WOOD HARVESTING

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ERGONOMIC EVALUATION OF FELLER-BUNCHER CABS AND CONTROLS

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Abstract

This report evaluates the ergonomic characteristics of commonly-used feller-bunchers as part of FERIC's ergonomic program aimed at improving machine performance and increasing operator efficiency and well-being in forestry machines. The access, cab, and control characteristics of a sample of 10 feller-bunchers were compared to the recommended standards. Narrow and often partly obstructed cab doors, cramped work spaces, and complex control operating requirements were the main weaknesses of this machine sample. The lack of control standardization among similar machines is a major concern.

Introduction

Mechanized felling is possibly one of the most complex tasks that a machine operator has to perform in modern logging operations. The feller-buncher operator must be a dextrous, highly-skilled, well-trained worker capable of sustained concentration and of making a large number of decisions over long hours. As part of FERIC's ergonomic program, the ergonomic characteristics of 10 common models of feller-bunchers were evaluated.

The study objectives were to compare the ergonomic characteristics of commonly used feller-bunchers to accepted standards and to propose related recommendations. The characteristics evaluated in this study were:

- the cab access and entrance;
- the cab inside dimensions;
- the seat dimensions; and,
- the type, number, and layout of controls.

The field data collection techniques and analysis procedures used here closely follow those of FERIC's guide to the ergonomic evaluation of logging equipment (Zerbe 1979) and FERIC's earlier ergonomic evaluation of stroke delimbers (Hope 1986). The reader should refer to these reports for additional information. Moreover, since the basic carriers of stroke delimbers and feller-bunchers are quite similar, the reader is advised to consult Hope (1986) for discussion on such factors as visibility, noise, vibration and cab climate. The present report concentrates in particular on control considerations since they differ between the two machine types.

Study Methods

Cab, seat, and control dimensions and the control actuating forces were measured following FERIC's standard procedures (Zerbe 1979). On one machine, a joystick motion recording device, developed by FERIC, was used to measure the frequency of activation of the nine possible positions of the right-hand joystick.

Machine Sample

A total of 10 feller-buncher models were examined (Table 1). In this sample, five of the machines were modified excavators. The other five were "built from the ground up" feller-bunchers. Nine machines had tracked undercarriages and one was wheeled with an

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articulated frame. This machine is no longer manufactured.

Nine models (#1-9) were evaluated in terms of their ergonomic characteristics. A tenth (#10) was monitored for joystick activation frequency. Except for one unit, all were less than three years old at the time of the study. Six of the felling heads were equipped with a circular saw blade.

Ergonomic Assessment

1. Cab Access and Entrance

Access

On tracked feller-bunchers, the upper structure rotates about the undercarriage. Thus, mounting and dismounting procedures are a function of both the step design and the relative position of the cab to the tracks (Figure 1). Also, in an off-road situation, the height of the 1st step above the ground can vary as the micro-site under that step varies. For comparison, the sampled machines were all tested on flat ground so the reader is cautioned that the results may not necessarily reflect actual operating conditions.

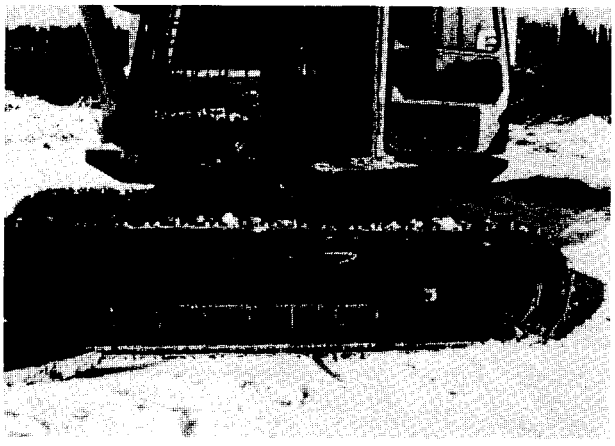

Figure 1. Access steps - the operator selects the upper step position by rotating the cab.

