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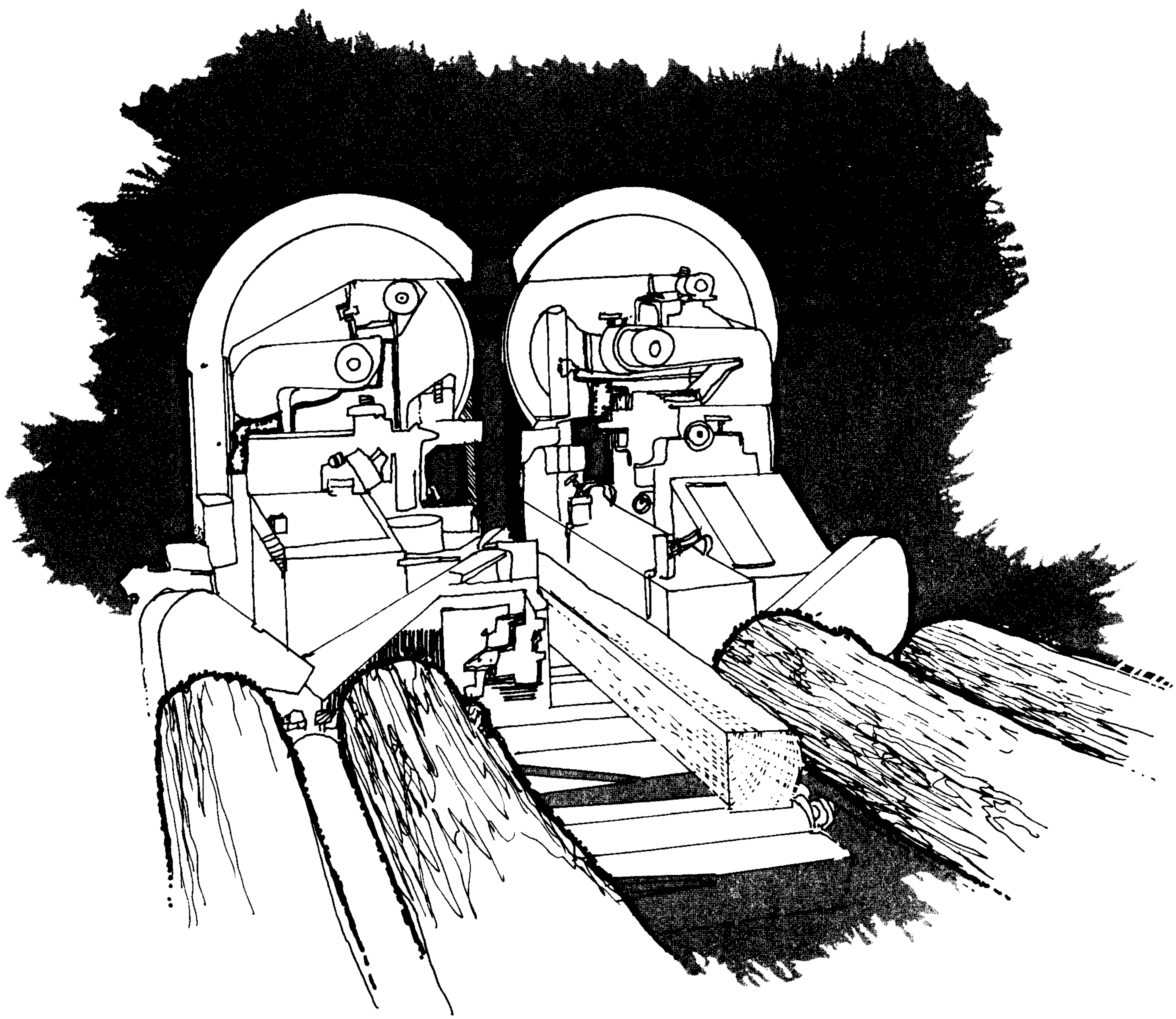
Balanced Saw Performance



Reference Abstract

Program “SAW” can help sawmillers to select and operate their saws according to sound design principles. This will enable them to (1) maximize production from their saws, (2) reduce saw operating problems, (3) maximize saw life, and (4) increase lumber recovery efficiency by producing more accurately sized lumber

Keywords: Saw, feed speed, bite, tooth speed, depth of cut, power

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BALANCED SAW PERFORMANCE[1]

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Abstract

Correctly selecting a saw for a job is one of the most critical decisions a sawmiller has to make. Even after the selection is made, the saw must be set up and operated within certain specifications for balanced performance. An understanding of the interrelationship of raw materials, end products, machinery, and the sawing process itself is essential.

Often sawmillers operate their saws with less than adequate knowledge about correct bite, feed speeds, tooth speeds, side clearances, depths of cut, and power requirements. Every saw is limited to a rather narrow operating range. Experience has taught most sawmillers which saws to choose for specific applications. However, for correct saw selection and saw operation, it is possible to mathematically calculate the variables involved. Program "SAW" has been developed to integrate these variables quickly and accurately. Operators who use Program "SAW" will be able to (1) maximize production from their saws, (2) reduce saw operating problems, (3) maximize saw life, and (4) increase recovery efficiency by producing more accurately sized lumber.

Background

I would like to relate some statements I have run across in my reading about the operation and care of saws that have appeared over the last 10 years or so. I quote:

"There is less technical thought given to the saw than almost any other component part of a sawmill."

"No engineer can tell you how much feed a given saw will take under given conditions."

"It's standard practice to over-bite the capacity of the gullet to carry the sawdust. In other areas, the practice is to underbite."

"I submit on a basis of facts shown that there is now no known standard or specification for saws, saw speeds, or rates of feed." And finally,

"Sixty to 65 percent of the saws are wrong for the job." Unquote.

These allegations probably have not been completely laid to rest, and if they hold any truth at all, it's a wonder we don't have more problems. Add to this, problems with harmonics or lack of quality control in blade manufacture--two areas that will be addressed in other presentations at this session.

The saw is one of the most abused pieces of equipment in the sawmill. It's run too fast; it's run too slow; it's overheated; it is overstressed; it's overfed or underfed; it's underpowered or, in rare cases, overpowered. Then there are problems with the wood itself. Often, density varies even within the same log or cant. Sometimes the wood is frozen or, worse, partially frozen.

The list could go on. You can begin to see all the combinations of problems possible in any given setup. Sooner or later, if saws are improperly set up and operated, problems will occur. Then we either fix the problems, or we learn to live with them.

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[1]Presented at conference entitled "Sawing Technology: The Key to Improved Profits," sponsored by the Forest Products Research Society, Jan. 30-Feb. 1, 1984, San Antonio, Texas.

Designing a saw for a specific application is a rather controversial and highly complex subject. Opinions differ as to what may constitute the best parameters for a given application. In fact, the problem seems to boil down to specifically defining a saw's task. Many saws are routinely operated beyond their design limits. Even if a saw's design limit is only exceeded 10 percent of the time, damage can still occur. If operators would consciously avoid operating their saws beyond their design limits, I am convinced there would be fewer saw-operating problems overall.

Once a saw's task is clearly established, the saw can be properly designed. Critical decision making can then be made as to tooth geometry, saw or wheel diameter, tooth pitch, gullet size, side clearance, and saw thickness. Once these specifications have been established, the operating variables or limits for that saw have also been established.

Once a saw is selected for a task, it must be set up and made ready for operation. In setting up the saw, further decisions must be made on tooth functioning, which involves the interaction of tooth pitch, tooth speed, and feedspeed. Lastly, power needs must be decided. What are the power requirements for the setup you have selected?

How do you integrate all the variables for a successful saw setup? This, as I see it, has been the stumbling block down through the years. A great deal of hand calculating was required to get the needed answers. Program "SAW" was developed to meet this need, It can be used to analyze ripsawing operations, except for sash gangs, to determine operating variables. It can also be used to redesign a saw setup to bring the saw more in line with good design principles,

Operating Variables

Saw or Wheel Diameter

The diameter of a circular saw should be the smallest possible that can handle the cant or log size to be sawn. Using a larger saw than required increases maintenance time and costs. For maximum efficiency, the saw diameter should be commensurate with the task.

