar, speed of drum, and loading capacity are summarized. Velocity and types of material movement within the drum are discussed. Movement is similar in drums of different diameter (D) if the ratio of revolutions per minute to v/D is held constant.


At 60-percent loading a drum barker with central drive shaft with spiral cutter removed 90 percent of the bark in 2 hours compared to 8 hours for an ordinary drum barker. The shape and sharpness of the cutting edge (at present damaging the wood), the speed of the shaft, and the method of bark removal, all require study to improve the rate of bark removal.


After first being submitted to an “impact” treatment by means of a pneumatic hammer device to weaken bark cohesion, birch bolts were debarked conventionally. Marked bark deformation was observed at 0.8 to 1.2 kilogram per square centimeter (specific impact force). The responses of frozen, hot-water-soaked, freshly felled, and old material are briefly discussed.


Experiments with a barker equipped with a rosser head (i.e., a rotating cutterhead) showed that r, the radius of rounding of the knife edge, depends on the condition of the wood and the sharpness angle of the knife. With sharpness angles of 45° and 65°, r should be respectively 1.0 to 0.8 and 0.3 to 0.5 millimeter for frozen wood. With sharpness angles of 45° and 60°, r should be respectively 2.0 to 2.5 and 1.5 to 1.0 millimeter for floated and freshly felled wood. A feed speed of 15.9 meters per minute is recommended for frozen wood with Kr = 3 (Kr being the number of cutter knives that pass over each part of the wood surface), and 23.8 meters per minute for floated and freshly felled wood. A feed speed of 30 meters per second on both frozen and unfrozen logs was obtained at a saw speed of 30 meters per second on both frozen and unfrozen logs.

Sawing


Explains procedure for determining the optimum setting thickness for boards. The procedure assumes that the sawmill has been adjusted for its most accurate work. Revised from C. J. Telford's FPL Rept. 899-2, dated 1953.


Describes a saw consisting of a series of fixed teeth or gouges, arranged one above the other, each taking a deeper bite than the preceding one as the work passes between them. Thus, continuous shavings suitable for pulping are produced.


A stepless speed changer was used to study the interactions of cutting and feed speed, feed per tooth, sawing area per tooth, gullet area, and power consumption. Under severe conditions, use of a speed changer might prevent overload.


A mathematical treatment of ripsawing, including formulae for calculating specific work.


With a band resaw cutting spruce (Picea excelsa): 1) optimum bite per tooth was approximately 1 millimeter in both frozen and unfrozen logs; 2) a tooth pitch of 1.5 inch gave better accuracy than a 2-inch pitch in both frozen and unfrozen logs; 3) best accuracy was obtained at a saw speed of 30 meters per second on both frozen and unfrozen logs; 4) because of greater water and ice content in sapwood, sawing accuracy was less on boards sawn from frozen sapwood than on boards sawn from frozen heartwood; 5) sawdust had a greater tendency to freeze to the sawn surface of sapwood than to heartwood; and 6) the power demand is greater for frozen than for unfrozen logs.

A geometrical determination of top bevel angle for spring-set saws based on the threshold of side interference. Single and double back-bevel teeth are considered. A general case equation cannot be solved analytically although approximations enable a graphical solution for the more common ripsaws.


The abrasion of white lacquer sprayed on the tooth tops of circular saws whose clearance angle ranged from 0° to 21° decreased with increasing clearance under practical conditions, but was constant under laboratory sawing where tooth deflections were minimized. Tooth deflection strongly influences the clearance angle required in practice. The direct influence of bluntness, feed speed, species, and depth of sawing on clearance requirement appears small, but all these factors may contribute to tooth deflections. A 15° clearance is recommended for Australian mills.


Describes experiments to determine effect of a number of process variables on specific work and surface quality when sawing hardboards (0.0968 gram per cubic centimeter) in sets of four (total thickness 12 millimeters), with a circular saw having teeth with rake angle of 10°, clearance angle of 15° to 17°, and front bevel of 75°.


A three-tooth, 1/4-inch kerf, tubular saw driven at 3,600 rpm by a 75-horsepower motor produces 10 round dowels per minute from short logs. The log remains stationary while the saw passes through it and is withdrawn. The log is then turned and another round extracted. Capacity is approximately 3,500 to 4,000 four-foot rounds in 8 hours. Sawdust is ejected from the initial cut by an ejection slit cut in the log. Subsequent ejection is into the void left by the preceding round. Rounds are solid-piled and kiln-dried without sticks.


Analysis of typical two-gang sawmill in Germany with emphasis on necessity of high recovery. Attempts comparable analysis on assumption of same mill operating in Britain.


Capacity was limited by deterioration of sawing quality above a critical feed speed. For cutting dry or green conifers at a cutting depth of 10 to 30 centimeters and saw speeds of 45 and 25 meters per second, the specific work was least for feed speeds of approximately 0.9 and 1.05 to 1.15 millimeters per tooth, respectively. Sawing at minimum specific cutting energy rarely produced accurately cut boards.


A theoretical discussion of inertia forces, feeding power, and main cutting force during one cycle of the frame (sash). Recommendations given for feed speed and lead to avoid cutting upward. Overhang yet to be tested.


Gulowsen, K. T. 1964. What is gained by sawing with thin cuts and with greater accuracy? Norsk Skogindustri 18(6): 210-211. (Also CSIRO Australian Translation 7145.)

1) If a square is cut from a log, a thin kerf will not increase yield. 2) If the square is reduced to two planks, the yield per plank will increase by half the saving in kerf. 3) If there are n planks, the yield per plank will increase by \((n-1)/n\) times the saving per kerf.


In logs 5.5 to 12 inches in diameter, sawing with a 9/32-inch kerf kerf increased lumber recovery 2.9 to 33.3 percent (average 7.3 percent). In some diameter classes no increase occurred. While the increase was maximum for logs 12 inches in diameter and less, results were erratic for logs of very small diameter.


When small loblolly pine logs were sawn into 8-foot 2 by 4's in a well-maintained circular sawmill: 1) it was possible to produce 95 percent or more studs with an overall thickness variation of ±2/32-inch and an overall width variation of ±3/32-inch; 2) variation between boards was a little less than variation within boards; 3) there appeared to be no statistically significant difference between sizing accuracy of studs from logs with and without compression wood; and 4) when studs are individually classified into one of three classes —no compression wood, mixed compression wood and normal wood, and all compression wood—the sizing variation of the mixed class was significantly greater than either of the other two classes or the mean variation of all three classes.