All tracked feller-bunchers in this sample had a first step of adequate height (i.e., < 55 cm high), located on the track frame. This step was either protruding or recessed. The next step was the upper track surface and the last was either the cab floor or a narrow ledge running along it. The spacing between these steps was also within the recommended limits. The access situation observed was an improvement over the older delimber sample (Hope 1986) where 62% had an excessively high first step.

Table 1. Machine sample

#	Carrier	Year	Tracks/ wheels	Excavator Conversion	Felling head		Production measured during evaluation (Trees/PMH)
					Make	Type	
1	Case 1187-B	1986	T	Yes	Tenco	Saw	188
2	Caterpillar FB 221	1988	T	No	Tenco	Saw	147
3	Caterpillar 227	1987	T	Yes	Harricana	Saw	136
4	John Deere 693	1988	T	Yes	Harricana	Saw	Not recorded
5	Koehring K625FB	1987	T	No	Koehring	Saw	357
6	Orenstein & Koppel (O&K RH8)	1986	T	Yes	Harricana	Saw	268
7	Tanguay AC 200	1983	T	No	Harricana	Shear	212
8	Tanguay BJ 20	1985	W	No	Forano	Shear	184
9	Timbco 2518	1985	T	No	Forano	Shear	270
10	Caterpillar 227	1986	T	Yes	Harricana	Saw	200

Entrance (Cab door)

The door is the transition zone between the cab and the outside. In this machine sample, none of the doors were of the recommended height, and only five were of the recommended width (Table 2). Half of the doors were not rectangular. This can give the operator a false feeling of space, while his head, feet and legs have to negotiate lateral obstructions.

Table 2. Feller-buncher door dimensions

		Height (cm)	Width (cm)
Minimum recommended*		≥ 160	≥ 65
Carrier	Year		
Case 1187-B	1986	146	99
Caterpillar FB 221	1988	136	53
Caterpillar 227	1987	149	94
John Deere 693	1988	142	92
Koehring K625 FB	1987	158	63
O&K RH8	1986	150	92
Tanguay AC 200	1983	138	54
Tanguay BJ20	1985	143	48
Timbco 2518	1985	142	87
% acceptable (out of 9)		0	56

* Sources: Hansson and Pettersson 1980; ISO 4252-1983, 2867-1980; SAE J185 1981; Zerbe 1979.

Most doors were obstructed by the seat and accompanying controls. This further reduced the available leg space. To overcome this problem and still keep the cab relatively small, one machine (the Timbco 2518) was equipped with a swivel-mounted seat.

2. Cab Inside Dimensions

Feller-buncher operators are required to stay in their cabs for extended periods of time. Thus, a minimum cab size is important for the operators' well being, which in turn will affect their productivity level.

Interior cab dimensions as measured are compared to recommended minimum values in Table 3. In all cases, the cab depth conformed to these recommendations. However, only 5/9 of the cab heights and 4/9 of the cab widths were acceptable. Furthermore, out of the 9 cabs sampled, only one conformed to the recommendation in all the dimensions.

Table 3. Cab inside dimensions*

		Height (cm)	Width (cm)	Depth (cm)
Minimum recommended**		≥ 160	≥ 90	≥ 130
Carrier	Year			
Case 1187-B	1986	160	84	162
Caterpillar FB 221	1988	147	91	147
Caterpillar 227	1987	163	83	144
John Deere 693	1988	158	83	140
Koehring K625 FB	1987	167	82	160
O&K RH8	1986	155	90	141
Tanguay AC 200	1983	162	94	145
Tanguay BJ20	1985	152	113	151
Timbco 2518	1985	173	80	134
% acceptable (out of 9)		56	44	100

* At seat level
** Sources: Hansson and Pettersson 1980; ISO 4252-1983, 3411-1982, 6682-1980; Zerbe 1979.