The diameter of a circular saw physically limits the depth of cut it can effectively handle, While it is technically possible to saw a depth of cut equal to the radius of the saw minus the radius of the collar, it is not the normal practice. Smaller saws, however, can accommodate this practice more easily than larger ones. As a general rule of thumb, a circular saw should saw a depth of cut no greater than approximately two-thirds of the saw radius. I label this the "effective depth of cut" (fig. 1).

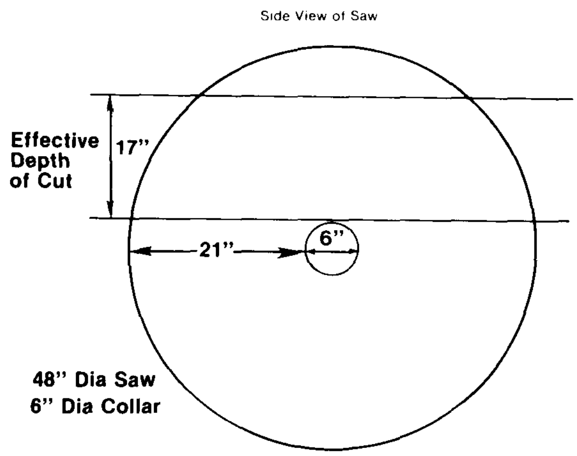

Figure 1.--Determining effective depth of cut. (ML84 5716)

The effective depth of cut is not synonymous with the maximum log diameter a saw can handle. When breaking down a log, a sawyer does not normally saw down the middle on the beginning cuts. Logs are slabbed, a few boards are sawn, then the log is turned to a new face. Thus a log is reduced to a size where it can be sawn without further turning (table 1),

For band saws, determining correct wheel diameter for a given task is more difficult than for circular saws. The saw gauge, blade width, tooth pitch and height, and the gullet size must be considered when making this decision. Once depth of cut is established, it should be strictly adhered to. If the depth of cut is exceeded, gullets become overloaded with sawdust, or the sawdust becomes excessively fine, which pushes the saw offline, causing variation in the lumber. Once depth of cut for an operation is established, the smallest wheel diameter should then be used (table 2).

Table 1.--SAW DIAMETERS AND EFFECTIVE DEPTHS OF CUT.

Effective depth of cut	Saw diameter
In.	In.
10	32
11	34 - 36
12	38
13	40
14	42 - 44
15	46
16	48
17	50 - 52
18	54 - 56
19	58
20	60

Table 2.--WHEEL DIAMETERS AND EFFECTIVE DEPTHS OF CUT

Effective depth of cut range	Wheel diameter range
In.	Ft
Up to 16	4.5 - 6
16 - 24	5 - 8
26 & up	8 - 10

For wheels of given diameters, there are standard relationships of band gauge, blade width, and tooth spacing and height combinations (table 3).

Table 3.--STANDARD VALUES FOR VARIOUS COMBINATIONS OF TOOTH PITCH/HEIGHTS, BANDSAW GAUGES, BLADE WIDTHS, AND WHEEL DIAMETERS

Tooth pitch, height	Band saw gauge	Blade width range	Wheel diameter range
In.		In.	Ft
1-1/2 / 9/16	19	3-6	4.5-6
1-1/2 / 5/8	18	4-8	4.5-6
1-3/4 / 5/8	18	4-10	4.5-6
1-3/4 / 3/4	17	4-10	5-8
2 / 3/4	16	5-12	5-8
2 / 7/8	16	5-12	5-8
2-1/4 / 1	15	6-12	5-8
2-1/2 / 1-1/16	14	11-14	7-10
2-1/2 / 1-3/16	13	11-15	8-10
2-3/4 / 1-5/16	13	12-16	8-10
3 / 1-7/16	11/12	15-16	8-10

Saw Thickness

A standard rule of thumb used over the years in determining saw gauge for band saws was to allow 0.001 inch of saw thickness for each inch of wheel diameter. For example, a 72-inch wheel diameter would require a saw 0.072 inch thick, which is 15 gauge. For larger saws, the gauge is usually somewhat heavier; and for smaller saws, the gauge is somewhat lighter than this rule of thumb.

When saw thickness is excessive for the wheel diameter, high stresses are placed on the band that often lead to fatigue cracks. Cracked saws lead to operational problems and contribute to excessive variation in the lumber. A saw that is too thin for a wheel does not necessarily cause fatigue cracks, but often such a saw cannot withstand the greater stresses imposed by sawing wider cut depths and generally higher load demands.

Determining saw thickness for circular saw applications is more difficult. Much depends on the sawing application and the type of maintenance the saw receives. For primary log breakdown in the hardwood industry, 7- to 8-gauge Inserted Point (I.P.) saws are very common. If the load demand is heavy and maximum production is desired, heavier gauge saws are used. For lighter load demands, smaller gauge saws may be used. When selecting a saw for a specific task, determine the severest load conditions that will be encountered on a sustained basis. Then a saw can be designed to handle those loads most efficiently. If a saw is exposed to continually overstressed conditions, the result is lumber variation, and a shortened service life.

For secondary breakdown, a wide range of saw thicknesses is being used today. For edgers and gang sawing applications in dimension mills, saws often run in the 10- to 12-gauge range. Cutting edge widths range from 0.150 to 0.200 inch. However, with today's guidance systems, some operators are successfully running 16- and 18-gauge saws with cutting edge widths around 0.100 inch. Reduced plate thickness and corresponding smaller cutting edge widths may not result in increased lumber recovery. The main reason being that a smaller plate thickness will not necessarily result in the least deviation of the saw if it is not operated and maintained correctly.

It never pays to reduce plate thickness and the corresponding cutting edge width at the expense of increased sawing variation. A saw improperly engineered and set up for its task and operated incorrectly will perform less efficiently. Maintenance time and costs are increased and, worse, the saw will wander in the cut, resulting in increased lumber variation. This results in a higher target set. The subject of thin saws will be addressed at greater length in another portion of the program.

Gullet Size

One of the main functions of the tooth gullet is to chamber and remove sawdust particles from the saw cut. Anything that hinders the tooth from performing this task should be averted. Hindering action might include feeding too fast, feeding too slow, cutting too deep, running the teeth too fast; or underpowering the saw. The end result might include excessive amounts of sawdust, sawdust particles excessively fine, or sawdust particles that are so big they clog the gullets, possibly stopping the saw dead cold in the cut.

How much sawdust can a gullet hold? That is indeed the $64,000 question! Gullet-holding capability never has been resolved satisfactorily. The answer is not easily obtained because it depends on many factors, such as wood density, moisture content, percent of the gullet that can be effectively utilized, and the amount of sawdust spillage incurred.

Freshly cut sawdust occupies from 3 to 6 times the space in the free state--that is, before any compaction occurs. Green, soft, low-density wood in sawdust form expands the least, while dry, hard, high-density wood expands the most.

Sawdust packs in the gullet cavity because of the pressure that is exerted from sawdust particles traveling at high velocity slamming into the sawdust that has already come to rest in the gullet. The fuller the gullet becomes, the greater the pressure. Laboratory tests have shown that pressure in the gullet can build up to 2,000 pounds per square inch in the compaction process. We also know that about 2,000 pounds of pressure per square inch are required to compress sawdust into an equal volume of solid wood. Conditions that would allow a buildup of 2,000 pounds per square inch in the gullet probably are not achieved regularly during normal sawing. Experts generally agree that sawdust will normally pack in the gullets to about 50 percent of its volume in the free state for band saws and larger circular saws. If this is true, then gullet size needs to be from one and one-half to three times the volume of the solid wood from which the sawdust is generated.

gullet Holding Index (or GHI) can be used to denote the sawdust-handling capability of gullets. The GHI is defined as a ratio of the volume of solid wood content, after it is converted into sawdust and compacted into the gullet, that the gullet can handle to the total gullet volume. For example, suppose a gullet with a volume of 0.160 cubic inch can handle 0.112 cubic inch of solid wood after it is converted into sawdust and compacted into the gullet; we would say the GHI is 0.7 (0.112/0.160). Or, for ease of understanding the math involved, the cross-sectional area can be used as shown in the illustration (fig. 2).