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Relates sawing methods, log diameter, juvenile core diameter, log position in tree, presence of compression wood, log eccentricity, and position of the stud in the log to warp in 2 by 4 studs sawn from small loblolly pine logs. The incidence of severe crook and bow was much greater in butt wood, log eccentricity, and position of the stud in the log to warp in 2 by 4 studs sawn from small loblolly pine logs. The sawing system prescribed for measurement of cutting forces. The effect of blade lead, blade thickness, feed, kerf height, and feed mechanism on cutting forces was determined. Eighty-five percent of the total work was performed in the working stroke. Peak vertical force was 3.5 to 5 times its mean value, while the peak horizontal force was 9.5 to 11 times its mean value. The peak feed force averaged 2.5 times the mean cutting force.


A strain-sensitive transducer system is described for measurement of cutting forces. The effect of blade lead, blade thickness, feed, kerf height, and feed mechanism on cutting forces was determined. Eighty-five percent of the total work was performed in the working stroke. Peak vertical force was 3.5 to 5 times its mean value, while the peak horizontal force was 9.5 to 11 times its mean value. The peak feed force averaged 2.5 times the mean cutting force.


Within certain limitations, thin circular spring-set saws use less cutting power than thicker saws. Other factors being equal, power demand is proportional to kerf width. Tests confirmed that at rim speeds lower than the conventional 10,000 feet per minute (8,500 and 7,800 feet per minute were tried) chips were thicker and specific cutting power—hence total horsepower—was thereby reduced. For each saw, power demand was minimized at some optimum rim speed related to the vibrational stability of the teeth or to gullet overload. A stronger tooth profile is described and recommended.


Rim speeds in the range from 6,000 to 10,000 feet per minute were tested on wood of dense species. Initial reductions below 10,000 feet per minute achieved some power saving, because chips were thicker. With spring-set saw teeth, however, a critical speed was reached at which the increased bite per tooth deflected the teeth, widening the kerf and therefore raising power demand. Swaged teeth were more stable than spring-set teeth, but required more power because bite per tooth was less. Saw diameter was 37.75 inches; gauges were 10, 11, and 12. The saws had 54 teeth.


Specific cutting energy and power requirements increase with increasing distance of the kerf from the pith.


In studies on a highly instrumented research sawing machine, axial vibration of the saw blade was influenced by cutting force, roughness, and chip size. Bite per tooth, chip thickness, depth of cut, and blade protrusion also affected cutting forces.


A detailed mathematical exposition.


Test apparatus is described. The horsepower obtained at the cutting point is, on the average, about half the horsepower rating of the engine alone. The sprocket, chain, and guidebar therefore absorb approximately half the available power.


Practical data, in tabular form.


Gullet volume and sawdust ejection mechanisms are discussed in relation to overloading and saw instability. Formulæ to determine capacity limits for various saws are presented.


Batches of logs varying in diameter, grade, density, and position in tree were processed in a modern high-speed mill by several sawing patterns. Time required on each major machine to convert
A tabular presentation of machining characteristics based on visual examination of defects in samples. The effect of specific gravity and growth rate is included.


Describes wood and knife characteristics affecting the quality of finish.


A detailed analysis.


Results, in graphical form, show that the best cutting angles are: clearance 15°, sharpness 55°, and rake 20° for tool steel and beech wood. Angles of 10°, 70°, and 10°, respectively, are recommended for carbide tools planing beech and particle and fiberboards.


The irregularities in feed movements of machines with chain drives are calculated. For a given feedworks configuration, feed irregularities depend on the number of links in the chain and are minimized by increasing the number of links. Since the irregularities influence only the workpiece feed velocity, they have no practical significance in sawing, but are of great importance in sanding and planing.


A series of 36 photographs illustrating sawdust chambering and escape from the gullet.


Variation (according to moisture content, species, cutting angle, and direction) of energy consumed by a chipper-type saw tooth.


A theoretical discussion of frame-saw dynamics in relation to sawing efficiency. Production capacity might be increased by lengthening the stroke, but a reduction in rpm may be required because of higher mass forces. Sawing on the up-stroke may have advantages, but engineering problems related to saw stresses and log deformation are involved.


Saws with a range of hook, clearance, and front bevel angles were tested on high-density fiberboards. Optimum angles were 40°, 13°, and 90°, respectively, at a cutting speed of 9,850 feet per minute and a feed of 5.9 feet per minute.


Discusses theoretical and practical aspects of sawing cants with sweep and describes a device for automatically feeding cants from the first to the second frame saw and processing them with maximum utilization.


Describes a swing-frame saw system that operates without cutting on the up-stroke.

**Jointing, Planing, Molding, and Shaping**

growth redwood can be worked if machines are well adjusted. This review considers only the machining aspects of the report.

Turning


The temperature in the tool (?) was measured with a thermocouple during turning. Temperature increased with decreasing moisture content, reaching a maximum of about 1400C. In teak, it also increased with increasing rubber (?) content.

Boring, Routing, and Carving


Presents a formula for calculating the energy required when drilling chipboards of different densities and binder content with bits of various diameters and cutting speed.


Discusses general problems in boring including species effects and hole tolerances. Makes specific recommendations for counter-boring and countersinking, mortising hardwoods, and for minimizing tool breakage.


Tool steels and designs with respect to boring requirements. Various tool types are illustrated.


Special processing of standard tools, various tools and their use, ordering and sharpening tools, and types of boring machines.

Mortising and Tenonng


A detailed theoretical study.

Sanding and Abrasive Tumbling


Lauan plywood was sanded parallel to the grain with wide belts having silicon carbide grits of 120, 150, 180, and 240 mesh; feed rate was 14.5 meters per minute and belt speeds were 482, 913, 1,350, and 1,785 meters per minute. The trials showed that: 1) degree of fuzzy grain was directly proportional to the rate of stock removal; 2) stock removal rate increased with belt speed and 3) with sanding pressure, but the curve had a maximum value related to grit size.


Surveys literature on surface measurements of sanded wood. Stylus-type surface probes are preferred to light and shadow microscopes. A moistened sanded surface yields profile information beyond that obtainable from the dry surface. Discusses technique for evaluating a sanded wood surface with deep anatomical or structural depressions.


A profilometer was used to evaluate machined wood surfaces.