3. Seating

The operation of complex machines such as delimbers, processors and feller-bunchers requires the operator's intense attention and concentration over extended periods of time. Therefore, it is crucial for the seat to be comfortable and allow an optimum "fit" between the operator and the machine.

The position of the seat reference point (SRP) in relation to the front wall, rear wall, floor, and sides of the cabs was measured. These measurements, along with the actual seat dimensions, are shown in Table 4. It should be noted that the observed seats were not necessarily those provided by the machine manufacturer at purchase time. For this reason, individual carriers are not identified in Table 4.

Table 4. Measured seat positions and seat dimensions

	Seat positions (cm)					Seat dimensions (cm)				
	Seat Reference Point					Cushion			Back rest	
To:	floor	front wall	rear wall	right wall	left wall	length	width	thickness	height	width
required (cm)*	40-50	≥ 65	≥ 35	≥ 45	≥ 45	37-43	≥ 44	4-10	40-55	40-50
no. in sample	9	9	9	9	9	9	9	5	9	9
mean	48.0	103.6	39.8	44.1	45.0	45.1	48.6	6.2	52.3	44.1
std. dev.	3.5	8.5	14.0	4.1	6.9	2.7	4.7	1.6	7.5	2.9
range	42-52	93-118	16-57	40-53	37-61	42-49	44-56	5-8	45-71	40-49
% acceptable	56	100	67	44	44	33	100	100	89	100

* Source: Hansson and Pettersson 1980; ISO 6682-1980; Zerbe 1979.

All SRP-to-front clearance measurements were acceptable while SRP-to-floor and SRP-to-rear were adequate on 5/9 and 6/9 machines respectively. Side clearances were acceptable on only 4/9 machines.

Most seat back rests had satisfactory heights (8/9 machines) and widths (9/9 machines). Seat cushion widths were good in all cases, but the seat cushions were too long on 6/9 machines. This situation makes it difficult if not impossible for shorter workers to rest their back while reaching for foot controls such as steering and drive pedals. Most machines in the sample had seat covers made from black vinyl.

4. Controls

The controls are the interface between the decisions and actions of the operator and the responses of the machine. Their number, layout in the cab, and operating requirements (i.e., direction of motion, and activation forces) influence production levels and the operator's fatigue and efficiency.

Ergonomic guidelines developed for the control characteristics were used to evaluate the present sample. Figure 2 illustrates both overhead and sideview comfort zone recommendations.

As is the case with most heavy machinery, both hand and foot controls are used in feller-bunchers. Hand controls included joysticks, buttons or switches, and levers. Foot controls were mainly double-action toe/heel-type pedals. None of the feller-bunchers had steering wheels. The number of controls per machine