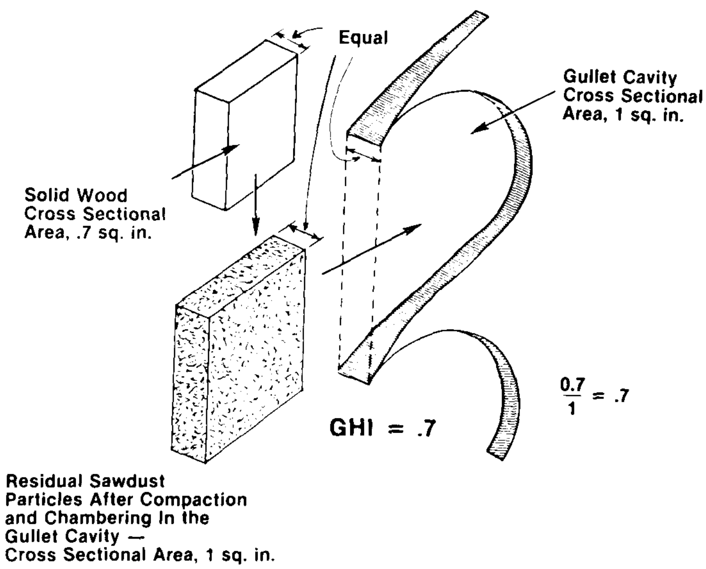

Figure 2.--Relationship of gullet cavity and the solid wood volume it can hold after the wood is converted to sawdust particles and compacted and chambered in the gullet cavity. (ML84 5715)

Many sawmill experts agree that for good saw performance, sawdust should be chambered in the gullet cavity and carried along and discharged as the tooth emerges from the cut. Overloading gullets results in excessive sawdust spillage. As sawdust particles are squeezed between the plate or blade and the wood, it causes friction, heating, and drag on the saw. In severe cases, overloading the gullets can stop a saw dead cold in the cut. Power demand dramatically increases at the point of overloading. Sawdust spillage usually occurs unevenly, thus forcing the saw offline and causing variation in the resultant lumber.

The volume of sawdust produced by a tooth depends on the cutting edge width, bite, and depth of cut. In no case should these factors combine to produce more sawdust than the gullet cavity can handle. Forcing more sawdust into the gullet cavity beyond its capacity puts severe strain on the tooth assembly. To help insure against overloading the gullets, a tradeoff can be made between bite, which is actually controlled by feedspeed, and depth of cut. For example, when increasing feedspeed, and thus the bite, the depth of cut can be decreased to make the same volume of sawdust. This tradeoff can be regulated within established limits.

Excessively large gullets for a task can also lead to sawdust carrying and discharge problems. An overly large perimeter in a gullet that is never filled may allow sawdust to escape more easily. Sawdust that escapes from the gullet may cling to the sides of the cut in an uneven fashion. This often happens in winter sawing and can result in excessive tooth vibration, which in turn can cause plate or blade cracks.

In general, when sawing smaller logs or cants and thus narrower depths of cut, tooth bite can be increased to the maximum. Maximum tooth bite should be translated into the corresponding feedspeed and care exercised not to exceed it. Overbiting on narrower depths of cut can damage the tooth assembly as well as the saw. On narrow depths of cut, the tendency is to overfeed because power is usually more than adequate. Overfeeding many times results in tearing the wood, particularly around larger knots, making a rough board surface.

When sawing smaller logs, it is usually best to use the maximum number of teeth to allow for maximum feedspeed, productivity, and smoothest board surface. Gullet size should be commensurate with the task. Using overly large gullets for sawing small logs or cants reduces the number of teeth that could otherwise be put into the saw. Thus the feedspeed is slowed and production is hindered. For sawing larger logs or cants, use larger gullets to handle the larger volume of sawdust. Sawing larger logs with inadequate gullet capacity generally results in gullet overloading and its attendant problems.

Gullet size should be measured accurately. One method that can be used LO determine gullet cross-sectional area is to trace the gullet outline on graph paper that has 100 squares of equal size per square inch. After the gullet outline has been traced carefully, count the number of squares enclosed within the gullet boundary. Divide the number of squares by 100 by simply moving the decimal point two places to the left. You now have the gullet cross-sectional area in square inches.

Side Clearance

The subject of side clearance must necessarily be discussed along with cutting edge width and saw thickness. Once side clearance is established for a task and the saw thickness or gauge is known, the cutting edge width is automatically established.

Side clearance should be matched to the task. Side clearance is affected by the saw and tooth type; species of wood sawn; wood moisture content; condition maintained on the cutting edge; alinement of equipment; type of guidance system; and tooth geometry.

The cutting edge must clear a pathway in the wood wide enough for the saw blade to pass through without excessive friction (fig. 3). Friction, of course, results in heat and this, in turn, may cause a heat gradient to develop in the saw. This, then, affects a saw’s tension forces. Excessive side clearance may cause overstressing of the tooth assembly and thus cause saw instability. It also increases power demand.

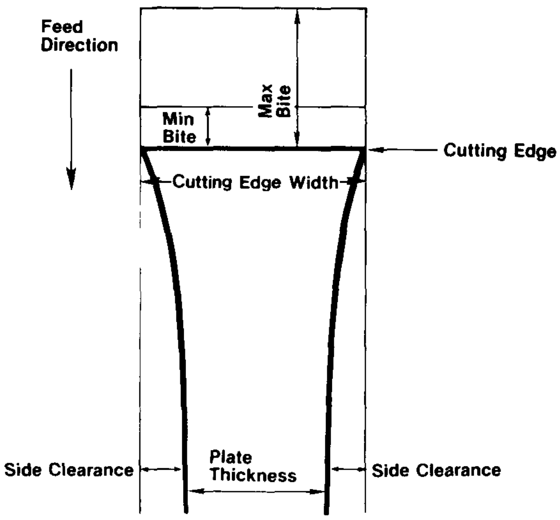

Figure 3.--Tooth bite (top view of tooth). (ML84 5717)

As the cutting edge penetrates the wood, the fibers are compressed slightly until they are actually sheared. After shearing, the compressed fibers adjacent to the shear point spring back nearly to their original position. The side clearance must be sufficient to keep the fibers in the sprung-back condition from contacting the saw.

Softwoods in general tend to be more stringy grained and therefore do not cut as cleanly and smoothly as do most hardwoods. There are exceptions of course. Softwoods in general, then, require somewhat more side clearance than do hardwoods. Typically, softwood sawing requires side clearance from 40 to 50 percent greater than the saw plate thickness, while hardwood sawing requires side clearance about 25 percent greater than the saw plate thickness.

Less side clearance is required when sawing frozen wood because the fibers generally cut cleaner than when sawing unfrozen wood. Therefore, a narrower path for the saw plate to pass through is possible. Reducing side clearance also reduces power requirements, which is an important factor in sawing frozen wood. To help offset the tendency to underfeed in winter sawing because of increased power demands, use the smallest side clearance possible.

Tables 4 and 5 show standard side clearances used on headrigs for both band and circular saws.

Table 4.--STANDARD SAW GAUGES, CUTTING EDGE WIDTHS, AND SIDE CLEARANCES FOR BANDSAW APPLICATIONS.

