Mechanized Felling in the Pacific Northwest: Existing and Future Technology

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Introduction

The forest industry in the Pacific Northwest is in a period of transition, which will undoubtedly affect mechanized harvesting. One major change is a decline in the average size of harvested trees because of a shift to younger, second-growth forests (Sessions et al. 1986, Sessions et al. 1990). The shorter-rotation, smaller-diameter trees are more uniform than those in large old-growth stands and therefore well suited to mechanized harvesting. Another change is the growing public advocacy of forestry practices that emphasize the importance of multiple resources and long-term site productivity, which could result in leaving tree limbs and tops in the stand as a nutrient base, conducting partial cutting instead of clearcutting, and working on smaller landings. A third change, the current interest in improving logging safety through increased mechanization, has been prompted by acceptably high rates of injury and fatality in the industry.

This publication synthesizes information on market development for mechanized felling equipment and the views of 46 researchers, equipment manufacturers, and contractors on current technology and future directions in this field. These views, obtained from telephone interviews, represent the practical experience of the selected group and do not necessarily reflect an industry consensus.

Development of Markets for Cutting Heads and Carriers

Cutting Heads

Cutting heads are of two types: fellers, which sever trees at the base, and harvesters, which not only sever trees but also delimb and cut them into log lengths. Most machines with fellers are referred to as feller-bunchers because they fell a tree and move it vertically to a nearby pile of trees. Several types of fellers and harvesters are currently on the market (Figure 1).

Fellers

The first feller in North America was the shear head, which appeared on the market in the 1970s. Butt damage and the associated loss of wood fiber have been the major disadvantages. Despite design improvements (McLauchlan and Kusec 1975, Overend 1980) and better shear maintenance, butt damage can never be totally eliminated (Greene and McNeel 1990). However, shears have remained popu-

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Figure 1. Categorization and example current brands (in parentheses) of mechanized cutting heads.
lar for harvesting trees for pulpwood and elicited no major complaints about loss of fiber quality.

To offset the drawbacks of shears, equipment developers introduced non-shear cutting heads in the early 1980s. Of these, the disk saw is the most popular, not only in the Pacific Northwest but throughout North America. Disk saws are of two types: continuous and intermittent (Figure 1). Continuous saws rely on the inertial energy of a thick disk with a large mass to propel the disk through the standing tree. Intermittent saws rely on high torque to provide the energy to sever the tree (Greene and McNeel 1990). Speed of both saw types is similar (between 1,000 and 1,300 r.p.m.) (MacLennan 1988). A disk saw has the disadvantage of making a wide kerf (2 to 3 in.) and, often, of leaving high stumps. Moreover, a large-diameter blade is required for severing a large-diameter tree. Some manufacturers have tried to overcome this drawback by developing modifications [e.g., the Borreal double-deck saw (Ashmore et al. 1987), the Denis twin saw]; however, neither of these is still on the market.

A competitor to the disk saw is the Lokomo cone saw (Boudreau 1984), which is based on a relatively simple design for severing the tree with a slowly rotating cone instead of a disk. Tree cutting can be completed close to the ground. The cone rotates only once; for a small tree, cone rotation can be stopped as soon as the cut is completed (Folkema 1984). There is now only one manufacturer of cone saws; 80 such saws are currently operational in North America.

Other non-shear cutting heads on the market include the auger and the chain and bar. The auger uses one slowly rotating screw-shaped cutting device for severing the tree. Only one brand of auger is now on the market. The chain and bar is similar to a chain saw but is controlled from the machine cab.

Virtually all feller heads can accommodate accumulator arms to handle multiple stems. Most heads designed for booms have as an option a side-tilt capability that reduces the chance of tree damage during felling (Anonymous 1989).

Harvesters

The harvester, which utilizes the chain and bar concept, has been developed primarily in Sweden and Finland (Figure 1). After the harvester fells and processes trees into short log lengths (maximum length about 20 ft), a forwarder transports the logs to the roadside. The harvester-forwarder operation is referred to as a mechanized cut-to-length system.

Harvester heads are of two types: single function, which severs the tree and places it, butt first, in the carrier-mounted processing unit for delimbing and bucking (double-grip harvester); and three function, which severs, delims, and bucks the tree (single-grip harvester).