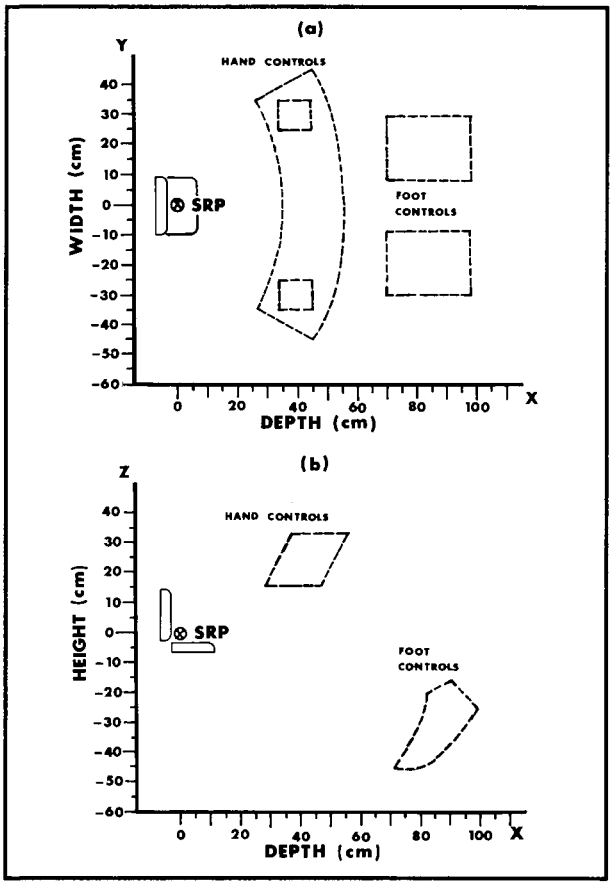

Figure 2. Comfort zone recommendations a) overhead view - b) side view. (SRP = seat reference point. Seat not to scale). Source: Hansson and Pettersson 1980; Zerbe 1979.

Table 5. Summary of control measurements

	Joysticks			Pedals		
	Sample size (#)	Recommended	Acceptable	Sample size (#)	Recommended	Acceptable
Control location (in neutral position)	18	As per Figure 2	depth 100% width 100% height 100%	23	As per Figure 2	depth 56% width 92% height 38%
Maximum actuating forces (N)*	37	20	81%	19	90	89%

* 1N ≈ 0.102 kgf. It is the force required to move a mass of 0.102 kg.

varied from 17 to 25, depending on carrier and felling head type. The Koehring K625 with a side-cut saw head had the lowest number of controls, while the Tanguay BJ 20 with the Forano shear head had the highest. The latter was also one of the older machines in this sample. Table 5 summarizes the measurements on the machine joysticks and pedals.

Joysticks

All machines had a pair of hydraulic pilot-type joysticks. This is an improvement over the earlier stroke delimber study (Hope 1986) where only 72% of the sample were so equipped. The joysticks usually controlled the upper structure swing, the boom and stick arm motion, and the felling head functions. The joysticks were most often used for highly repetitive tasks.

All joysticks were correctly located in relation to the operator position. However, while the required actuating forces were acceptable in 81% of the cases, on average this force was just slightly below the recommended 20 N maximum. A total of 37 toggle switches or push buttons were positioned on the joysticks in the sample. Sixty-eight percent of them were thumb activated; the rest required the use of another finger, usually the forefinger. The actuating forces required to activate these switches (≈ 10 N), while close to the recommended maximum, were acceptable.

Levers

Levers were less common than joysticks, and were used mainly for the activation of leveling devices and, in the case of the wheeled unit, travel and steering functions. In general, they were not used for repetitive tasks. Some levers were located to the side of the seat back rest. This position forced the operator to turn his head to see and activate them.

Pedals

Pedals were mainly used for travel and steering functions on tracked machines, but also for felling-head side tilt, saw-head automatic advance, swing and emergency brake activations. While 92% of the pedals were correctly located on either side of the operator, 62% were too low and 44% were too far away. Actuating forces were high, ranging from 39 to 117 N, but below the recommended maximum of 90 N in 89% of the cases.

Joystick Movement Analysis

A prior FERIC study (Gingras 1988) has indicated that swinging and positioning the felling head to the tree was the longest time component (36%) of a felling cycle, and that a series of trial and error approaches were involved in this process.

To obtain a realistic estimate of the number of moves made by a machine operator, a time and motion recorder was attached to the right hand joystick of a

Cat 227 feller-buncher (machine 10). The recording period lasted one hour during which the machine felled 200 trees. On average, the accumulator on the felling head was used to accumulate 2.7 trees prior to bunching.

The results illustrated in Figure 3 are expressed in terms of the number of times a position was taken (count) and in terms of the percentage of time spent in a position during the hour (time in position). In all, nine positions were monitored. None of the electrical switches on the joysticks were evaluated. The results are specific to this control layout, with this operator, and in the specific stand conditions encountered. However, they are indicative of the type of movements made by the operators of feller-bunchers.

