WOOD HARVESTING

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FERIC

AN INTRODUCTION TO OFF-ROAD PROCESSORS AND HARVESTERS

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Abstract

European harvesters and processors have generated increasing interest in eastern Canada. This technical note reviews their current configurations, major components and suitability to Canadian logging systems.

Introduction

Ninety-one percent of the wood produced by fully-mechanized systems in eastern Canada is in the form of full trees [2]. Recently however, there has been a growing interest in mechanized tree-length and shortwood systems because of the increased industrial responsibility for forest regeneration, reduced volume allocations, and the possibility to lower system costs and/or extract higher value wood products. Therefore, FERIC has initiated a long-term study of off-road processing systems which will assess the fully or partially-mechanized tree-length and shortwood harvesting alternatives.

Tree-length and shortwood harvesters were common in eastern Canada in the 1970's, but the shift to full-tree operations, the low mechanical reliability of multi-function machines, and the trend to contractor operations prompted a shift to single-function machines. Now, a new generation of shortwood harvesters and processors has been developed in Europe, principally in the Nordic countries. First introduced to eastern Canada in 1983, these machines have been gaining in popularity and acceptance. Now, there are over 10 different models and 30 individual machines in operation in eastern Canada (Table 1).

This first report serves as an introduction to European harvesters and processors by providing a general description of their componentry including a discussion of the various options. A subsequent report will summarize the results of a series of FERIC short-term and longer-term studies on various models, highlighting machine performance and costs in the operating conditions encountered.

General Description

Processors are designed for delimbing and slashing to length, while harvesters perform the same functions plus felling. All the European processors and harvesters being imported into Canada are designed for off-road application. Most of the manufacturers are based in Sweden and Finland, but one processing head is made in Austria.

In contrast to the sliding-boom delimbers popular in North America, these machines are not equipped with bulky over-head booms but have compact feeding mechanisms. Most European processing units pull the stem through the delimbing knives rather than pass the delimbing knives over the stem. All are equipped with at least three delimbing knives, a stem-feeding mechanism, and saws for slashing and/or felling. Most have a length-measuring system, while a few boast of diameter sensors. On-board computers are standard equipment on all but a few small farm tractor-mounted models.

Harvesters vs. Processors

The choice of machine depends on system requirements, stand conditions and the availability of skilled

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KEYWORDS: Felling, Delimbing, Slashing, Harvesters, Processors, One-grip, Two-grip, Off-road.

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Table 1. Technical specifications of harvesters and processors currently available in Canada

NAME	BRUUN 7610 H	LAKO 3T	PIKA 45	ROTTNE RAPID SNOKEN 860	ROTTNE EGS-85	STEYR KP40 SERIES I
Machine	1-grip harvester	1-grip harvesting head	2-grip processing unit	2-grip processor or harvester	1-grip harvester	1-grip processing head
Country of Origin	Sweden	Finland	Finland	Sweden	Sweden	Austria
Carrier						
- wheeled or tracked	6 wheel, bogie	N/A[1]	N/A	6 wheel, bogie	6 wheel, bogie	N/A
- length	7.0 m			≃ 8-9 m	≃ 8-9 m	
- width	1.9 m			2.5 m	2.5 m	
- weight	8 900 kg					
- ground clearance	0.55 m			0.55 m	0.55 m	
- engine power	72 kW			72 kW 2100 rpm	72 kW 2100 rpm	
- transmission	mechanical gear box with 'beefed up' clutch			hydrostatic	hydrostatic	
Boom	Bruun			Rottne RG81	RG 81	
- reach	5.1 m			10 m	10 m	
- slewing angle	300°			350°	350°	
- lifting moment	60 kN•m			150 kNim	150 kNim	
- tilt platform	15° all around			± 15° on one plane only	± 15° on one plane only	
Felling head	part of harvesting head (see below)	part of harvesting head (see below)	N/A	Rottne RF-81	part of harvesting head (see below)	N/A
- saw type				chain		
- max. cutting diameter				60 cm		
Processing or harvesting unit						
- feeding mechanism	2 rubber tires with chains	2 metal spiked rollers + 1 track or 3 metal rollers	4 metal rollers	2 large diam rubber tires	2 rubber tires with chains	1 chain
- feed speed	2/ms	3.5 m/s	2.7 m/s	2.5 and 5.0 m/s	4 m/s	1.5 m/s
- feed force	25 kN	23 kN	23 kN	48 kN	20 kN	25 kN
- no. of delimbing knives or arms	4	3	3	3	4	5
- max. delimbing diam		55 cm	50 cm	45 cm	40 cm	40 cm
- topping knife	no	no	no	yes	no	no
- saw type	circular, 70 cm diam	chain	chain	chain	chain	circular, 90 cm diam
- max. cutting diam	28 cm	55 cm	45 cm	60 cm	45 cm	35 cm
- no. of programmable lengths	3	12	10	3	3	7
- measuring device	roller	wheel	wheel with light cell	wheel with light cell	wheel	feed mechanism
- diameter sensor	no	no	available	available	available	available
- working weight		750 kg	1200 kg		600 kg	810 kg
- recommended carrier power	72 kW	75 kW	65 kW	72 kW	72 kW	88-100 kW
- recommended hydraulic flow	130 L/min	200 L/min	200 L/min	210 L/min	210 L/min	160 L/min
- recommended hydraulic pressure	20 mPa	23 mPa	19 mPa	27 mPa	25 mPa	20 mPa