The tensile and axial forces on the belt largely determine the required belt strength and initial pre-stress force. A greater pre-stress force is needed for oscillating sanding belts. Contact-free pneumatic limit switches are used to prevent belt damage from axial movement.


Tests with a wide-belt sander were run on oak and maple. Net horsepower per inch of belt width is plotted against depth of cut to show effect of feed direction and feed rate, and life is plotted against linear feet run. Surface quality was improved and power requirement reduced if stock was fed against direction of abrasive rotation. High belt speeds yielded a better finish and lower specific cutting energy than low speeds. Total cutting power increased with feed rate. For sanding oak at 75 feet per minute at depths of cut of 1/32, 1/16, and 3/16-inch, cutting power per inch of belt width was respectively 2.2, 4.6, and 14 horsepower. At 20 feet per minute and 1/16-inch
depth of cut, 0.9 horsepower was required. No appreciable dulling occurred in removing a 1/32-inch cut from 4,000 lineal feet of maple flooring at 80 feet per minute and 2.75 horsepower per inch of belt width.


The ordinary conveyor-type feed is not satisfactory for abrasive planing. Power-driven, planetary-type feed rolls are necessary. One installation of a two-head, top-and-bottom belt sander removed 0.06 inch per side from edge-bonded particleboard at 60 feet per minute. In this application an open-coat and flexible belt greatly increased belt life. In another belt sander installation, 0.022 inch was removed from rough oak flooring at 130 feet per minute.

Veneer Cutting


Logs of water oak (Quercus nigra, Q. phellos, Q. laevisfolia, and Q. lyrata) are best cut into veneer if heated in long lengths to 140° to 150°F. (barking was more readily accomplished at 180°F, however), cut to bolt length, and then peeled with the lathe settings tabulated. Grub holes, knots, sweep, butt-swell; and flutes in logs should be avoided, as should protruded log storage without protective end coating. Green veneer will stain blue-black when in contact with iron. Tangential shrinkage during drying (to 5-percent moisture content) was 12 percent of green width. Drying schedules are tabulated. No special gluing difficulties were encountered. A large proportion of the 4 by 8-foot panels fabricated were grade 2 on the best face.


A brief description of the design and operation of an autoclave with a comparison of its advantages over pit steaming.


Heated blocks yielded veneer that was tighter (that is, depth of lathe checks was less and tensile strength perpendicular to the grain was greater) than veneer from unheated blocks. Depth of lathe checks was reduced greatly by heavy pressure on the nosebar; but such pressure caused excessive compression that weakened the wood. Roughness of veneer and variation in thickness were not reduced by heating the blocks before peeling. There appeared to be a slight increase in strength of veneer parallel to the grain when blocks were heated before peeling. It was concluded that optimum temperature for peeling Douglas-fir is 140°F. Shelling or separation of wood at the springwood-summerwood boundaries was noted in veneer steamed at 200°F. for 103 hours.


Describes successful trials in rotary cutting of thin (1/28 to 1/85-inch) yellow birch veneers from straight and curly-grained bolts. Accurate lathe adjustments were required to avoid major defects. Heat distortion was minimized by cutting at 120°F. Optimum settings are reported.


Logs should be heated in water 175°F. until the core reaches 150°. Heating time ranges from 6 hours for a 6-inch log to 98 hours for a 36-inch log, assuming initial log temperature of 70°F. For 1/28-inch veneer, optimum knife angle is 90° on a 21-inch bolt and decreases steadily to 88° and 30 minutes at 9-inch diameter. Optimum practical vertical nosebar opening is 0.01 inch in conjunction with a horizontal opening of 0.03. A 20° knife bevel (sharpness angle) is practical. Angles for thicknesses other than 1/28-inch are tabulated. Optimum nosebar angle was from 10° to 14°. When cutting veneer thicker than 1/28-inch (1/24- and 1/20-inch) danger of raising the fibers increased rapidly. Veneer laid up with the loose side out could be sanded much smoother than if the tight side was out. With close control of machine settings, a high proportion of grade A and grade 1 plywood can be produced from curly birch logs.


In laboratory trials hemlock was successfully cut at 70°F. on a rotary lathe with a motorized roller bar and a knife with a main bevel angle of 21° 30 minutes, 30° microbevel, and 0.020 inch wide at the tip. Optimum settings are given for five veneer thicknesses. Grade was low, and recovery of green veneer was only 57 percent, although all met U.S. Fed. Spec. PPPV-205a.

Felescuk, V. N. 1964. Effect of the position of the nosebar and of its position relative to the knife, on the resistance of wood to peeling. Lesn. Z. Arhangel'sk 7(4): 91-96.

Evaluates, for birch, the effect of nosebar sharpness angles of 44°, 51°, 58°, 65°, and 70° in combination with angles between nosebar and knife of 72°, 76°, 80°, and 84°.

Felescuk, V. N. 1964. Effect of the position of
the knife relative to the bolt on the resistance of wood to peeling. Lesn. Z. Arhangel’sk 7(3): 129-136.

On birch, the knife clearance angle should be 1 to 1-1/2 degrees. The knife edge should be level with, or 1 millimeter above, the spindle centerline.


Concludes that conditions are favorable for establishment of a southern pine plywood industry. Suggests peeling temperatures between 150°F to 180°F and a moderate drying temperature such as 300°F. A plant to produce 30 to 36 million square feet of 3/8-inch plywood per year would cost, at minimum, $1.5 million. One board foot log scale will yield 2.4 square feet of 3/8-inch plywood. Overlays should be applicable to southern pine plywood.


Preheating veneer blocks reduces splitting and thus increases recovery of A-grade veneer. The net gain in value is estimated at $4.35 per 1,000 log scale for No. 2 peelers and $12.83 for special mill logs. Heating vaults are estimated to cost $73,000 for a mill peeling 90,000 feet board measure daily. Steam is estimated at $0.178 per 1,000 board feet, while all heating costs might total $0.825 per 1,000.


A laboratory-scale apparatus was used to study the effects on equilibrium cutting properties (final equilibrium condition attained after several cuts) of systematically introduced wood and tool variables. Energy consumption, block strain recovery, and veneer tensile strength increase with increasing nosebar pressure, while check depth, surface roughness, and veneer thickness decrease. Increasing the knife angle (the angle between the back of the knife and a line perpendicular to the cutting plane) generally reduces energy consumption and strain recovery. Cutting at higher temperature reduces energy and improves veneer quality, while effect on strain recovery is related to the nosebar pressure. At high temperatures, optimum nosebar pressure (with respect to veneer tensile strength retention) is decreased. Cutting fully saturated wood involves greater energy and strain recovery and results in thinner veneer of lower tensile strength. Specific gravity affects energy consumption but is not correlated with strain recovery of thickness. Growth ring orientation affects cutting behavior.