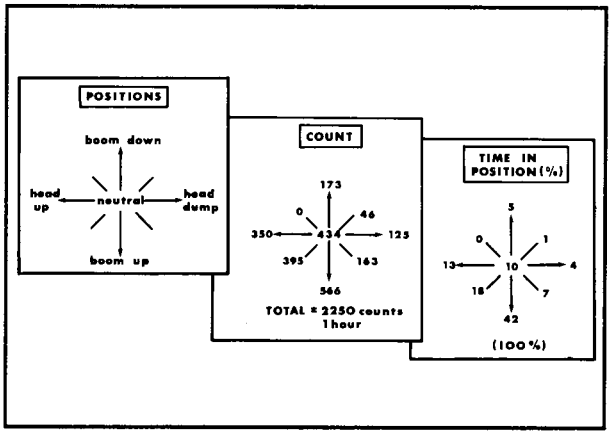

Figure 3. Right joystick monitoring results.

During the hour, the joystick moved 2250 times. Three positions (all in the southwest quadrant) accounted for 58% of those moves. Seventy-three percent of the hour was spent in that region. While 20% of the counts were in the neutral state, only 10% of the hour was spent there. The high count in neutral probably represents a transition state to other positions more than an idle one.

The number of recorded motions other than neutral reached 1816 counts, each requiring an average physical effort of 19.4 N. Thus, the hourly effort of the right arm accumulated a total of 35 230 N (≈ 3600 kgf). Sixty-two percent of these efforts were retractions of the arm, that is pulls towards the body, 26% of them were forearm rotations (74% counter clockwise, 26% clockwise), and extensions, or pushes away from the body, accounted for the other 12% of the effort. These efforts, although intermittent, could cause back and neck muscle pains and problems if the worker is not in an optimum working position, which in turn may contribute to production losses.

The exact number of operator motions over the entire shift was not measured. Based on this limited evaluation, it could be higher than 20 000 for this particular feller-buncher if both joysticks, their electrical switches and the pedals are considered.

Discussion

This ergonomic evaluation was limited to four machine characteristics. Except for the access steps, the other characteristics (i.e., door, cab size, seat & controls) are related. They are the core of the operator work space, and must be considered as a unit during the design stages.

In general, those machines designed "from the ground up" as feller-bunchers did as well as or better than the modified excavator units. However, none of them perfectly met all the recommended guidelines.

Cab doors were small and often obstructed by the seat and controls. To overcome the problem, one machine was equipped with a swivel seat. This configuration is recommended on all feller-bunchers. The cabs of most machines were smaller than recommended, mainly in terms of cab height and width. Seats were generally acceptable except, in some cases, for their excessive cushion length which can inhibit shorter operators from reaching the pedals while maintaining a comfortable position. While all seat manufacturers offer a wide range of seat cover materials and colors, most machines in this sample were equipped with the traditional black vinyl. Black vinyl is hot during the summer months, and does not allow for moisture evaporation. Some operators used a large towel or light colored blanket to overcome this problem.

A large diversity in control locations and functions was encountered. This may be related in part to the compromise of using a base carrier for various applications. Such is the case with the conversion from excavator to feller-buncher. Besides the addition of some extra controls, few other internal cab modifications are made. Furthermore, the selection of the control locations does not follow any set rule, and is at the discretion of either the carrier/felling-head manufacturers, the local dealer, or the owner.

It is not surprising that on this sample of nine machines, only two functions were consistently found at the same control location. These were the swing and the head dump functions. All other functions were variably found on either hand or foot and left or right controls. This makes it difficult for a trained worker to change machine without losing productivity. Moreover, the operator may face a potentially dangerous situation if old reflexes override newly learned ones in cases of emergency.

The high number of repetitive joystick motions recorded on one machine, and the high actuating forces involved, indicate that local muscular fatigue may occur during the shift, possibly leading to more serious problems over time. While the number of motions may not easily be reduced (except perhaps through self-learning machines, scanners, and resolve motion control technology, etc.), the actuating forces could certainly be. One approach is to select electrical over hydraulic joysticks. Still uncommon on North American forest machines, electrical joysticks are commonly used throughout Europe.