[1] N/A - Not applicable.

Table 1. "continued"

TAPIO 400	TAPIO 550R	TIMBERJACK/FMG 990	TIMBERJACK/FMG 990E	VALMET 901	ARBROFIT 30	NOKKA 400	VIMEK G30
1-grip harvesting head	1-grip harvesting head	1-grip harvester	1-grip harvester	1-grip harvester harvester unit	2-grip processor or unit	2-grip pro- or harvester	2-grip processor
Finland	Finland	Finland	Finland	Sweden	Finland	Finland	Sweden
N/A	N/A	6 wheel bogie	4 wheel	4 wheel	designed to work off a farm tractor (PTO)	designed to work off a farm tractor	designed to work off a farm tractor (PTO)
		7.0 m	6.5 m	5.7 m			
		2.75 or 2.95 m	2.65 or 2.85 m	2.5 m			
		12 000 kg	11 000 kg	11 000 kg			
		0.62 m	0.62 m	0.60 m			
		114 kW	114 kW	83 kW			
				2400 rpm			
		Clark Powershift	Clark Powershift	hydrostatic-mechanical			
		FMG 184 or telescopic	FMG 170	telescopic	Arbrolift 550 or other	Nokka 3000 A or other	winch
		8.3/10.0 m	8.3 m	9.5 m	7.0 m		
		233°	233°	270°			
		155 kN•m	155 kN•m	100 kN•m			
		± 15° on one plane only	± 15° on one plane only	cab & loader tiltable sideways + lengthwise			
part of harvesting head (see below)	part of harvesting head (see below)	part of harvesting head (see below)	part of harvesting head (see below)	part of harvesting head (see below)	Arbrolift or other	Nokka or	N/A
				chain			
				38 cm			
		FMG 762 or	FMG 746				
1-m stroke device	2 metal spiked rollers and 1-m stroke device	2 rubber tires with chains or 2 steel rollers	2 rubber tires with chains cr 2 steel rollers	2 metal spiked rollers	2 metal spiked rollers	2 metal spiked rollers	3 or 4 metal spiked rollers
1.2 m/s	≃ 2.7 m/s	4.8 m/s	4.5 m/s	4 m/s	3 m/s	3.5 m/s	2.5 m/s
25 kN	25 kN	24 kN	21 kN	18 kN			
5	5	5	5	3	3	3	3
	45 cm	62 cm	52 cm	36 cm	35 cm		30 cm
no	no	no	no	no	no	no	no
chain	chain	chain	chain	chain	chain	chain	chain
45 cm	45 cm	50 cm	45 cm	45 cm	38 cm	35 cm	33 cm
6	6	44 per species x 4 species	44 per species x 4 species		2	0	
wheel	wheel	wheel	wheel	wheel	wheel	wheel	wheel
no	no	yes	yes	no	no	no	no
450 kg	900 kg	950 kg	670 kg		640 kg	480 kg	750 kg
60 kW	60 kW	114 kW	114 kW	83 kW	40 kW	40 kW	38 kW
110 L/min	110 L/min	180 L/min	180 L/min		90 L/min	110 L/min	35 L/min
16 mPa	16 mPa	24 mPa	24 mPa	24 mPa	25 mPa		13 mPa

labour. Both harvester and processor-based systems allow the possibility of double shifting and either may provide the best wood costs depending on conditions.