Saw gauge	Cutting edge width	Side Clearance
	- - - - In.	- - - -
19 (0.042 in.)	0.095	0.027
18 (.049 in.)	.110	.031
17 (.058 in.)	.125	.034
16 (.065 in.)	.135	.035
15 (.072 in.)	.155	.042
14 (.083 in.)	.170	.044
13 (.095 in.)	.190	.048
12 (.109 in.)	.215	.053
11 (.120 in.)	.235	.058

Table 5.--STANDARD SIDE CLEARANCES FOR CIRCULAR INSERTED SAW TEETH (Unfrozen Softwood)

Style	Saw Gauge				
	9/10	8/9	7/8	6/7	5/8
	- - - -	- - - -	In.	- - - -	- - - -
2-1/2, F	0.067	0.067	0.074	--	--
B, 3	--	.067	.074	0.082	--
3-1/2	--	--	.074	.082	0.086
D, 4-1/2	--	--	--	.097	.102

Tooth Geometry

Saw tooth geometry includes setting up the clearance angle, the tooth angle, and the hook angle (figs. 4 and 5). These angles should carefully be matched to a saw's task. In general, circular saws use larger hook angles than do band saws; faster feedspeeds require larger hook angles than do slower feedspeeds; conventional sawing requires larger hook angles than does climb sawing; and softwood sawing requires larger hook angles than does hardwood sawing (table 6).

A proper hook angle insures that the tooth will literally "hook" itself into the wood to consummate the sawing action without adverse effects. When the hook angle is excessive for the task, the saw may self-feed and, in the case of band saws, may pull itself off the wheels. If the feedspeed is excessively slow for the hook angle,

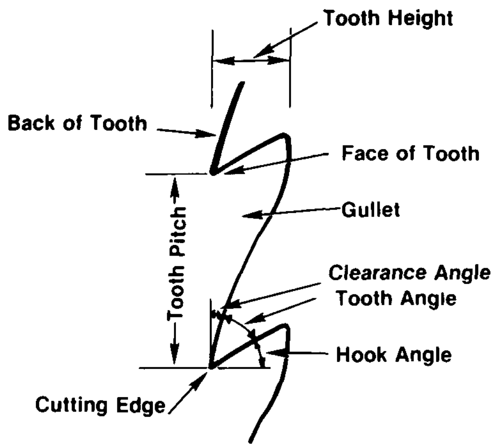

Figure 4.--Band saw tooth anatomy (side view). (ML84 5712)

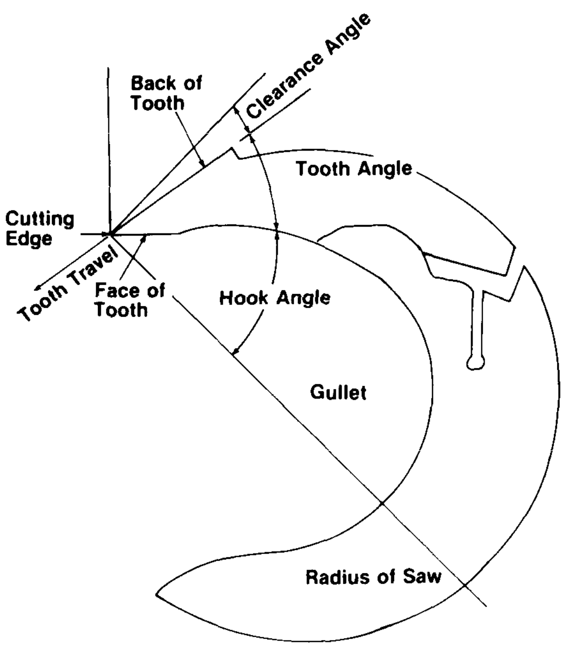

Figure 5.--Circular saw tooth anatomy. (ML84 5714)

the teeth, instead of hooking into the wood, will be forced. This produces excessive drag and increases power consumption. The cutting edge of the teeth dulls more rapidly, thus increasing the sharpening frequency. As a rule of thumb, use the greatest hook angle a task will allow.

The tooth angle, or sharpness angle, determines tooth strength and stiffness. In general, for band

Table 6.--STANDARD SAWTOOTH ANGLES FOR VARIOUS SAWING CONFIGURATIONS

Configurations	Hook	Sharpness	Clearance
	- - - - -	Degrees	- - - - -
Circular, Inserted Tooth	43-45	35-37	9-11
Band Saws			
Feed Speed 150-240 FPM			
S.G. < 0.42	25-30	44-52	12-16
Feed Speed 90-150 FPM			
S.G. 0.43-0.51	20-24	56-60	8-12
Feed Speed up to 90 FPM			
S.G. > 0.52	15-22	60-67	6-8
Carbide Teeth			
Conventional Cut			
S.G. < 0.46	25-40	45-60	5-10
S.G. > 0.46	10-20	65-80	5-10
Climb Cut			
S.G. < 0.46	10-30	45-60	5-10
S.G. > 0.46	0-15	65-80	5-10

sawing, faster feedspeeds used on softer woods require smaller tooth angles and slower feedspeeds used on harder woods require larger tooth angles (fig. 6). Feedspeeds should be matched with the hardness of the wood sawn. If tooth angles are excessively small for the task, the cutting edge becomes weak, and the tooth is more inclined to crumble under load. With an excessive tooth angle, feedspeed is restrained and power demand is increased.

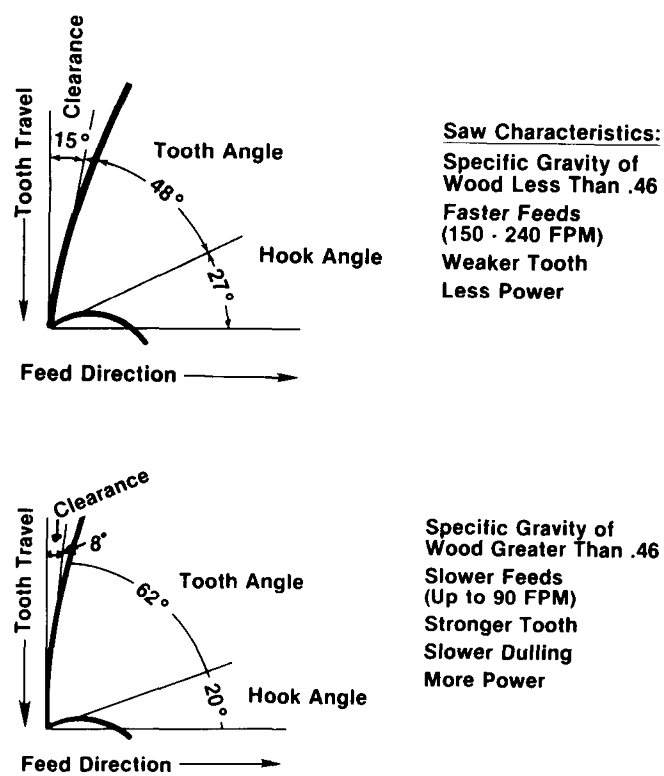

Figure 6.--Tooth geometry for two sawing configurations (side views). (ML84 5711, ML84 5713)

The clearance angle must be sufficient for the tooth back to clear the wood as it progresses through the cut. If the tooth back drags against the wood during cutting, friction and heating of the saw result. For circular I.P. saws, the clearance angle should be from 9 to 11 degrees. For band saws feeding above 150 feet per minute, the clearance angle should be from 12 to 16 degrees. Slower feedspeed should be coupled with smaller clearance angles. Large clearance angles have a tendency to decrease the feed force but also cause the saw to dull faster because of causing a smaller tooth angle. Conversely, a smaller clearance angle results in a stronger tooth and slower dulling of the cutting edge. Balanced saw performance again demands that tooth geometry be matched carefully with the saw's task and the way the saw will be operated.

Tooth Functioning

In discussing the subject of tooth functioning, three components must be considered do,i;ysmrpi;duz: tooth speed, tooth pitch, and feedspeed.