A review of factors affecting veneer cutting, including cutting speed, knife angles, nosebar, deformation of knife and nosebar, and deflection of the core. The author draws heavily on Fleischer’s research. The bibliography lists 82 pieces of world literature on veneer cutting.


Final paper of a series of four that explore the technical and economic aspects of converting small southern pine logs into thick-sliced veneer and then into long laminated beams of uniform high strength. Laminae are located in each beam according to their stiffness. Both technically and economically, the proposed system appears promising. Application depends on the anticipated development of a practical slicer that will produce a green veneer 0.6 inch thick.


Only the effects of one of the seven variables (i.e., peel) is here abstracted. Veneer peeled cold and loose had significantly higher wood failure, lower wet shear strength, lower dry rolling shear strength, lower compression strength parallel to the grain, and more severe face checks than veneer peeled hot and tight, Shear specimens tended to fail at or near loose-to-loose rather than loose-to-tight interfaces.


A summary of literature.


Reviews the work of Hoadley, Kivimaa, and Lutz.


Rotary-cut and sliced veneer from slow-growing (12 rings per inch), 2-foot diameter, clear logs of chestnut oak (Quercus prinus L.) was converted into panels and flooring. Chestnut oak is in the white oak group but has pores not blocked by tyloses. Conditioning temperature prior to peeling had little effect on veneer roughness. An increase in peeling temperature increased the tensile strength of sliced veneer perpendicular to the grain except when the heat treatment was sustained.
for example, a 4-day heat treatment at 180°F. caused decreased strength. With increased peeling temperature, volumetric drying shrinkage of the veneer increased. Veneer cut from heated bolts was darkened by both increased temperature and increased time. End-splitting of bolts occurred above 180°F. A 200°F. water bath is recommended to bring the flitches to 190°F; for bolts the water-bath should be only 150°F. to bring the core to 140°F. For 1/8-inch veneer, either sliced or rotary cut, a horizontal fixed nosebar opening of approximately 0.115 inch in conjunction with a vertical opening of approximately 0.029 inch was optimum. The best veneer was produced by quarter-slicing, cut, a horizontal fixed nosebar opening of approximately 0.115 inch in conjunction with a vertical opening of approximately 0.029 inch was optimum. The best veneer was produced by quarter-slicing, and exterior exposure is discussed. Wood of both species reacts similarly during processing, and slow growth is desirable from the standpoint of reduced lathe checking, shelling, and warping.


Photographs illustrate the effects of growth rate on shelling and knife checking in southern pine and Douglas-fir veneer. The relation of growth rate to air drying, performance in glue bonds, and exterior exposure is discussed. Wood of both species reacts similarly during processing, and slow growth is desirable from the standpoint of reduced lathe checking, shelling, and warping.


General discussion and comparison of designs.


The maximum deflection of veneer bolts 180 to 200 millimeters in diameter and 1,700 millimeters long was 12 millimeters. The horizontal component of deflection varied both in magnitude and direction. Nosebar compression had a considerable effect.


A mathematical analysis describing the advantages of continuous regulation of peeling speed.


The authors devised a dial gauge for measuring the amplitude and frequency of peaks and troughs on the veneer surface. From these measurements, they developed a visual roughness scale suitable for both research and quality control applications.

Chipping, Flaking, Hogging, and Grinding for Wood Flour


Analysis of advantages in "Beaver" peripheral-milling type of chipping headrig for random-length logs. Elimination of 1/4-inch kerf on each cant face increased chip recovery by 2,000 cubic feet of solid wood per 8-hour shift, assuming 6-inch cant faces and average sustained feed speed of 100 feet per minute (maximum linear feed speed is 183 feet per minute). At a chip price of $6 per ton, the additional revenue from kerfless conversion as compared to conventional sawing, is $360 per 8-hour shift. Seven-inch logs 8 feet long have a Scribner log scale of 10 board feet. Average recovery from such logs was 16 board feet, that is, 60-percent overrun. Data based on operating experience.


Laboratory-scale investigation of the mechanics of pulpwood-chipping was conducted. Chipping in the conventional mode and in the parallel and near-parallel cutting modes was studied with knife angles of 20° to 50° and a cutting speed of 50 centimeters per minute. Chipping work increased with knife angle and was generally greater for conventional than for near-parallel chipping. Departure from strict parallelism increased the work rapidly. Axial deformation in the grain direction greater than 1 percent could be observed in all conventional chips at their bruised ends and occasionally in the body of the chips. In near-parallel chipping no axial deformation greater than one percent could be observed, although deformation perpendicular to the grain was large. All conventional chips were damaged more than the parallel and near-parallel chips. Paper has 19 references.


A new machine, the Chip-N-Saw, operating on the peripheral milling principle, profiles debarked logs in 2-inch steps with a series of chipper heads. The cants are then converted to lumber by an in-line sawmill. Stated capacity is 80,000 board feet of lumber per 8-hour shift on logs 12 inches in diameter and less (averaging 9 inches). The average study log had a 9.7-inch top diameter, was 14.7 feet long, and yielded 64 board feet of 4/4 and 8/4 lumber (7.9 board feet of lumber per cubic foot of log). Overrun of lumber over B.C. Log Scale was 56 percent. Sawdust volume, 7 percent of log volume, was 1/3 to 1/2 of that from a conventional sawmill. Chip yield per 1,000 board feet of lumber recovered was equivalent to 40
cubic feet of solid wood or about 1,000 pounds ovendry. Relative lumber recovery was higher from short than from long logs.


Square sugar maple cants 4 by 4 inches by 8 feet long were chipped on a 39-inch, 3-knife chipper at 225 rpm. Chipping power was observed by measuring torsional strain on the chipper shaft and relating this strain to torque. Vertical spout angles in the range from 0° to 60° had no significant effect on specific chipping energy. A 30° side spout angle decreased specific cutting energy slightly in comparison with a 0° angle. The average of all tests with knife angles (sharpness angle or rake?) of 30°, 40°, and 50° showed specific cutting energy to be respectively 8.25, 11.4, and 13.9 horsepower hours per cord. These values are for 1/2-inch chips and 85 cubic feet of solid wood per cord.