Harvesters are used in fully-mechanized systems where the worker is removed from the forest floor. These systems, often involving only one harvester and one forwarder, are safer than semi-mechanized or motor-manual systems. Planning and machine coodination requirements are less stringent with harvesters because the cutting and processing phases are combined. However, harvesters require a higher capital outlay than processors of similar power; though the system cost on a per unit volume basis may be comparable. Harvesters are best used in stands with little under-brush and a low number of unmerchantable trees. Their production is greatly affected by operator skill.

Processors can be used in fully-mechanized systems, after feller-bunchers or directional fellers. They also are used in semi-mechanized systems where the trees are felled motor-manually, processed mechanically, and then forwarded to roadside. This is advantageous where there is a ready availability of trained woods workers, but the operation can suffer when deep snow or poor weather restricts access for the fallers. Processor production is less affected by site and stand conditions; merchantable volume per unit area has the most influence on production. Compared to harvester operations, operator skill is less critical.

Two vs. One-grip

European harvesters and processors are classed as either two or one-grip machines depending on the number of times a tree stem is handled by the machine.

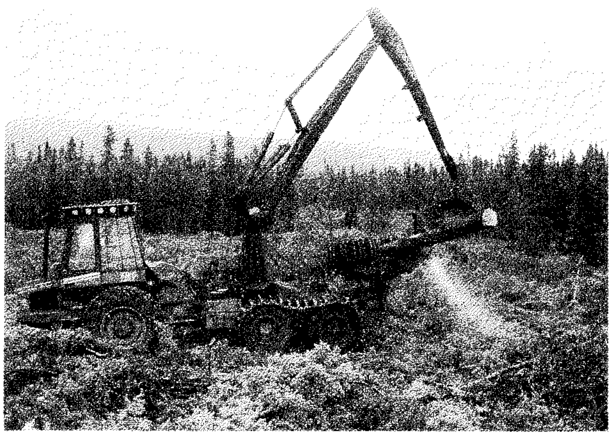

Figure 1. Two-grip processor.

Two-grip processors are equipped with a grapple on the end of a boom which is used to pick pre-felled trees off the ground and load them into the processing unit (Figure 1). They then are gripped a second time by the processing unit, hence the name. The processing unit usually is mounted behind the rear axle of the carrier on a pivoting arm with up to 270° arc. This facilitates loading and permits processing from either side.

Stems usually are processed one at a time and at right angles to the machine, although with smaller trees, it is sometimes possible to process two or three together. Once loaded into the processing bunk, the tree(s) is gripped by the feeding mechanism and pulled through the delimbing knives located at the infeed end of the bunk. The high feed speeds (2 to 5 m/s) facilitate delimbing because of the impact generated. Larger models are capable of shearing branches up to 10 cm in diameter, but the amount of branch clustering will affect feed speeds. Smaller processors (i.e., farm tractor-mounted units) have more restricted delimbing capacity. If branches are not severed, the feed mechanism can be reversed and another run taken. Large branches should be cut off manually before loading into the processor, although it is sometimes possible to cut them with the slashing saw.

Once the stem has been advanced a specified distance through the processing unit, the feed mechanism is stopped, usually automatically, the bunk is tilted and swung so that the delimbed section of stem is well placed, and the slashing saw is engaged. High speed saws placed at the outfeed end of the bunk are used to sever stems in one or two seconds to avoid splitting the free-hanging log. After slashing, the piece falls to the ground or on top of other pieces forming a pile. The stem is advanced and the sequence repeated until the top is reached and is ejected. Sorting can be achieved by swinging the processing unit before slashing or by advancing the machine slightly.

Two-grip harvesters are an adaptation of the processors and work in precisely the same manner except that they fell trees as well (Figure 2). Instead of grapple loaders, they are equipped with hydraulic chain-saw felling heads. These felling heads are light, weighing approximately 350-500 kg, and are capable of felling trees up to 60 cm in diameter depending on the model. After the tree is cut, it is loaded into the processing bunk as with two-grip processors.

Normally, the two-grip harvester works along the stand face cutting trees on one side and piling bolts on the other. However, in open stands, the harvester can cut into the block, harvesting trees from either side, though care must be taken to ensure that the slash does not fall on piles of wood.