In general, tooth speed is excessive in American sawmills. While there may be some advantages in running saws fast, the disadvantages are of greater consequence. Factors to consider when selecting tooth speed for a given setup include saw type, tooth type, species, production needs, and maintenance practices.

In general, saws with carbide teeth are run at higher tooth speeds than other similar saws. Circular saws are usually run at higher tooth speeds than band saws. Unfrozen wood is normally sawn at higher tooth speeds than frozen wood. For obtaining maximum production, use the fastest tooth speeds allowable for a Particular saw design. Faster tooth speeds do not necessarily induce saw vibration, but any tendency a saw has to vibrate will be aggravated to a greater degree by higher tooth speeds. Saw vibration contributes to poor performance and results in excessive lumber variation. Saws run at higher tooth speeds demand topnotch maintenance. The slower a saw runs, the easier it is to maintain (table 7).

Table 7.--STANDARD RANGE OF TOOTH SPEEDS FOR VARIOUS SAWING CONFIGURATIONS

Tooth speed[1]		Circular			Band saws					
		Frozen or knotty wood	Specific gravity < 0.46	Specific gravity > 0.46	7-inch saws, 18 g, 1-3/4-inch space	12-inch saws, 14 g, 2-inch space	16-inch saws, 11-12 g, 3-inch space	Frozen or knotty wood	Specific gravity < 0.46	Specific gravity > 0.46
fpm	mpm									
6,000	1,850	X								
6,500	2,000	X						X		
7,000	2,150	X			X			X		
7,500	2,300	X		X	X	X		X		X
8,000	2,450			X	X	X				X
8,500	2,600			X	X	X	X		X	X
9,000	2,750			X		X	X		X	
9,500	2,900		X	X		X	X		X	
10,000	3,050		X			X			X	
10,500	3,200		X							
11,000	3,350		X							
11,500	3,500		X							
12,000	3,650		X							

[1]The English and metric values are not exactly equal but are sufficiently close that the recommendations still apply.

Tooth pitch determines primarily how much work a saw can accomplish. If the maximum amount of work is desired, the saw must contain the maximum number of teeth commensurate with the proper gullet size. Gullet size, in turn, determines to a large extent the maximum number of teeth a saw can effectively carry. Tooth pitch should allow for sufficient strength in the shoulder to support the tooth during sawing.

If small logs are cut with saws that have large gullets, and thus contain fewer teeth, feedspeed must necessarily be slowed to insure against overbiting. This restricts productivity. Because the tendency is to feed fast on small logs, overbiting thus becomes a problem, and damage to the saw is likely. Therefore, when sawing small logs, use the maximum number of teeth with gullet size matched to the task.

If large logs are cut with saws that have small gullets, the feedspeed will possibly be slowed because of the higher power demand and the need to avoid overloading the gullets with sawdust. Again, productivity suffers. Underfeeding results in a bite less than the side clearance, thus producing sawdust particles that more easily spill from the gullet cavity. This forces the saw offline, thus creating friction and heating of the saw. All of this contributes to lumber variation. Sawing large logs requires increased gullet capacity to avoid overloading the gullets. Larger gullet capacity means fewer teeth with wider shoulders, thus providing more strength for the tooth to do its work. This allows proper feedspeed without adverse effects on the operation.

For band saws, tooth height should be in proper proportion to the pitch. If tooth height is excessive, the saw tends to flutter, thus resulting in vibration and deviation in the cut. For softwood operations, gullet depth should be approximately 43 percent of tooth pitch. For heavier gauge saws, higher tooth speeds, and greater depths of cut, tooth depth can be up to 50 percent of tooth pitch without adverse effects. Heavier gauge saws provide sufficient tooth stiffness for accurate sawing without excessive tooth flutter. For smaller gauge saws with a tooth pitch of 2 inches or less, tooth height should be approximately one-third the pitch. When pitch becomes greater than 2 inches on smaller saws, tooth height should be approximately one-fourth the pitch for best results.

To help insure saw stability, tooth pitch should always be less than half the smallest cutting depth so that at least two teeth will be in action during cutting.

The interaction of tooth speed, tooth pitch, and feedspeed combine to produce a finite tooth bite during sawing (fig. 7). When any of these three components change, tooth bite also changes. Obtaining the proper bite is essential for good saw performance. Overbiting can cause saw damage. Underbiting can cause saw undulation which results in lumber variation.

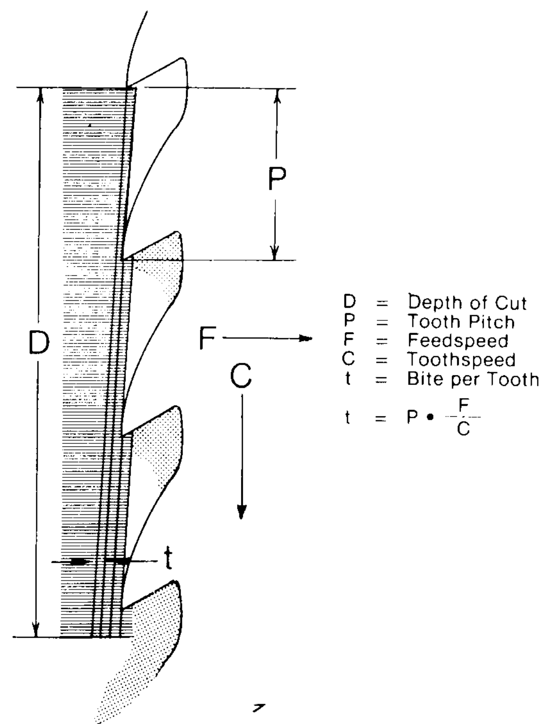

Figure 7.--Tooth functioning (side view of bandsaw). (ML84 5736)

Tooth bite can be defined as the distance a log or cant advances forward when the tooth has traveled through the wood a distance equal to the tooth pitch. Tooth bite determines sawdust particle size, which is important in determining its cambering characteristics.

As a log or cant advances into a saw, the sawdust particles produced may vary in size or characteristics. In band sawing, the wood moves at a right angle in relation to the direction of tooth travel. The actual path of the tooth through the wood, however, is slightly inclined from the perpendicular. As long as saw speed and saw feed are constant, the resultant sawdust particles will be sized fairly uniformly.

With circular saws, sawdust particles vary in size from the time a tooth enters the wood until it exits. In conventional sawing the teeth travel in cycloidal curves such that the paths of two successive teeth diverge as they pass through the wood. Therefore, the sawdust particles formed on the side where the teeth exit are somewhat larger than the sawdust particles formed on the side where the teeth enter. Even though the horizontal distance between successive teeth is constant, thus producing a constant bite, the physics of the formation and breakup of the wood into sawdust also causes a difference in sawdust particle size. Therefore, with circular saws when speaking of sawdust particle size related to a given bite, we are really speaking of an average particle size.

Researchers at the University of Maine recently determined that for circular saws the minimum bite should be approximately 32 percent larger than the side clearance for the saw. This helps to insure that the smaller sized sawdust particles will not be less than the side clearance. If bite is less than side clearance, sawdust particles will more easily escape between the kerf wall and the saw. Escaping sawdust results in excessive friction and thus a heat gradient builds up in the saw. Sawdust that escapes from the gullet rarely spills evenly on both sides. Uneven sawdust spillage inevitably pushes the saw offline, thus causing variation in the lumber. While some sawdust spillage is inevitable, it can be kept to a minimum by making proper-sized sawdust particles.

The upper bite limit is more arbitrary than the lower bite limit. For band saws, the upper bite limit is generally set at not more than the gauge of the saw. For other saws, it is set as follows: large circular headsaws--0.l25 inch; smaller circular saws with other than carbide teeth--0.063 inch; and circular saws with carbide teeth--0.040 to 0.050 inch. The main reason for establishing an upper bite limit is to prevent overstressing the tooth assembly. Overbiting imposes heavy strain on the tooth shoulders since they bear the brunt of the sawing stresses. Overbiting is also likely to cause distortion of the shoulders and thus eventual fatigue and failure. Tearout caused by overbiting can also become a problem, especially around large knots.