Describes apparatus for studying various factors in chipping spruce rods 20 by 20 millimeters in cross section. 1) No significant difference in quality (determined by pulping) was found between chips produced at the beginning of the cutting action and those produced further along the cutting plane. 2) Impact force when the knife first hits the wood, chip damage, and, as a rule, chipping force increased and chip thickness slightly decreased, with increasing cutting speed. 3) Impact force increased gradually with increasing sharpness angle, whereas chipping force remained fairly constant at approximately 15 kiloponds per centimeter for angles of 25° to 40°, but rose to approximately 40 kiloponds per centimeter for an angle of 20° (possibly because of blunting of the 20° knife). Chip thickness was unaffected by variations in the angle. Chip damage generally increased with increasing angle. 4) Temperature in the range 5° to 50°C. had no effect on either chipping or impact force, but both increased noticeably with increasing dry matter in the range 60 to 90 percent. Chip damage and chip thickness decreased with increasing dry-matter content but were not affected by changes in temperature. 5) Photographs showed that cracks, formed along the grain direction when the knife penetrated the wood, start at the edge of the knife regardless of cutting speed when in the range 5 to 20 meters per second.


Discusses the three phases (cutting, shearing, and breaking) of the chipping process and the effect of loads applied parallel or perpendicular on wood shear strength. Compares strength properties of acid bisulphite pulp from chips compressed either parallel or perpendicular to the grain. Describes and illustrates a new chipper in which the main force is directed perpendicular to the longitudinal axis of the log. Chips obtained in the experimental run were of high quality.


Choice of small chippers should be based on average and maximum wood diameters, capacity in cunits of roundwood desired, and desired chip length. Squirrel-cage induction, wound-rotor induction, and synchronous motors are discussed. Pull-out torques of 250 percent are essential, and windings of stator and rotor must be capable of withstanding the large starting loads occasioned by inertia of the chipper disks.


Brief restatement of four of the several methods of producing sawdust having sufficient particle size to be pulped. Mentions 1) U.S. Forest Products Laboratory research on extreme bites per tooth and on 2) the Duo-Kerf saw, 3) step-sawing with the Grifif saw, 4) peripheral milling research at the Southern Forest Experiment Station with production machines typified by the Beaver and the Chip-N-Saw. Mentions the static saw for kerfless cutting by means of a stationary series of knives through which the log is moved.


Three unconventional headrigs were invented and tested. Each is capable of cutting, in a single 12-second operation, an accurately sized, heart-center S4S cant plus pulpable chips (or flakes for flakeboard). Neither sawdust nor slabs are produced. Specific cutting energy for 3/4-inch-long pulp chips cut from green slash pine by the END-MILLING configuration averaged 0.011 horsepower minute per cubic inch of wood removed, whereas with the PERIPHERAL-MILLING configuration the average was only 0.0023 horsepower minute. Flakes for flakeboard cut 1 inch long and 0.015 inch thick were made at an expenditure of 0.009 horsepower minute per cubic inch of wood removed with the SHAPING-LATHE configuration. Chip types, machine designs, and flow-plan sequences are illustrated. The headrigs are designed for logs of uniform short lengths and variable, but small, diameters.

Analysis of the difference between planer shavings and specially made chips.


Chip-forming blades of small diameter and large gullet area were mounted on shafts arranged one above the other so as to successively increase the depth of cut. Particleboard from the chips was as strong as that from conventional chips.


A theoretical and experimental study with a special apparatus for moving the work against a fixed knife at 20.7 millimeters per second. For improving chip quality while reducing power consumption in drum-type chippers, clearance plus sharpness angle should be as small as possible; the angle between the velocity vector and the wood grain should be small (approximately 30°, maximum 50° to 55°); the clearance angle should be small or nil; moisture content should be 70 to 100 percent. Chip width has no effect on chip quality.


Under optimum conditions, power consumption by a drum-type chipper was 1.162 to 1.331 KW-hour per cubic meter with a yield of 78 percent of the standard chip fraction. The angle of incidence (not defined) should be as large as possible on drum-type chippers, the optimum being 65° to 75°. The complement of the cutting angle (rake?) should be as small as possible, that is, 30° to 40°. Wood moisture content should be as high as possible.


Experiments at the University of Florida in high-yield kraft pulping have shown some advantages from increasing the exposed surface of wood chips by splitting along the natural lines of cleavage without breakage across the grain and without crushing or otherwise mechanically damaging the fibers. The chief gains are: 1) high-yield pulps more easily produced, 2) chip screens eliminated, 3) knot breakers eliminated or operated lightly, 4) washing improved, 5) fiberizing power reduced, 6) pulp made cleaner, 7) cooking time reduced, and 8) digestion production increased.


A series of four papers which examine in detail the many complicated factors affecting chip quality and machine performance.


A versatile experimental machine was used for measuring cutting force on the tool and feed force on the work. Power consumption increased with chip thickness, while specific cutting energy decreased. Depth of cracks, roughness, curling, quantity of fines, thickness variation, and percentage of coarse chips were also affected. High moisture content increased the number of coarse chips and reduced fines. Thin chips from dry wood had greater roughness, curvature, and thickness variation. Lower cutting velocities reduced power consumption and improved chip surface uniformity, although output was reduced and the machine clogged at times. If chip collection space is inadequate, the chips will be crushed and power consumption will increase.


Describes capabilities of the “Beaver” four-head, peripheral-milling, chipping headrig for random-length logs. Manufacturing rights have since been acquired by Stetson-Ross, Seattle, Wash.


If wood has a moisture content of 80 percent, a cylinder-type chipper is more economical than a disk chipper for producing quality chips for flakeboard. Sliver-like particles must be screened from the cut material.
A general discussion of design and quality requirements for knife disks and blocks so as to optimize chip quality and work efficiency.


An engineering manual covering the design and operation of disk chippers.


Briefly describes the "H-P Canter," which reportedly is capable of slabbing (in one pass) two sides of random-length logs. Sixty-six knives are mounted in spirals on each of two cutterheads. Each cutterhead has the shape of a hollow and relatively flat truncated cone. Each knife cuts on two edges. Fibers are severed and wood is removed in a modified end-milling configuration to form pulp chips. No sawdust or slabs are generated. Logs up to 26 inches in diameter can be slabbed to 18 inches in one pass. If desired, the cutterheads can be brought together and the entire log chipped. The machine requires 150 horsepower, feeds at 160 linear feet per minute, and requires no heavy foundation. A nomogram relating log diameter, feed rate, and cords per hour is included. Feedworks for centering log not illustrated.