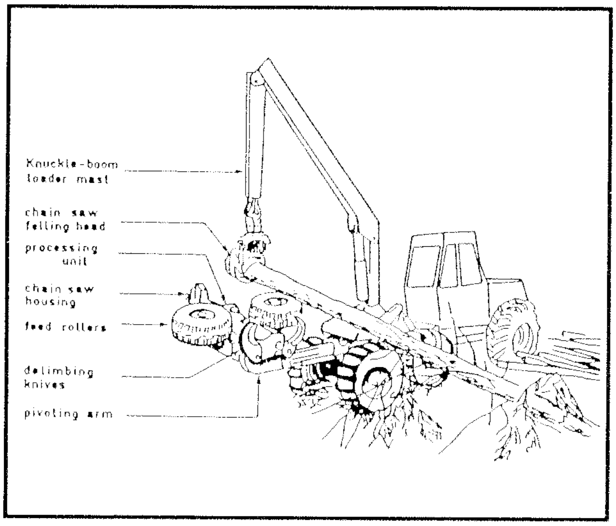

Figure 2. Two-grip harvester.

One-grip harvesters, also called grapple harvesters, have an integrated felling-delimbing-slashing head mounted on the boom of a suitable carrier (Figure 3). Carriers can be either wheeled or tracked excavator types. One-grip machines are designed for implementation in stands of smaller trees and thus are well suited for many of the eastern Canadian forests.

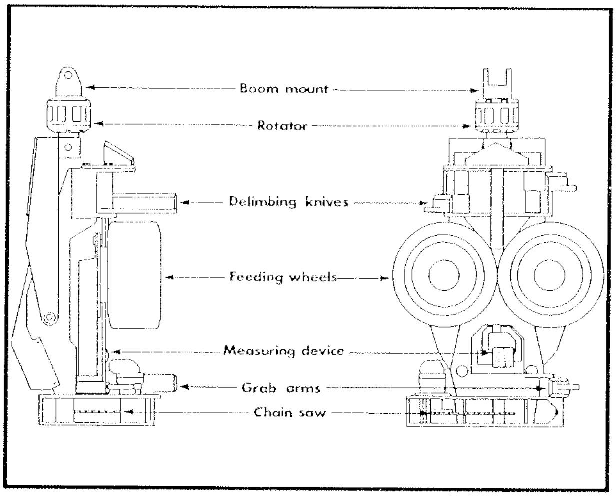

Figure 3. One-grip harvesting head.

The working method is different from the technique used with two-grip harvesters. The boom is extended, placing the head near the base of a tree (Figure 4). The feeding mechanism, delimbing knives and grab arm(s) are used to grapple the tree. Once grappled, the felling/slashing saw cuts through the tree and the tree is then pushed or pulled over. Once the stem is horizontal or approaching horizontal, the feeding mechanism is engaged and the tree is pulled through the delimbing knives. The feeding mechanism can be reversed if needed. When the desired length has been delimbed, the head is manoeuvered to the shortwood pile, and the delimbed section is cut off with the felling/slashing saw. Because the processing head is mounted on the boom, trees can be delimbed and slashed anywhere within boom's reach of the machine, providing more operational flexibility.

Figure 4. A one-grip harvester felling a tree.

One-grip processors are much less common; only two models (Steyr KP40 and KP60) are currently sold in North America (Figure 5). Their slashing saw cannot be used for felling. These processing heads can be mounted on any feller-buncher carrier of appropriate size and used off-road after manual fallers, feller-bunchers or directional fellers. However, most of these machines in Canada (mainly in B.C.) are working at roadside or on landings.

Figure 5. One-grip processor.

The relative merits of two-grip versus one-grip harvesters and processors are listed in Table 2.

Table 2. Two-grip versus one-grip machines

Machine Type	Advantages	Disadvantages
Two-grip	• capable of delimbing and/or felling larger trees than a one-grip of similar engine power and carrier weight. • more powerful processing unit with better delimbing capabilities. • more likely to have automatic length measurement and slashing options.	• higher capital cost, although not necessarily a higher system cost on a per unit volume basis. • the first metre of the butt cannot be delimbed because of the distance between the feed rollers and the delimbing knives. • piles are not as neat, especially on slopes or rough terrain. The bolts, dropping from as high as 2 metres, tend to scatter more. • the slash builds up at the side of the processor. Either the slash or the machine must be moved if the entrance to the processing unit should become blocked. • slash cannot be dropped in the machine path during processing to improve flotation in soft ground. However, the slash windrows created can improve flotation during the subsequent forwarding phase. • the slashing saw can be a safety hazard, even to the operator in the cab. However, many manufacturers have recognized this and have installed proper guarding.
One-grip	• lower capital cost. • delimbing starts 20-30 cm above the butt. • the piles are neat because the head can be placed close to the pile before slashing and the bolt does not drop far. • can be used in commercial thinning. • allows more flexibility in the choice of working method • in softground, trees can be delimbed so that slash falls in the path of machine travel. • the saw is activated farther away from the operator and therefore, there is less- chance of injury from broken chains on the chain-saw models.	• generally have poorer delimbing capabilities because of lower feeding forces. Thus, one-grip machines tend to be less effective on large trees with thick limbs. • while many have computers, most do not have automatic processing since it normally makes the building of neat shortwood piles more difficult. This general lack of an automatic processing feature is also related to the fact that one-grip machines often handle lower value material, and thus many users elect less sophisticated, lower cost computerized systems. • one-grip harvester production is very operator dependent.