Implementing correct tooth functioning is critical in the setup and operation of saws. For balanced saw performance there must be proper interaction between tooth speed, tooth pitch, and feedspeed to produce a bite that makes sawdust particles that can be correctly handled by the gullet. If tooth functioning is left to chance, saw operating problems and excessive lumber variation will inevitably result.

Power

It seems that many formulas for calculating horsepower do not take into account all the variables that affect power needs. It’s difficult to determine all variables involved. It’s even more difficult to determine how these variables interact and to bring them together into a single formula that accurately accounts for their behavior in the sawing process.

For a saw to work properly, the teeth should travel at constant speed and bite into the wood within prescribed limits. To do this, adequate power must be supplied to the saw. This includes a power source designed for the task and a proper belt/pulley hookup system correctly installed.

Power needs constantly change during the sawing process, Wider depths of cut require more power than do narrower depths of cut; harder woods require more power than do softer woods; faster tooth speeds, and thus faster carriage speeds, require more power than do slower tooth speeds and thus slower carriage speeds; wider cutting edge widths require more power than do narrower cutting edge widths. However, increasing the bite does not necessarily mean increasing power needs. Let me illustrate three situations.

In the first situation (fig. 8), assume the number of teeth and carriage speed are constant and the tooth speed is decreased--bite will increase, power needs will decrease. This is due to fewer across-the-grain severances per inch of feed.

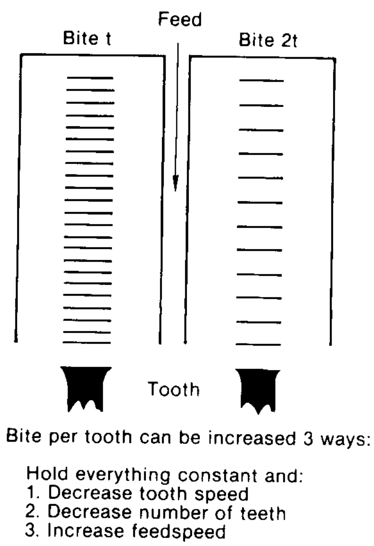

Figure 8.--Changing bite (top view of tooth biting into wood). (ML84 5737)

In the second situation, assume the tooth speed and carriage speed are constant and the number of teeth are decreased--bite will increase, and power needs will decrease. This is also due to fewer across-the-grain severances per inch of feed.

In the third situation, assume the number of teeth and tooth speed are constant and carriage speed is increased--bite will increase, and power needs will increase. This is due to more work being done per unit of time as compared to situations 1 and 2. However, the across-the-grain severances are the same as in situations 1 and 2.

The force used at the cutting edge is the same for producing a thin chip as for a thick one. It normally exceeds that used along the sides and under the cutting point. By doubling the chip thickness, the minor forces used for side-shear and chip-crumble may be double, but the major force used at the cutting edge to sever across the grain remains the same. Therefore, a chip that is twice as thick can be produced using less than twice the original force.

The formula used to calculate power needs in Program SAW was developed by Phil Quelch in his well-known book “Sawmill Feeds and Speeds,” published by the Armstrong Manufacturing Company in the 1960’s. In his formula, Quelch used a constant 0.003 horsepower for each square inch of gullet area per minute, with a baseline derf of 0.250 inch for band saws and 0.344 inch for circular saws. In each case, when using a kerf other than the baseline value, an adjustment for horsepower is made. The formula has been further refined to account for additional factors that affect power needs. These refinements were largely the work of Hiram Hallock, a Forest Products Technologist retired from the Forest Products Laboratory in Madison, WI. These factors are bite, wood hardness, and depth of cut.

For the bite factor, 0.125-inch bite represents a baseline value of 1. When bite is less than 0.125 inch, an adjustment is made to power requirements that is less than 1.

For the wood hardness factor, 0.46 specific gravity represents a baseline value of 1. When wood has a specific gravity greater than 0.46, an adjustment is made to power requirements that is greater than 1; and when specific gravity is less than 0.46, an adjustment is made to power requirements that is less than 1.

The depth-of-cut factor uses an adjustment to power requirements that recognizes the fact that cutting a wider depth of cut requires more power than cutting a narrower depth of cut, with all else being equal. This adjustment factor is based on earlier work done in the late 1940’s and early 1950’s by C. J. Telford of the Forest Products Laboratory and G. W. Andrews of the Forest Products Laboratory of Canada.

In Program SAW, power needs are based on filling the gullets to capacity at the stated Gullet Holdin~ Index value. Thus, if you are not using the saw under those conditions, then the horsepower values calculated will be misleading. The horsepower values from Program SAW must be interpreted correctly to be meaningful.

My experience has been that the horsepower formula in Program SAW gives reliable results. As with most things, however, it can probably be improved upon.

Balancing Saw Performance

Achieving balanced saw performance cannot be left to chance if the greatest efficiency of operation is desired. It can only come about first, by determining what task is to be accomplished; second, by designing a saw to do that task; and third, by setting up the saw properly and operating it within its design limits. Of course, maintenance must be given a high priority.

Saw Design Using Program SAW

I have already mentioned that Program SAW was developed to help assess a saw's operating limitations. It can also be used to design a saw to best fit a particular task.

Program SAW requires seven pieces of input information: saw or wheel diameter; arbor or tooth speed; saw plate thickness; cutting edge width; tooth pitch or number of teeth (circular saws only); gullet area of one tooth or gullet depth (band saws only); and the specific gravity value of the heaviest wood sawn. To properly design a saw for a task, the typical depth of cut range and the typical feedspeed must also be known. Program SAW can currently be run on an HP-41 CV handheld calculator or an APPLE II Plus desktop computer. It can be run in either English or metric units.

Output from Program SAW includes the range of feedspeed, depth of cut, and bite values. However, just because these values are calculated for a saw does not mean that they are correctly established for that particular situation. This is where the redesign capability of Program SAW comes in handy. A saw can be properly designed and the operating variables correctly established for a particular setup. Program SAW also shows tooth speed and the power required to fill the gullets to capacity with sawdust.

To make the output from Program SAW easier to understand and apply, it can be plotted on a special graph entitled "Operating Range and Performance Limitations." This graph consists of a vertical axis labeled feedspeed and a horizontal axis labeled depth of cut.

After obtaining output data, the maximum feedspeed line is plotted. This line terminates at the depth-of-cut value where the gullet is filled to capacity. Similarly, the minimum feedspeed line is plotted. Next, the termination points of the intermediate feedspeed/depth-of-cut values are plotted. A curved line can be established through these termination points. You now have the boundary limits within which the saw should be operated provided it is properly designed for its task (fig. 9).

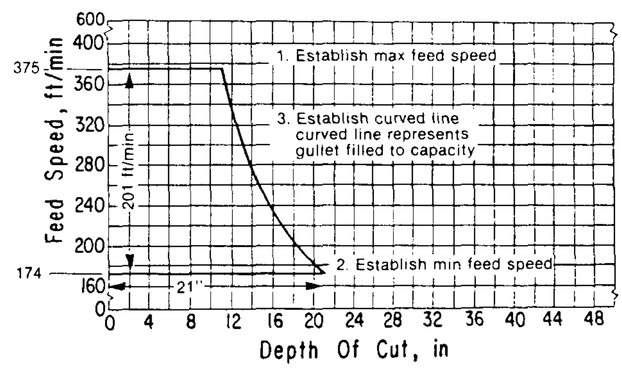

Figure 9.--Operating range and performance limitations graph for circular saw, 2-1/2 style tooth. (ML84 5738)

When a log or cant is fed into a saw, the observed feedspeeds and corresponding depths of cut should fall within the established boundary limits for a saw that is properly designed for the job. If observations fall outside the boundary limits, the saw is not operating efficiently.