Defibrating


Panel discussion of operating variables and recent research.


At low speeds, friction was the sum of surface friction and a component arising from the viscoelastic deformation of the wood. Surface friction decreased as speed increased, approaching zero for some conditions of cylinder radius and specific load. Under certain conditions, energy was sufficiently localized to cause charring below the wood surface. It is concluded that a large fraction of the grinding energy in commercial units is dissipated in viscoelastic deformation of the wood.


The plate pattern was ground from the surface of a refiner disk in a series of stages. Chips were fiberized and examined. Results indicated several distinct phases in refining. Match-stick fragments are produced in the breaker-bar section. Further breakdown occurs toward the center of the disk, and groups of fibers assume a cylindrical shape. Lastly, small fragments are refined into paper pulp.


Disk-refined spruce produces pulp superior to stone groundwood at any freeness down to 50 milliliters. Pretreatments like steaming and chemical dips are effective on spruce and soft hardwoods. Dense hardwoods require more drastic treatment. Power requirements are high, but the disk-refining process is more flexible and can be accurately controlled.


Best results were obtained with plates having narrow radial bars and grooves and numerous intermediate dams. Optimum conditions include: 1) two-stage refining, 2) application of 30 to 50 percent of total power in first stage, 3) a 15 percent or higher consistency, and 4) best possible uniformity of feed.


The mechanical energy to produce a unit area of surface is measured. The results are on the order of 10^6 ergs per square centimeter and indicate that the efficiency of mechanical pulping may be about 20 percent, whereas previous estimates were about 0.10 percent.


A discussion of groundwood production on a commercial scale. A hypothesis of the mechanism of refining is given along with the effects of single operating variables on handsheet properties.


A practical discussion of groundwood production on a commercial scale.

The second part of this article will be continued in the October issue of the Forest Products Journal.
Wood Machining Review,
1963 Through 1965

By
Peter Koch and C. W. McMillin
Southern Forest Experiment Station
Alexandria, La.

This is the second and last part of an examination of significant research in wood machining. The reviewers' principal sources were the major world journals in wood science and technology, Forestry Abstracts, and personal communication with researchers known to be active. The first installment appeared on page 76 of the September Yearbook issue of the Forest Products Journal.

Properties of the Cutting Edge and Cutter

Tool Materials


In Parinari, the length of sawing time without blunting was 8 times greater with stellite-faced teeth than with ordinary saw teeth. Saw speeds ranged from 500 to 2,500 meters per minute. A 40-fold increase in sawing time without sharpening could be expected with stellite and the slower speed.


Describes the properties of a ceramic tool material and the results of machining tests.

1The citations and abstracts marked with a superscript 1 are taken by permission (with some revision) from Forestry Abstracts, Commonwealth Forestry Bureau, Oxford, England.


On gangsaws, treatment was ineffective across the width of the tooth face but reduced the height wear 50 percent.


For machining solid timbers as well as laminates, tools tipped with hard alloys offer the advantages of increased life, reduced adjusting time, and reduction of later finishing operations.


Tools are first sharpened, degreased, and washed, and then boiled 15 to 20 minutes at 95° to 100°C in a mixture of 1 part MoS₃ powder (by weight) and 8 to 10 parts water. Approximately 300 cutters can be treated with 300 grams of MoS₃. Treatment increased cutter service life 20 to 50 percent.


A discussion of the properties of solid wood, particleboards, fiberboards, and plastic as they affect the use of hard-alloy-tipped circular saws and molding cutters. Formulæ and data are tabulated to aid in selecting the optimum tool and cutting conditions.


On birch plywood, saws tipped with tungsten carbide cut 25 to 50 times as long as saws of high-speed steel and 10 times as long as stellite-tipped saws. Tool wear is illustrated, and recommendations are given on cutting angles and sharpening methods.


Trials with laminated birch compared a large number of saw-tooth materials (steels and hard alloys) applied either by deposition or in the form of welded tips. With tooth wear of conventional steel rated at 1, several high-speed steels were rated at 2.3 to 3.1, proprietary alloy at 2.7 to 2.6, and stellite at 1.


Describes a technique for gluing tips to planing and molding cutters and the successful results of trial runs.

Dulling Phenomena


The material to be tested (30 millimeters thick and 900 millimeters long) is mounted in a clamping device sloped so that free surfaces of gluelines will not wear at any particular spot on the knife. The material is then fed past a rotating cutterhead having one knife cutting and one balancing. A fixed depth of cut is maintained. Change in power demand, as measured by a wattmeter, is the measure of dulling rate. To further monitor tool wear, the cutting edge can be photographed at 10X without removing the knife from the head. Net cutterhead power is plotted against calculated length of tool path in the material.


Whereas unplated gangsaw teeth became dull and lost 5.5 percent of swaged tooth-width in 4 hours of cutting western red cedar, electrolytically chrome-plated swaged teeth maintained satisfactory edges for 8 hours and lost only 1.8 percent of tooth width. The more economical process of spark impregnation (whereby the transfer of tungsten carbide takes place through an arc passing from the anode composed of the impregnating carbide to the metal tooth which is the cathode) increased service life on western hemlock from 4 hours for untreated saws to over 8 hours for treated saws. Spark impregnation with tungsten carbide did not slow the rate of wear in tooth width, that is, tooth sharpness was maintained as the tooth wore.


Wood cutting tools wear by contact with dirt and through friction and chemical attack. Blue-staining of steel tools is evidence of chemical corrosion. Microscopic examination of such stains revealed a raised layer of material which, when

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removed with dilute caustic soda, revealed the grain structure of the steel etched on the polished surface. Because acetic acid and tannins occur in wood, these compounds were investigated. In 30 minutes, acetic acid in a 0.6-percent aqueous solution at a pH value of 3 caused etching 0.06 micron deep in polished carbon steel. At pH 4 the action was less severe. Phenolic compounds common in wood extractives (for example, tannins) were applied in solutions ranging up to pH 6 and were found to etch iron more or less severely than did acetic acid, depending on the compound. Those containing three vicinal phenolic groups (gallic acid, pyrogallol, and gallocatechin) attacked the cutter more quickly than compounds containing two such groups (catechin), but both were more corrosive than acetic acid. The protective value of an applied electro-potential was explored by insulating the cutter and pressing an electrode to the workpiece immediately in front of the cutter. A negative potential ranging from zero to 100 volts was applied to the cutter, and etching was much reduced, even when no voltage was applied.