Major Components

Components which are of interest to users or potential buyers of these machines include saws, feeding mechanisms, knives, measuring systems, computers, head mountings, boom-mounting and carrier characteristics.

Saws

Two types of saws are used: hydraulic chain saws, by far the most common, and hydraulic circular saws. Processors and one-grip harvesters usually have only one saw, while two-grip harvesters have two, one on the felling head and the other on the processing bunk.

The chain on the **chain saws** only turns when the retractable bar is swung out from its protective scabbard. Chain speed on the hydraulic slashing saws is almost double that of conventional gasoline chain saws so as to cut through a free-hanging, cantilevered piece of wood quickly, and thus avoid cracking the stem. Dedicated hydraulic felling saws are usually slightly slower than the slashing saws.

A broken chain can represent a hazard for machines, operators and others on the ground because of the high chain speed [3, 4, 5]. Slashing saws on the bunk of two-grip machines pose the greater risk since the operator is only about 5 m away. Saws on a felling head or a single-grip harvester head are safer because the saw is usually further away and angled in another direction. Many of the manufacturers have installed appropriate safety protection, but potential users should verify such safety features.

Chain saws used for felling are more fragile than circular saws. The operator requires good visibility to ensure that the saw is not being pinched and is not cutting dirt or rocks. Chains wear out, break, and fall off at a variable frequency depending on operator skill, site conditions, and harvester type. In an extreme case, a failure rate of 10 times a shift was observed though an average of once or twice a shift is typical for one-grip harvesters.

The problem is magnified in stands with considerable underbrush, since the lightweight heads should not be used to knock over small unmerchantables. Each small pole must be cut individually, thereby severely limiting productivity and increasing the likelihood of chain failure or displacement. Most heads are designed so that the chain saw cannot be activated until the tree is grappled. This safety mechanism helps ensure that the bar is not bent or broken during felling, but it reduces brushing efficiency.

Circular saws are found on only three models available in Canada (Bruun harvester, Steyr KP40 and KP60 processing heads). Most circular saws are designed to rotate continuously. Because of their high mass (45 kg or more), they can develop high momentum and high cutting speeds at lower rpm. The circular saw discs vary in size between models, with the smallest being 70 cm in diameter. Protection for these large discs increases the weight of the head. As a result, heads with circular saws may require heavier, more robust booms. Also, the felling heads (Bruun) have a larger bottom area than chain-saw heads and therefore, they tend to float on the snow and cut higher stumps in winter.

Circular saws are not as subject to breakage as chains and bars because they are more-ruggedly constructed, though rocks can still cause damage. Circular saw blades cost more to replace. Generally, at least two blades are needed per machine as they cannot be sharpened well in the field and must be removed for a proper regrinding.

Continuously-turning circular saws (Bruun) have the capability of clearing dense undergrowth and small poles using a mowing movement; they do not have to first grapple the stem. Thus, circular-saw heads prove advantageous in stands with small-diameter trees and a high number of unmerchantable poles (< 10 cm). Processor systems are also effective under such conditions.

Feeding Mechanisms

Most European machines have roller feeding mechanisms which develop forces to pull the trees through the delimbing knives. These forces depend on the pressure of the feeding mechanisms on the tree, the area of contact, the coefficient of friction, the efficiency of the force transfer, the hydraulic pressure and flow to the feed motor, and the angular velocity of the feeding mechanism.

If the feed mechanism pressure against the stem is too low, there will be slippage in the feeding. If pushed too hard against the stem, the feed mechanism will not have the power to move the stem. Only when applied pressure equals torque will the tree be moved forward most efficiently.