Harvesters can optimize selection of appropriate log lengths, as required by the mill, with the aid of a computerized tree-measuring program and a link between the harvester and the mills. However, existing Scandinavian software requires adaptation to suit the North American market. Log-measuring techniques and log-quality checks also must be refined to ensure greater usefulness. Log-measuring technique has been identified as a priority in the Scandinavian manufacturers’ research and development programs over the next 5 years (Brink 1989).

Carriers

Carriers are of two types: swing boom, usually of the excavator type, and fixed (tree to tree) (Figure 2). The swing boom is by far the dominant carrier in the Pacific Northwest because of the terrain. Feller heads are attached to either carrier type, harvester heads typically to swing booms. But selecting a feller or harvester head is not easy because many factors must be considered, including availability of a carrier with suitable hydraulic flow and cooling capacity, tree diameter, presence or absence of rocky terrain, and operator skills and attitudes (Folkema 1984).

For fellers, the match of cutting head to carrier is crucial so that the machine is not off-balance at critical moments, such as directly after a tree has been severed. Carrier power also must be balanced to the hydraulic demands of the feller head (Nicholas 1988). A continuous disk saw head requires a large carrier because of its weight and constant demand on hydraulic systems; intermittent disk heads adapt more readily to lighter carriers because the heads themselves are lighter and make fewer demands on hydraulics (Greene and McNeel 1990). Most harvester brands come with a cutting head matched to the carrier.

To overcome restrictions placed on machines by unfavorable terrain, several manufacturers currently market carriers with self-leveling cabs (Pawlett 1985, Stirling 1986). A further step in adapting to steep slopes is the development in Liechtenstein of the Kaiser Spyder, which moves about by “walking”
Figure 2. Categorization and example current brands (in parentheses) of carriers. Asterisk (*) indicates no brands currently on the market.

Instead of "rolling" (Schiess et al. 1983). In addition to the Kaiser Spyder, a fully walking, six-legged prototype has been developed jointly by Adaptive Machine Technologies, Ohio State University, and Fetting Inc.

Interview Procedures

We interviewed four interconnected groups—researchers, manufacturers, dealers, and contractors. For the researchers, open-ended discussions were held and a questionnaire was administered. Five leading researchers with expertise and experience with mechanized harvesting, all from outside Oregon State University’s Forest Engineering Department, were questioned about the shear, disk, and chain and bar heads, harvesters, carriers, and future trends foreseen.

For the manufacturers and dealers, a telephone interview consisting of seven questions about existing and future markets for mechanized harvesting was conducted. Respondents included 19 representatives, primarily company presidents, marketing managers, and design engineers, from 13 manufacturers and 4 major dealers. These companies market 21 feller heads, not including different models of the same head.

For the contractors, a telephone interview consisting of nine questions about their current and preferred felling equipment and future trends foreseen was conducted. Twenty-two contractors were contacted, the list for whom was obtained from the Associated Oregon Loggers (1990), equipment manufacturers and dealers, and an earlier survey (Schuh and Kellogg 1988). The contractors interviewed own a total of 31 machines: 15 intermittent saws, 14 shears, 1 cone saw, and 1 continuous saw.

Contractors were equally distributed between the west and east sides of the Cascade Mountain Range. Fifty-eight percent produce primarily saw logs, the other 42 percent primarily pulpwood. One-half work their equipment on slopes exceeding 35 percent, primarily on the west side of the Cascades. The majority (73%) work in stands with an average tree diameter between 12 and 22 in., 23 percent in stands with an average tree diameter of less than 12 in. (primarily pulpwood). The maximum slope negotiated by fixed-head, rubber-tired carriers is 30 percent, whereas the maximum range for tracked machines is 35 to 70 percent.

We first present researchers’, manufacturers’, and dealers’ views on specific cutting heads and carriers and follow with a summary of contractors’ views to evaluate the similarities and differences between the two groupings.
Researchers', Manufacturers', and Dealers' Views

The interviewed group of researchers and equipment representatives noted that a principal problem confronting manufacturers is the small size of the total North American market for mechanized felling—5,000 to 7,000 machines. One manufacturer believes this is why major American and Japanese corporations have not become major manufacturers of feller-bunchers. The small market makes it difficult for manufacturers to recover product research and development costs; consequently, useful innovations may be lost. Furthermore, problems experienced with prototype machines are often picked up quickly within the industry, causing a loss of interest. Purchasers usually special-order equipment, making it difficult for manufacturers to mass-produce and take advantage of economies of scale.