Blunting proceeds in three stages: 1) primary—initial equilibrium reached at the first contact of the ideally sharp edge with wood is caused by yielding of both cutter and wood; 2) secondary—the edge is abraded with increasing frictional forces; and 3) tertiary—the front and back faces of the cutter are abraded in the vicinity of the edge. An understanding of the blunting phenomenon requires consideration of chip formation, cutting force components, sharpening conditions, stresses at the cutter-wood interface, coefficient of friction, and mechanical properties of wood.

Nosovskii, T. A. 1963. The effect of bluntness in wood-cutting tools on cutting force, taking into account direction of grain and wood species. Lesn. Z. Arhangel’sk 6(3): 102-106. (Also CSIRO Australian 7176. 4 pp.)

1) The severance or incision force (as contrasted to chip formation, breakage, friction, and acceleration forces) depends solely on the radius of the cutting edge; hence the thinner the chip the stronger the effect of tool sharpness on total cutting force.

2) Average cutting force is equal to an initial cutting force plus an experimental constant times chip thickness plus a second experimental constant times chip thickness squared: 
\[ P = P_0 + k b - k b^2 \]

3) With decreasing rake angle, sharpness of the cutting edge has a lesser effect on cutting forces.

4) Sharp knives are more effective in decreasing cutting forces on hard and inelastic woods (beech and hornbeam) than on soft, more elastic woods (spruce).

3) Sharp knives reduce cutting forces more effectively when cutting parallel to the grain than when cutting in the veneer direction.


Blunting was investigated with stereoscopic pictures of the coating and by examining individual grains with a profile projector. Wood surface roughness was measured with an electronic surface tester. Belts became blunt because abrasive grains were broken off or cut, and because fine wood material accumulated between grains. Other results were: 1) Roughness of wood surface increased (↑) as belt dulled. 2) Under constant belt pressure, wood removed per unit of time decreased as belt dulled. 3) To remove a constant volume of wood per unit of time, contact pressure had to be continually increased as the belt dulled. 4) Cleaning a clogged belt did not guarantee substantial improvement.


Pine particleboard blunted knives of hard alloys and high-speed steel sooner than poplar particleboard though at an equal state of knife bluntness, poplar required more cutting power than pine. Knives blunted by poplar showed fairly regular wear along the length of the cutting edge, whereas pine caused irregular wear.


Tool wear depends primarily on density of the various layers of particleboard, but also on silicates and other impurities in the board. Formulæ are given for calculating the most economic cutting rate.


Cutting velocities of 36 to 38 meters per second minimized cutting forces. Cutting forces were inversely related to rake angle. Cutter life was equal to a constant divided by cutting velocity raised to the 2.55 power. Rake angles 5° to 6° maximized cutter life. The stronger hard-alloy cutters improved tool life, although performance depended on the manufacturer of the alloy.


Fitting and Sharpening

Anon. 1963. Technical memos on sawing. Technical Center for Wood (Paris) Memos 1.5, 1.6, 1.7, 7, 6, and 4 pp. respectively.

Principles and application in swaging and shaping band saws.


Describes saw-blade cracking attributable to transverse blade deflections. Tabulates causes, detection, and remedies of deflections.


Anon. 1965. Technical memos on sawing. Technical Center for Wood (Paris) Memos 1.8, 1.9, 1.10, and 1.11. 2, 6, 3, and 3 pp. respectively.

Band saw tensioning equipment and anvils (1.8), application of hard alloy (stellite) to saw teeth (1.9), truncation of alternate teeth (1.10), and tooth profiles (1.11).

Abeels, P. 1965. Effect of tensioning treatment on cutting force and blade behavior during sawing. IUFRO, Sec. 41, October Meeting, Melbourne. 7 pp.


Swaging increased microhardness 50 to 60 percent over initial hardness. Deformations were greatest in the tooth tips at the point of contact between the tooth face and the swaging roller, and on the lateral shaped surfaces.


Correct saw tensioning is difficult because it is not easy to measure the stress at any point in the saw-plate. Hardened steel sheets change their ferromagnetic properties through cold forming, which thus affects inductive measuring methods. Because these methods are also affected by surface properties, interpretation of results is difficult. A radiographic method permits determination of size and location of surface tensions, from which the stress distribution can be calculated and plotted.


Describes research to decrease saw fluttering by reducing temperature differences in the blade body or by alleviating the stresses caused by temperature differentials. Blades with elastic center zones—that is, perforated center zones—proved superior to those of the normal type when overstressed by temperature differentials.


Data on the micro-hardness of saw teeth after swaging do not support previous reports that rolling affects only the surface layers.


On steel saw teeth having initial hardness of Vickers 448 cold swaging up to 300 percent increased the hardness by only 40, an amount insufficient to affect saw life.


Band-saw welds prepared by experienced fitters were examined to determine the likely causes of failure. Principal faults were: 1) fissures resulting from penetration of the solid bead into the parent metal during forging; 2) unsatisfactory post-welding heat-treatment; and 3) decarburization of the melt.


Several practices help to avoid gullet cracking: maintain light grinding pressures, minimize hammering and rolling (particularly near the tooth line), keep mounting tension in band saws and gang saws at a minimum and minimize rolled tension and
back crown to reduce longitudinal stress, correlate band saw thickness to wheel diameter, run circular saws at the lowest possible speed to reduce centrifugal stress and vibration, use swage-set teeth in preference to spring-set teeth on spring-set saws, minimize lateral tooth load by employing a square tooth front and minimum set, employ sturdy tooth profiles with generous gullet curvature, avoid nicks or sharp corners in gullets, keep saws sharp, maintain feedworks and saw guides in accurate alignment, and keep band saw wheels clean.


Grinding costs are reduced approximately 13 percent with anode-mechanical tool grinding as compared to conventional abrasive grinding.