Conclusions

Over the last decade, feller-buncher manufacturers have tried to modify their machines in response to the industry's requests. Seats are more often adjustable, hand-operated controls have evolved from front-mounted levers to correctly-placed joysticks, and cabs have generally been improved, at least in terms of their accessibility. However, these modifications appear incomplete and limited to a few leading manufacturing firms.

Narrow and often partly-obstructed cab doors, cramped work spaces, and complex control-operating requirements were the main weaknesses in this machine sample. While all the machines were equipped with joysticks, none was of the electric over hydraulic type. Cabs were still crowded with hydraulic pilot valves and hoses, to the detriment of the control positioning flexibility and the cleanliness of the cabs.

The most severe problem was the lack of standardization among controls. Usually, expectation stereotype principles (Hope 1986) were respected, but only two machine functions could be found at the same control location over the entire machine sample. The simplification and standardization of controls would ensure a better working environment, shorter training periods, and lower maintenance costs. Moreover, the control standardization process would permit the use of cab simulators for training purposes, and thus allow a more appropriate selection of future operators prior to their first contact with production machines.

In summary, the author suggests that the following recommendations be implemented in future generations of feller-bunchers as much as possible:

1. Feller-buncher cab doors should be rectangular in shape and at least 160 cm high. They should also be at least 65 cm wide if the seat and controls are not in the way. Otherwise, the door should be larger, or the seat should be swivel-mounted to facilitate movement through the door frame.

2. Cab dimensions should be at least those of the referred standards (Table 3). Furthermore, cab width should allow for a swivel seat to be fitted in if so desired. This seat should have a suspension system.

3. Electrical over hydraulic joysticks are an ergonomically desirable feature on complex machines. They should be adjustable in the horizontal plane in relation to the seat's arm rests and the arm rests should be adjustable in the vertical plane in relation to the seat itself.

4. The function and location of each control should be standardized among all feller-bunchers.

FERIC/CPPA are creating a joint task force with the mandate to develop a series of recommendations on nine safety and ergonomic priority items for off-road equipment. These investigations include the access, the cab, and the control layouts of logging machines. It is expected that through this kind of cooperative work, future equipment will offer an improved working environment for the operator.

Literature

1. Gingras, J.-F. 1988. The effect of site and stand factors on feller-buncher performance. For. Eng. Res. Inst. Can. Pointe Claire, Québec. Technical Report No. TR-84. 18 p.

2. Hansson, J.-E.; Pettersson, B. 1980. An ergonomic checklist for transport and materials handling machinery. The National Board of Occupational Safety and Health, Royal College of Forestry, and Skogsarbeten, Sweden. 24 p.

3. Hope, P.A. 1986. Ergonomic evaluation of stroke delimbers. For. Eng. Res. Inst. Can., Pointe Claire, Québec. Technical Report No. TR-72. 34 p.

4. ISO (International Organization for Standardization). 1983. Agricultural tractors: access, exit and operator's workplace - dimensions. ISO 4252-1983(E), Switzerland. 7 p.

5. ISO (International Organization for Standarization). 1982. Earth-moving machinery: human physical dimensions of operators and minimum operator space envelope. ISO 3411-1982 (E), Switzerland. 9 p.

6. ISO (International Organization for Standarization). 1980a. Earth-moving machinery: access systems. ISO 2867-1980 (E), Switzerland. 7 p.

7. ISO (International Organization for Standarization). 1980b. Earth-moving machinery: zones of comfort and reach for controls. ISO 6682-1980 (E), Switzerland. 12 p.

8. SAE (Society of Automotive Engineers). 1981. Access systems for off-road machines. SAE Standard J185 JUN81. 5 p.

9. Zerbe, W. 1979. Preliminary guide to ergonomic evaluation of logging equipment. For. Eng. Res. Inst. Can., Vancouver, British Columbia. Technical Note N° TN-30. 46 p.

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