Cutting Heads

Shear

In the Pacific Northwest, shears are used predominantly for felling trees for pulpwood and, occasionally, saw timber. Although researchers are unanimous that the shear will continue to lose in popularity, they believe it will still have a niche in the pulpwood market. It does appear, however, to the interviewees that users of shear heads can expect to be subjected to tighter quality control at the mill in the future.

Disk saw

Although the continuous disk saw has the major overall market share in North America, researchers, manufacturers, and dealers agree that the intermittent disk saw predominates on the West Coast, where terrain is more adverse and average tree diameter is larger than in other timber regions in North America. Even though the disk saw head, especially the continuous type, has a relatively wide kerf, none of the researchers felt that butt damage or fiber loss is an issue. However, the manufacturers believed that butt damage with intermittent saws that grip the tree during felling could be reduced, and that the large kerf with continuous saws is responsible for considerable fiber loss.

Researchers, manufacturers, and dealers identified the following advantages for the continuous disk saw: (1) it results in minimal butt damage because the tree is gripped only after being severed, and (2) it is most effective in dense stands of small-diameter trees. The same groups identified the following advantages for the intermittent saw: (1) it is safe to operate because of the intermittent action of the disk and provides better overall control during felling because the tree is gripped from the beginning of sawing, (2) it can be used in larger timber than the continuous saw, and (3) it requires less power to run than the continuous saw; consequently, smaller, simpler carriers can be used, and the machines can operate on steeper terrain.

Researchers believe that major future developments will be cost-driven. For example, refinement of the heads would ensure lower initial outlay of capital and lower operating costs. Such disk heads should be easier to maintain and standardize throughout the market. One researcher expects increased automation of the felling process.

Most manufacturers and dealers believe that there will continue to be a market for feller-bunchers with disk saw heads. Some manufacturers are convinced that the feller-buncher is the best option for all types of terrain. Cable yarding will always be prominent on the West Coast, and feller-bunchers capable of working on steep slopes are expected to harvest increasingly more timber.

Chain and bar

Researchers believe that, because of its clean cut and narrow kerf, the chain and bar head results in the least amount of fiber loss but, because of the need to prevent bar damage, requires a more skilled operator than any other saw type. In spite of high maintenance costs, the chain and bar requires a low initial capital outlay—about a third of the price of a comparable disk saw head.

Harvesters

Some researchers, manufacturers, and dealers believe it is more economical to have two machines—for example, a harvester and forwarder working in the cut-to-length system—than to have the three or four machines typical of the feller-buncher/skidder system. However, the interviewees also noted that the high initial investment places this equipment out of reach for many contractors.

The majority of researchers, manufacturers and dealers contacted believe that single-grip harvesters
will become more popular than double-grip machines. Manufacturers predicted that single-grip machines will have between 8 and 40 percent of the total Northwest market share in 5 to 10 years, largely because of the anticipated increase in environmental restrictions on logging along with a shift to smaller trees and partial cuts. One manufacturer even consults with the major environmental groups operating in the market area and considers their reaction to current research and development projects.

Most manufacturers interviewed believe that the present Scandinavian harvester heads are not well adapted to North American markets without modifications. Areas of concern are the ability of the machines to effectively delimb Pacific Northwest tree species and produce long logs or tree-length material for extraction. Equipment manufacturers expect future machine designs capable of processing multiple stems.

**Developments in cutting technology**

Over the years, saw teeth have been substantially redesigned—witness the cup tooth of Rotosaw and the two-way rotating blade of ESCO. Researchers favor the cup tooth because of its low purchase price and low running cost, but they see a need to further refine tooth design for all saw heads. At least one manufacturer is looking at alternatives to saws, such as high-pressure water jets and the laser beam. These new technologies could result in lower initial investment and maintenance costs. Furthermore, fiber utilization would increase because tree damage and wood loss to kerfing would be virtually eliminated.

**Carriers**

Researchers estimate that tracked machines hold 95 percent of the carrier market in the Pacific Northwest. These machines are mostly swing-boom excavators rather than crawler tractors. The researchers also point out that feller-buncher carriers are mostly dedicated to felling, even if they can be adapted to applications such as excavating. Researchers believe that rubber-tired machines cause moderate soil disturbance and compaction but that tracked swing-boom machines cause less. Site-specific levels of impact are related to the degree of planning and operational practices (Zaborske 1989).