A large area of contact assures the transfer of a higher amount of force. Different designs for increasing the area of contact include feed rollers with wide, large-diameter rubber tires, multiple feed rollers, or chain feeds which have a long area of contact.

The coefficient of friction dictates the amount of slippage incurred. This coefficient changes depending on the material used, the shape of that material, and the state of the stem (e.g., species, bark roughness, wetness, dry or sap season, etc.). Metal rollers or chain feeds with spikes generate the most friction. Rubber tires are sometimes equipped with chains to increase the friction, reduce slippage, and protect the tires.

The desired state of the stem after delimbing affects feed mechanism design as well. Certain countries prefer rubber-tire feed rollers because damage to the stem surface caused by metal spikes is unacceptable. Fungus can enter into the stems through openings made by the spikes, and may cause staining or rot. Also, bark which is pushed into the stem by the spikes cannot be removed with the usual debarking processes.

Feeding mechanisms on single-grip machines are generally more compact than those on double-grip machines. The rollers are usually smaller and the squeezing pressure is lower, resulting in about half the feeding force of similar sized two-grip machines. On one-grip machines, the number of feed rollers is usually restricted to two, while two-grip machines may have up to four rollers.

Knives

The delimbing knives are similar on most models introduced into North America. They consist of one fixed and two wrap-around curved steel knives which encircle the stem when closed. The Steyr processor is different in that it has five delimbing knives. On all models, an automatic pressure control continuously forces the knives against the stem. A few models (Rottne two-grip) have limb deflectors on one or more of the knives.

The grab arms on one-grip harvesters are sometimes used to pre-limb the base of a tree before felling. However, they are not usually as sharp as the delimbing knives. Harvester heads are equipped with either one or two grab arms.

A topping knife is available on some models (Rottne). These are especially useful on two-grip machines where the distance between the slashing saw and the delimbing knives is approximately 2 m. The topping knife situated near the delimbing knives can be used to cut off ends of 15 cm diameter or less and sometimes allows 2 extra metres to be produced which might otherwise be rejected.

Measuring Systems and Computers

Most machines are equipped with a computer in which the desired bolt or log lengths can be specified. A few makes also are equipped with diameter sensors which again are linked to the computer. Generally, the computers are trouble-free. The number of lengths that can be programmed into the computer vary from as little as 3 to over 40. Therefore, a decision on which machine to buy may hinge upon the number of assortments, by length, required by a company.

Each manufacturer has a different system for measuring the length of stem, and for stopping the feeding mechanism. Devices for measuring log lengths includes wheels, rollers or the feeding mechanism itself. The length reader is connected to a length encoder (often a pulse generator) which sends signals by electric means to the computer and thence to a box with a digital readout placed in the operator's line of site within the cab.

The wheel-type length measurer is turned by the log as it passes. With this type of mechanism, inaccuracies are caused by crooks and sweeps which bring the stem out of contact with the wheel and can alter the measurement. Another problem, especially in spring, is caused by bark which strips off the stem, wraps around the wheel, and prevents it from turning. However, these devices are not affected by feed mechanism slippages or by reversing feeding direction.

Rollers mounted on pivoting arms are also turned by the stem, but they are not as affected by sweeps or crooks because the arm is pressured to keep the roller in contact even through large displacements. Neither feeding slippages nor reversing the stem affect their accuracy. The disadvantage to this type of length-measuring mechanism is that it is complex and can be damaged by branches and underbrush.

Length-measuring devices intrinsic to the feeding mechanism itself measure by the amount that the feed roller turns. Therefore, feeding slippages will cause inaccuracies, but sweeps, crooks, or reversing direction do not affect the measurement unless they cause slippage.

Each time that a bolt or log is cut, the length readout in the cab returns to zero. In some cases, the length readout is zeroed by activating the slashing saw; zeroing is accomplished when a bolt on the chain-saw blade housing near the sprocket passes a magnet and breaks the magnetic field. This type of zeroing mechanism is reliable and works well for one-grip harvesters. However, it is inconvenient on two-grip machines because the butt of each newly-loaded stem must be advanced until it is abreast of the slashing saw, and then feeding must be stopped and the saw engaged for the sole purpose of zeroing the length readout before processing starts.

Other machines use a light, situated just behind the slashing saws, which sends a beam across to a photo cell. With this system, the readout is zero when the light beam is intact but as soon as it is broken by a stem being advanced through it, the length measuring begins. One problem encountered is that the light beam may be broken by solid objects other than logs, such as shrubs or other types of underbrush.