Stability


In previous research by Jones, tooth instability limited the reduction of kerf in spring-set saws. Here Jones reports studies (by brittle-lacquer and photo-elastic techniques) in which he concluded that the best compromise is a profile very similar to the North American standard saw tooth: 30° rake and generously rounded gullet, but a clearance angle of 24° rather than 14°. In such a tooth, stresses are at a practical minimum under lateral and axial load, but mechanical sharpening is possible.


Presents oscillograms and a table of critical, possible, and optimum speeds for 31 blades 200 to 500 millimeters in diameter, run at 200 to 13,500 rpm (rim speeds 3 to 300 meters per second). Diameter and thickness determine optimum speeds. Optima were generally higher than commercial practice, varying from 10,000 to 12,000 rpm for diameters of 100 to 150 millimeters, to 3,400 to 4,700 or 2,500 to 3,500 rpm (accoring to thickness) for a diameter of 500 millimeters. Blades of 350 millimeters diameter or more tended to have more than one critical (resonance) zone. Oscillation increased with cutting load, and with number or size of slits.


To determine optimum tensioning conditions, such blade parameters as rotational speed, thickness, and temperature distribution were analyzed by fundamental structural stability theory. An optimum condition is proposed and illustrated by example.


Flexural natural frequencies always decrease with increasing band velocity, the rate of decrease being dependent on the pulley mounting system. Simple, accurate, and bounding fundamental frequency approximations are presented. The pulley mounting system determines whether the tension is constant (fixed pulley support) or increases parabolically (dead weight and lever mechanism) with saw velocity. From the standpoint of dynamic stability theory, the dead weight and lever mechanism now commonly used by the wood industry is best for high-speed saws.


The approximate free vibration characteristics of centrally clamped disks of variable thickness are analyzed by the Rayleigh-Ritz technique. Natural frequencies of transverse vibration are computed, taking into consideration rotational and thermal in-plane stresses as well as purposely induced initial stresses. Initial stresses can significantly raise the minimum natural frequency throughout a prescribed rotational and thermal environment. The fundamental mode of disk vibration is one of zero nodal circles and either zero, one, or two nodal diameters, depending upon the disk geometry and the rotational-thermal environment.

Thunell, B., and L. Kilström. 1962. The influence of sawtooth dimensions on lateral stability. Holztechnologie (Dresden) 3(2): 145-149. (Also CSIRO Australian Translation 6252. 7 pp.)

Describes deflection of tooth tip under influence of lateral forces. Ninety-six types of triangular teeth without rounding at the base were tested, representing combinations of two thicknesses (1 and 2 millimeters), four tooth height (h = 12 to 24 millimeters), four angles θ (45° to 90°, θ being the angle between the tooth-base b and a line from its midpoint through the tip of the tooth), and three b/h ratios (0.375, 0.75, and 1.5). With other factors constant, deflection increased non-linearly with increasing b and with increasing b/h and θ. For a thickness of 2 millimeters and a load of 8 kiloponds, deflection varied from 0.01 millimeter for θ = 90°, b = 12 millimeters,
and \( b/h = 1.5 \), to 1.44 millimeter for \( \phi = 45^\circ \),
\( b = 24 \) millimeters, and \( b/h = 0.375 \).

\textit{Thunell, B.} 1963. Effect of gullet radius and
shape of back on the lateral stability of a saw

Normal and curved-back frame saw teeth were
30 percent more rigid than straight-back teeth.
A large gullet radius is important for lateral
rigidity in these designs although of little value
for symmetrical triangular teeth.

\textit{Thunell, B., and B. Noren.} 1964. Stability inves-
tigations on frame-saw blades. Parts 1, 2, 3, 4,
and 5. Pap. ja Puu 46(8) (10) (11) (12): 453-460,

Background information 1), theoretical methods
of studying stability 2), influence of thickness and
blade tension on saw deflection and stresses 3),
graphs and tables with details of results 4), and
validity and application of previous research 5).

\textbf{Temperature}

\textit{Atack, D., and I. T. Pye.} 1964. The measure-
ment of grinding zone temperature. Pulp and

Reviews previous attempts to measure grinding
zone temperature and discusses measurement tech-
niques. In the miniature grinder used here, a
maximum of 104°C. was observed in the heated
layer of wood at the grinding zone. The thickness
of the heated layer was approximately 0.004 to
0.010 inch. The temperature at the stone surface
did not exceed 100°C. Wood temperature deter-
ninations were also made on a commercial three-
pocket Great Northern grinder. Temperatures were
significantly higher than observed in the mini-
tature grinder. It is concluded that although thermal
softening of lignin and hemicelluloses may be a
prerequisite, it is not the predominant factor in
acceptable groundwood production.

Temperature rise and moisture movement in wood

Heat generated by friction in cutting, dried
out wood in the cutting zone and caused migration
of moisture away from this zone. The cutting
properties of wood were altered because 1) wood
loses strength with rise in temperature, 2) dry
wood is stronger than wet wood, and 3) dry
wood has a lower coefficient of friction than wet
wood. Dry wood has less heat conductivity than
wet wood. Migration of moisture away from the
cutting zone was observed in bandsawing, ash
eucalypt at 12.4 percent moisture content with
feed parallel to the grain. When the saw was
about 3 millimeters from the end-grain surface
before emerging, a band of liquid water about
the width of the kerf was observed on the surface
because some of the vapor had diffused along the
vessels ahead of the saw and condensed on reach-
ing a cooler zone.

\textbf{Research Instrumentation and Techniques}

\textit{Ardenne, M. von, et al.} 1963. Monitoring the
attainment of given temperatures in steamed wood
with a radio transmitter probe. Holztechnologie
(Dresden) 4(3): 249-251.

An instrument, consisting of a thermocouple
and radio transmitter, is inserted into a hole in
the core portion of a veneer bolt, and a signal is
emitted when the minimum effective temperature
(60°C.) is reached.

\textit{Borovikov, E. M.} 1963. A test rig for investigat-
ing the process of frame-sawing. Lesn. Z. Arhan-

An apparatus for studying the effect of cutting
and feed forces on tooth dulling.

\textit{Clark, L. N.} 1963. A new dynamometer for
measuring cutting forces in three dimensions.
Pap. 30. 16 pp.

Reviews existing techniques and describes a new
three-dimensional "platform" type of dynamometer
having 3 load cells, instead of the customary 4.
The normal component of the load carried by each
cell is registered by one set of 4 resistance-strain
gages mounted on each cell. Associated electronic
equipment includes a small computer that operates
on these load signals and produces new signals
that are a measure of the three forces under study.