Researchers expect future machine designs to be more efficient, especially in terms of operator controls and cab design. More emphasis will be placed on self-leveling cabs or the walking machine concept, both of which allow safe negotiation of steep slopes. With the increased harvesting of second-growth stands, stumps will be much closer together, allowing a walking machine to move from stump to stump with minimal soil impacts. To increase personal safety, operators could control the machine by radio from a distance (Figure 3).

![Figure 3. Conceptual view of a radio-controlled feller-buncher facilitating cable yarding on steep slopes.](image-url)
Manufacturers and dealers also view refinement in feller-buncher carriers as important for the future. They foresee lower maintenance costs and better designs for negotiating steep slopes effectively. They also anticipate that many future harvester heads will be mounted on tracked rather than rubber-tired carriers.

Contractors' Views

All the contractors interviewed except one believed that mechanization of felling equipment will increase. Of the 22 participants, 45 percent felt that the shear market will decrease, but nearly all believed that the shear is still the most cost-effective way to harvest stands of small trees for pulpwood, especially when shears are well maintained so that butt damage is minimized. When asked to predict the most popular felling head on the West Coast in the future, 36 percent indicated the intermittent disk saw, 14 percent the harvester head, 5 percent the shear, 5 percent the chain and bar, 5 percent the cone, and 30 percent were not sure.

Of the participants operating only in moderate terrain (<35% slope), most are on the east side of the Cascades and work in small-diameter timber. The majority (68%) were happy with their current harvesting system (predominantly, track-mounted feller-bunchers with either a shear or an intermittent saw head). Of the contractors willing to make a change, 14 percent said they would prefer an intermittent saw, 13 percent a harvester head, and 5 percent a cone saw.

Half the survey participants operate in steep terrain. Of these, 55 percent use an intermittent saw and are generally pleased with their current harvesting system. Of the 27 percent who are not happy, most use a shear and would like to switch to an intermittent saw; 9 percent prefer the cone saw.

Contractors estimated that down-time for fellers is extremely low, averaging only 6 percent. Eighty-two percent felt that their levels of down-time were acceptable, and 77 percent were happy with their dealer's service. However, 23 percent felt that fellers still require refinement. Only 18 percent were willing to pay additional money (10-50% more) for a felling head. In spite of high maintenance costs with the chain and bar, the relatively low capital outlay is attractive to contractors unable to finance the more expensive disk saw heads.

Conclusion

The chainsaw, still responsible for cutting a significant portion of trees in the Pacific Northwest, will always have a niche. However, increasing environmental restrictions and the consequent decline in timber availability, the shift to second-growth harvesting of smaller-diameter trees and consequent need to optimize wood-fiber utilization, and a more safety-conscious timber industry combine to almost assure increased mechanization.

Two distinct technological phases have already occurred within the market for mechanized felling heads: the shear, which originated in the 1970s, is reaching the end of its development, and the disk saw is now peaking. Our interviews of researchers, equipment manufacturers, and contractors indicated that felling machines making use of the chain and bar, intermittent disk saw, auger, and cone saw are more applicable in Pacific Northwest conditions than is the continuous saw because they require a smaller carrier, can cut larger-diameter trees, and minimize fiber loss in sawlogs. New technologies such as water jets and laser beams could appear in future mechanized felling markets.

Single-grip harvesters, working with forwarders, could gain a significant portion of the market—replacing some feller-buncher operations on moderate terrain. However, the high initial investment places this equipment out of reach for many contractors.

Swing-boom tracked carriers with feller heads are likely to continue their dominance over rubber-tired machines. Moreover, more harvester heads will be mounted on tracked rather than rubber-tired carriers. There will also be more emphasis on carriers with self-leveling cabs or walking machines for steep terrain. Inside the machine cab, controls and cab design will be more comfortable and efficient for the operator.
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Researchers, equipment manufacturers, dealers, and contractors were interviewed to assess present mechanized felling technology in the Pacific Northwest and predict developments within the next 5 to 10 years. Contractors interviewed jointly own 15 intermittent disk saws, 14 shears, 1 cone saw, and 1 continuous saw. It is the opinion of the interviewed group that a relatively small mechanized felling market is a major problem confronting equipment manufacturers; that the shear will continue to lose market share as the need to maximize wood-fiber utilization increases; that the intermittent disk saw dominates on the West Coast where terrain is adverse and trees are relatively large; that single-grip harvesters could gain a significant portion of the market, replacing some feller-buncher operations on moderate terrain; that swing-boom tracked carriers are likely to continue their dominance over rubber-tired machines.
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