The degree of automation available on these machines varies considerably. The simplest has no computer and the operator manually stops the feeding mechanism when the appropriate length has been reached; this often involves jockeying the stem back and forth. On the more complex systems, an operator only has to load the stem into the processing bunk or head, and then the stem is powered through the delimbing knives, stopped at the appropriate length and cut automatically. On such systems, desired lengths are pre-programmed into the system and priorized. The computer then makes the decisions on what length to make each bolt based on diameter and priority. Accuracy is a problem with some of the semi-automatic feeding systems which are influenced by the feeding speed and braking distance as well as by operator judgement and skill. Piling neatly can be a problem with the automatic processing systems as the operator often cannot position the head or the bunk quickly enough and therefore the bolts do not land in an orderly pile.

Head Mounting to the Boom

Most harvesting or processing heads on one-grip machines, or felling or grappling heads on two-grip machines, have a pendulum mounting to the boom. Although simple and lightweight, a pendulum mounting does not allow for as precise control of the head as a 2-pin or fixed mounting. The head swaying increases the time to position for both felling and slashing, but dampeners available on some models (Rottne 1-grip) can considerably alleviate the problem. Also, a pendulum mount provides much less control of the felled stem. Overall, the pendulum mounting works well for processors most of the time and for harvesters working in conditions with good visibility and few unmerchantable stems per hectare. Productivity is greatly reduced where there is a large number of unmerchantables or poles under 10 cm dbh.

The only European head on the market with 2-pin mounting (Bruun harvester) has shown the highest production (trees/PMH) in stands of small timber with a high number of unmerchantables. This is partially because the stability of the head reduces the time to approach and grab a tree. Also, this machine is equipped with a continuously-turning circular saw which allows unwanted stems to be cut without having to grapple them first. However, booms with 2-pin or fixed mountings are subject to greater stresses than with pendulum mountings and therefore must be more robust and/or shorter.

Booms and Boom Mountings

Booms vary in length from about 3 m to 10 m. Short booms mean that the carrier will be moved more often and that the swath widths will be narrower. Long booms can be slower to manoeuvre and usually decrease the stability of the carrier. The trend in Europe is towards telescopic booms which are desirable for thinning purposes, but less necessary for clearcutting operations.

Most processor and harvester carriers designed specifically for the purpose have the boom mounted behind the articulation joint. Many have leveling tables under the boom mast; some with unidirectional leveling and others with complete leveling capabilities. The Valmet has both the cab and the boom on a leveling and slewing table. Most carriers which have been converted from other functions are not equipped to level the base of the boom and as a consequence may be less stable or have less swing power on slopes.

The size of the boom and its position can affect the field of visibility for operators of single-grip machines. Large diameter masts in the centre of the carrier can obstruct the view, forcing operators to fell and process to the side. Currently, most booms are mounted in the centre on Nordic carriers.

Carriers

Some processors and harvesters come with their own carriers such as the Rottne, Timberjack/FMG, Bruun, and Valmet. Others, such as the Steyr, Lako and Tapio heads can be mounted on any carrier of appropriate size, power level and hydraulic capacity. To reduce capital costs, many have been mounted on domestic carriers.

Features to consider when choosing a carrier, other than the attachment compatibility, are machine stability, transmission type, cab size and control type.

Machine stability is affected by a number of factors including boom length, leveling capabilities, carrier width, head weight, and by machine weight and centre of gravity. The most stable North American carriers are tracked excavators commonly used for feller-bunchers. Wheeled feller-buncher carriers also provide greater stability than converted forwarders or skidders. Nordic carriers all have leveling tables under the mast; most also have bogie wheels and 6-wheel drive although Valmet and Timberjack/FMG have 4-wheel drive models as well. They have good stability, good mobility and exert a low ground pressure.

Processors and harvesters working off-road move frequently over short distances. In this application, hydrostatic transmissions excel, although their high initial cost may make them less attractive. Many of the tracked excavators or Nordic wheeled carriers are equipped with hydrostatic drives or some other type of powershift transmission which has the desired features of smooth start-offs without changing engine speed, easily adjustable speed, and automatic braking when the machine is stopped. Conversely, most North American wheeled machines do not have ideal transmission systems for off-road processing or harvesting.