There are five possibilities when observing feedspeed and depth-of-cut combinations. First, observations will fall within the boundary limits as established by Program SAW (fig. 10, No. 1). Second, observations will fall below the minimum feedspeed line, thus indicating that sawdust particles are smaller in size than the side clearance (fig. 10, No. 2). Third, observations will fall

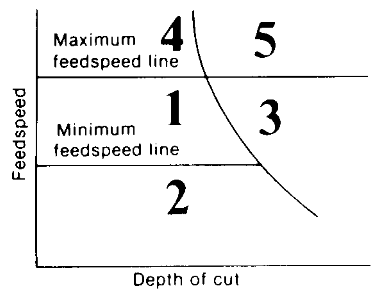

Figure 10.--Five possibilities established by program SAW for observed feedspeed and depth-of-cut combinations. (ML84 5743)

within the maximum and minimum feedspeed lines but also fall to the right of the curved line, thus indicating that gullets are overloaded with sawdust (fig. 10, No. 3). Fourth, observations will fall above the maximum feedspeed line but also to the left of the projected curved line, thus indicating that overbiting has occurred (fig. 10, No. 4). And fifth, observations will fall above the maximum feedspeed line but also to the right of the projected curved line, thus indicating that both overloading the gullets with sawdust and overbiting have occurred (fig. 10, No. 5).

In figure 11, the minimum feedspeed is 135 feet per minute and the maximum feedspeed is 293 feet per minute. The curved line delineates the points at which feedspeed and depth of cut are in balance with the gullets being filled to capacity with sawdust at the assumed GHI value. For example, at the maximum feedspeed of

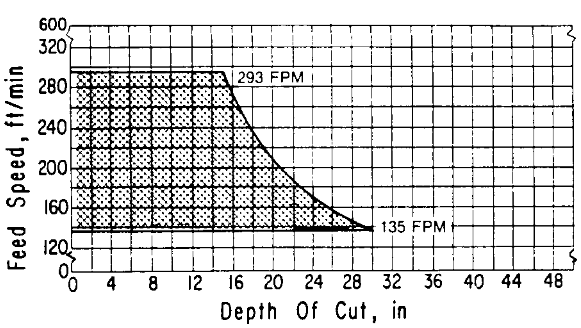

Figure 11.--Operating range and performance limitations graph for example mill. (ML84 5739)

293 feet per minute, the corresponding depth of cut is 15 inches, at which point the gullets are filled to their capacity.

Figure 12 shows how saws are designed to perform different tasks. Saw A is designed with a maximum feedspeed of about 415 feet per minute at a depth of cut of about 8 inches. Saw B is designed for a maximum feedspeed of about 280 feet per minute at a depth of cut of about 15 inches. This vividly illustrates the different capabilities of two different saws.

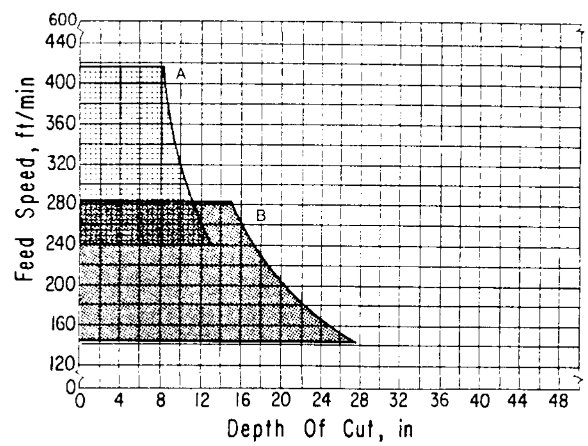

Figure 12.--Operating range and performance limitations graph for two band saws. (ML84 5740)

Program SAW Results

The best way to illustrate the capabilities of Program SAW is to show an example of how a specific saw setup can be improved.

Tables 8 through 11 show how changes in saw design change operating parameters so the saw is better fitted for its task. Situation 1 (table 8 shows the specification for the original saw. The operator normally fed this saw at about 280 feet per minute. This being true, the bite was always smaller than the side clearance. The saw constantly produced fine sawdust particles that would not readily remain in the gullet. Notice that the saw as originally designed had a maximum feedspeed of about 500 feet per minute, which

Table 8.--CHANGES IN DESIGN OF A BAND SAW: SITUATION 1 VERSUS SITUATION 2

Parameter	Situation 1	Situation 2	Relationship of feedspeed, depth of cut, and bite values: Situation 1			Situation 2		
			Feed-speed	Depth of cut[1]	Bite	Feed-speed	Depth of cut[1]	Bite
			fpm	- - - In. - - -		fpm	- - - In. - - -	
Wheel diameter	108 in.	108 in.				251	18.3	[2]0.048
Arbor speed[3]	373 rpm	373 rpm				260	17.7	.049
Tooth speed	10,560 fpm	10,560 fpm	290	16.0	[2]0.055	280	16.5	.053
Saw thickness	.095 in.	.095 in.	300	15.5	.057	300	15.5	.057
Cutting edge width	.205 in.	.191 in.	320	14.7	.061	320	14.7	.061
Tooth pitch	2 in.	2 in.	340	13.9	.064	340	13.9	.064
Gullet area	1.14 sq. in.	1.14 sq. in.	360	13.2	.068	360	13.2	.068
Gullet depth[3]	1.00 in.	1.00 in.	380	12.6	.072	380	12.6	.072
Maximum bite	.095 in.	.095 in.	400	12.0	.076	400	12.0	.076
			420	11.5	.080	420	11.5	.080
			440	11.1	.083	440	11.1	.083
			460	10.7	.087	460	10.7	.087
			480	10.3	.091	480	10.3	.091
			500	9.9	.095	500	9.9	.095
			502	9.9	.095	502	9.9	.095

[1]Based on a GHI of 0.70.
[2]Side clearance of teeth
[3]Calculated value.

represents capacity that was never used. It costs to maintain capacity that is not used. If the stated feed-speed of 280 feet per minute is the desired upper limit, then the saw is not properly designed for its task and will not achieve the greatest efficiency of operation. Changes in saw design will make this saw more efficient and will likely alleviate operational problems.

Situation 2 (table 8) shows the side clearance reduced from 0.055 to 0.048 inch--a reduction of 0.007 inch. For a 13-gauge saw, 0.048 inch is a normally acceptable side clearance. It can possibly be reduced further depending on the situation. The new side clearance is achieved by reducing the cutting edge width from 0.205 to 0.191 inch. Lowering the side clearance increases the feedspeed range by extending the lower end. Notice also that this extends the depth of cut capability from 16 to 18.3 inches. Reducing the cutting edge width also reduces power requirements.

Situation 3 (table 9) shows tooth speed reduced from 10,560 to 8,560 feet per minute--a reduction of 2,000 feet per minute, This is achieved by reducing the arbor speed from 373 to 303 RPM. Reducing tooth speed shifts the feedspeed range downward. Maximum feedspeed has now been reduced from 502 to 407 feet per minute and the minimum feedspeed has been reduced from 290 to 203 feet per minute.

Situation 4 (table 10) shows tooth pitch increased from 2 to 2.75 inches--an increase of 3/4 inch. Again, the feedspeed range is shifted downward. The maximum feedspeed has now been lowered from 502 to 296 feet per minute, and the minimum feedspeed has been lowered from 290 to 148 feet per minute. Notice also the corresponding change in depth of cut. Fewer teeth are now available to accomplish the work. The remaining teeth will perform their task more efficiently by taking a larger bite. Less power will be consumed with fewer teeth in the cut at any given time.

Situation 5 (table 11) shows the gullet cross-sectional area increased from 1.14 to 2.16 square inches. The accumulated changes to this point now accommodate an 18-inch depth of cut at a feedspeed of 280 feet per minute. Larger depths of cut may also be accommodated although at realistic decreased feedspeeds.

Table 9.--CHANGES IN DESIGN OF A BAND SAW: SITUATION 1 VERSUS SITUATION 3

Parameter	Situation 1	Situation 3	Relationship of feedspeed, depth of cut, and bite values					
			Situation 1			Situation 3		
			Feed-speed	Depth of cut[1]	Bite	Feed-speed	Depth of cut[1]	Bite
			fpm	- - - In. - - -		fpm	- - - In. - - -	
Wheel diameter	108 in.	108 in.				203	18.3	[2]0.047
Arbor speed[3]	373 rpm	303 rpm				220	17.0	.051
Tooth speed	10,560 fpm	8,560 fpm				240	15.7	.056
Saw thickness	.095 in.	.095 in.				260	14.6	.061
Cutting edge width	.205 in.	.190 in.	290	16.0	[2]0.055	280	13.7	.065
Tooth pitch	2 in.	2 in.	300	15.5	.057	300	12.9	.070
Gullet area	1.14 sq. in.	1.14 sq. in.	320	14.7	.061	320	12.2	.075
Gullet depth[3]	1.00 in.	1.00 in.	340	13.9	.064	340	11.5	.079
Maximum bite	.095 in.	.095 in.	360	13.2	.068	360	11.0	.084
			380	12.6	.072	380	10.5	.089
			400	12.0	.076	400	10.0	.093
			420	11.5	.080	407	9.9	.095
			440	11.1	.083			
			460	10.7	.087			
			480	10.3	.091			
			500	9.9	.095			
			502	9.9	.095			

[1]Based on a GHI of 0.70.
[2]Side clearance of teeth
[3]Calculated value.

Table 10.--CHANGES IN DESIGN OF A BAND SAW: SITUATION 1 VERSUS SITUATION 4

Parameter	Situation 1	Situation 4	Relationship of feedspeed, depth of cut, and bite values					
			Situation 1			Situation 4		
			Feed-speed	Depth of cut[1]	Bite	Feed-speed	Depth of cut[1]	Bite
			fpm	- - - In. - - -		fpm	- - - In. - - -	
Wheel diameter	108 in.	108 in.				148	18.8	[2]0.048
Arbor speed[3]	373 rpm	303 rpm				160	17.6	.051
Tooth speed	10,560 fpm	8,560 fpm				180	15.9	.058
Saw thickness	.095 in.	.095 in.				200	14.5	.064
Cutting edge width	.205 in.	.190 in.				220	13.4	.071
Tooth pitch	2 in.	2.75 in.				240	12.4	.077
Gullet area	1.14 sq. in.	1.14 sq. in.				260	11.6	.084
Gullet depth[3]	1.00 in.	.73 in.				280	10.9	.090
Maximum bite	.095 in.	.095 in.	290	16.0	[2]0.055	296	10.5	.095
			300	15.5	.057			
			320	14.7	.061			
			340	13.9	.064			
			360	13.2	.068			
			380	12.6	.072			
			400	12.0	.076			
			420	11.5	.080			
			440	11.1	.083			
			460	10.7	.087			
			480	10.3	.091			
			500	9.9	.095			
			502	9.9	.095			

[1]Based on a GHI of 0.70.
[2]Side clearance of teeth
[3]Calculated value.

Table 11.--CHANGES IN DESIGN OF A BAND SAW: SITUATION 1 VERSUS SITUATION 5

Parameter	Situation 1	Situation 5	Relationship of feedspeed, depth of cut, and bite values					
			Situation 1			Situation 5		
			Feed- speed	Depth of cut[1]	Bite	Feed- speed	Depth of cut[1]	Bite
			fpm	- - - In. - - -		fpm	- - - In. - - -	
Wheel diameter	108 in.	108 in.				148	33.9	[2]0.048
Arbor speed[3]	373 rpm	303 rpm				160	31.5	.051
Tooth speed	10,560 fpm	8,560 fpm				180	28.2	.058
Saw thickness	.095 in.	.095 in.				200	25.6	.064
Cutting edge width	.205 in.	.190 in.				220	23.5	.071
Tooth pitch	2 in.	2.75 in.				240	21.7	.077
Gullet area	1.14 sq. in.	2.16 sq. in.				260	20.2	.084
Gullet depth[3]	1.00 in.	1.37 in.	290	16.0	[2]0.055	280	18.9	.090
Maximum bite	.095 in.	.095 in.	300	15.5	.057	296	18.0	.095
			320	14.7	.061			
			340	13.9	.064			
			360	13.2	.068			
			380	12.6	.072			
			400	12.0	.076			
			420	11.5	.080			
			440	11.1	.083			
			460	10.7	.087			
			480	10.3	.091			
			500	9.9	.095			
			502	9.9	.095			

[1]Based on a GHI of 0.70.
[2]Side clearance of teeth
[3]Calculated value.

This saw is now better designed to do its task albeit more efficiently than the original saw. With the new saw, the mill should experience fewer operational problems and lower maintenance costs. There is less opportunity for gullet overloading since the saw is designed to handle larger logs that may occasionally be encountered.

Figure 13 is another example of some changes that were instituted in one band saw setup. First, notice the bite of 0.019 inch, which is somewhat less than the side clearance of 0.030 inch. The saw originally had a hook angle of 30 degrees. The maximum feedspeed was 349 feet per minute. Tooth pitch was 1.75 inches. The mill operator normally fed the saw at about 100 to 125 feet per minute for hardwoods.

In redesigning this saw, tooth pitch was increased from 1.75 to 2.25 inches--an increase of 1/2 inch. Hook angle was reduced 3 degrees. With the mill's feedspeed of about 100 feet per minute, bite increased

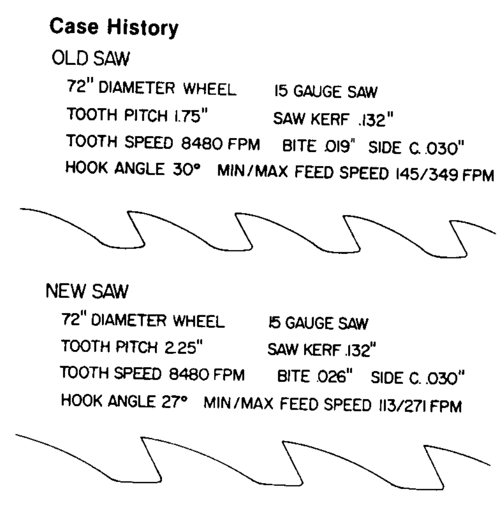

Figure 13.--Example of how to use program SAW to improve saw performance. (ML84 5741)

from 0.019 to 0.026 inch with the new saw--an increase of 0.007 inch. Maximum feedspeed dropped from 349 to 271 feet per minute, while minimum feedspeed dropped from 145 to 113 feet per minute. Notice what this accomplished (fig. 14). Number of teeth decreased 23 percent; gullet size increased 52 percent; and bite increased 37 percent. Power consumption dropped 3 percent according to actual meter readings, Maintenance time for benching the saw dropped 28 percent according to the head filer. Running time for the saw increased 1.5 hours.

Case History

Effect on operation
- Number of teeth reduced 23%
- Gullet size increased 52%
- Bite increased 37%
- Power consumption reduced 3%
- Maintenance time reduced 28%

Figure 14.--Case history of saw performance improvement using program SAW. (ML84 5742)

Summary

Some general observations for Program SAW over the last few years are that saws are routinely pushed beyond their design limits; gullets are frequently overloaded with sawdust; teeth are run too fast for the conditions; and saws often contain too many teeth, thus producing excessively fine sawdust. I feel that many operational problems can be traced directly to these shortcomings. When there is a better way of doing things and you do not take advantage of it, then there is a price to pay for not making a change.

To obtain balanced performance from your saws, they must be designed properly for the task, then operated within their design limits, Know what those limits are and insure that they are not exceeded.

It does not cost to upgrade your saw's efficiency of operation but rather it pays you in the long run.

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