Cab size is perhaps more critical in processors and harvesters than in most other forestry machines. Cabs on all the wheeled carriers should be large enough so that an operator can face forward while driving longer distances and then swivel his seat to face the boom while harvesting or processing or moving over short distances. Two of the Nordic carriers are exceptions: the Timberjack/FMG harvester is always operated in one direction so the seat does not need to swivel, and the entire cab on the Valmet harvester swivels instead of the seat. Cabs must be large enough to accommodate a computer, a length readout box, and often, dual driving controls. Most of the Nordic carriers have spacious, climate-controlled cabs. In contrast, North American wheeled skidders or forwarders do not have adequate cab space. One exception is the Timberjack 230 which has been adapted by Atmus Equipment of Nova Scotia specifically for use as a carrier for processing and harvesting heads. Although the cab is not large, it is adequate. Generally, excavator-type carriers have enough cab space as the operator does not have to swivel his seat because the entire cab turns.

Some of the computers are dust sensitive and require that cabs be pressurized and the air filtered. In these cases, air conditioning is a must during the summer since windows/doors should not be kept open.

Controls on one-grip machines should be joy sticks, finger tip buttons, or combinations. Conventional lever controls prove fatiguing for the operator because there are many movements per cycle. The first Bruun and Rottne one-grip harvesters into Canada had lever controls but have since has been retrofitted with electric over hydraulic joy-stick controls. It is quite common for two-grip harvesters and processors to be ordered with conventional lever controls for the boom, and buttons for controlling the processing unit. Reasons given are lower capital cost, low maintenance requirements, and less complexity than with electric over hydraulic control systems. Although joystick controls are better, ergonomically, operators can tolerate the lever controls because the boom is not operated 100% of the time allowing hands and arms a chance to rest through the processing phase.

Summary and Conclusions

Many contractors, particularly in the east, are becoming interested in the off-road processing and harvesting concept and are looking into European-built harvesters and processors for the following reasons:

- Increased safety consciousness and shortages of skilled labour combine to promote mechanization.
- Smaller wood is being harvested. Therefore, mechanical systems designed for large trees may not be suitable.
- Wood quotas may be too small to support conventional, multi-machine, mechanical systems.
- Multi-functional machines are more reliable than previously.
- They are easily integrated into the existent shortwood systems in eastern Canada.
- Roadside delimbing is becoming less attractive because of the problem of slash accumulation at roadside.
- The cones and slash are left in the woods which may be attractive for regeneration proposes and can enhance flotation during the subsequent forwarding phase.
- Length measuring devices and programmable computers allow production of assorted lengths of wood to optimize wood quality and value.

The choice of machine, whether it be a harvester or a processor, a one-grip or two-grip, one model or another, depends on many factors:

Tree size: Large trees usually require more power and in general, two-grip machines deliver more power.

In most cases, the maximum processing diameter as specified by the machine manufacturer should be considered as an upper limit. Because most of these processors and harvesters have only been on the market for a short time, there is little information on how they stand up over the long-term. It is therefore recommended that they not be used consistently at their limit. FERIC's studies were not specifically designed to determine when one-grip machines should be used versus two-grip; however all one-grip harvesters were observed to be working in stands with an average stem diameter of 16 cm or less.

Branch size: A machine's stated feeding power must be compared to the tree branchiness and branch size, keeping in mind that the actual power delivered through the hydraulic system may be less than claimed. Large branches require more power as do clumps of medium-sized branches. In general, jack pine, aspen and open-grown white spruce require high delimbing power, while other spruces and fir are easier to delimb.

Number of unmerchantables per area: One of the most influencial factors on harvester production is the degree of unmerchantables in the stand. In areas with a high ratio of unmerchantable to merchantable trees, processors working after manual fallers or feller-bunchers may be more cost effective than harvesters.

Undergrowth and visibility: These can influence the choice of saw type on harvester heads. Circular sawheads are superior to chain saw heads in difficult understories. Also, harvester production is affected more by undergrowth and by poor visibility than for processors.

Availability of skilled operators: Operator skill has a major influence on one-grip harvester productivity. The production of two-grip machines is not as operator dependent.

Mill requirements: The tolerance of the mill regarding bolt length can influence the choice of harvester or processor models. Some models are very accurate (e.g., Steyr), others are not and produce both over and underlength pieces.

The number of different bolt lengths and assortments requested by the mill(s) can also affect the choice of model. Most have at least three programmable lengths and many have more.

Stem-quality requirements may preclude the use of metal feed rollers because their aggressive spikes penetrate the stem surface which can affect lumber/veneer trim, create openings for fungus attack, and push bark into the stem where it cannot be removed easily.

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