Technical Note **TN-233** October 1995

FELLING LEVERS FOR FELLING TREES IN EASTERN CANADA

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Abstract

Several felling levers (lifting and step-on models) were evaluated in terms of their theoretical mechanical advantage, and a computer model was used to evaluate the lifting ability of two representative models. The design characteristics of the levers are discussed and recommendations are given on choosing an appropriate lever for various uses.

Introduction

Manual felling of timber has always been physically demanding. Although many facets of this operation have improved significantly, pushing over trees once they're cut remains arduous and often time-consuming, and represents a significant risk of injury. Loggers have used wedges, pushpoles and Sansom arms (compound levers) to help, but pushing by hand has been the most common method for smaller trees.

Wedges are better-suited to large trees (>40 cm DBH), as smaller trees have limited space to insert the wedge in the backcut. Although wedges can be used for small trees, many fallers are unaware of the appropriate techniques or are reluctant to spend the time to make the necessary cuts. Pushpoles are often considered a last resort, and most fallers cut a pole only when necessary and then discard it after one use. Sansom arms, which are seldom used today, are also often discarded after a single use. Thus, most loggers continue to push trees over manually.

The felling lever, designed to assist loggers in tipping over trees, was first introduced commercially to North America from Sweden some 20 years ago. Despite initial interest in Quebec and eastern Canada, the technology was not widely adopted. A general perception developed that only young and inexperienced fallers used these levers; the cost of the levers and a lack of usage guidelines also resulted in many fallers using them only on problem trees. As a result, the initial experience was poor and fallers were left with a negative impression of the capability of the levers.

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KEYWORDS: Felling, Manual method, Felling levers, Hand tools, Eastern Canada.

Recently, however, "step-on" levers have arrived in eastern Canada. This new class of lever and the trend toward partial-cutting regimes have renewed interest in felling levers.

Unfortunately, forest workers have little information to help them select an appropriate felling lever. This report addresses this concern by describing the components of felling levers, suggesting tree diameter limits, and discussing the effect of various factors (e.g., tree lean, notch and hinge dimensions) on a lever's ability to generate an effective tipping force.

Description

Felling levers fall into two broad groups: lifting levers and step-on levers (Figure 1). The most common lifting levers in eastern Canada, suitable for trees up to 50 cm in DBH under specific conditions, are 0.6 to 0.7 m long and weigh approximately 1.6 kg; these are the primary style of levers considered in this report, as several makes and models are available. Step-on levers, relatively new in Canada, have generated considerable interest for use in partial cuts. With lengths ranging from 0.40 to 0.55 m and weighing about 0.7 kg, these levers attach easily on a faller's tool belt. They offer sufficient lifting capacity to fell well-balanced trees up to 30 cm in DBH.

Although it is impossible for this report to suggest the most suitable lever for a given individual, understanding a lever's various components permits an informed decision. Figure 2 identifies the several key features of levers that should be considered.

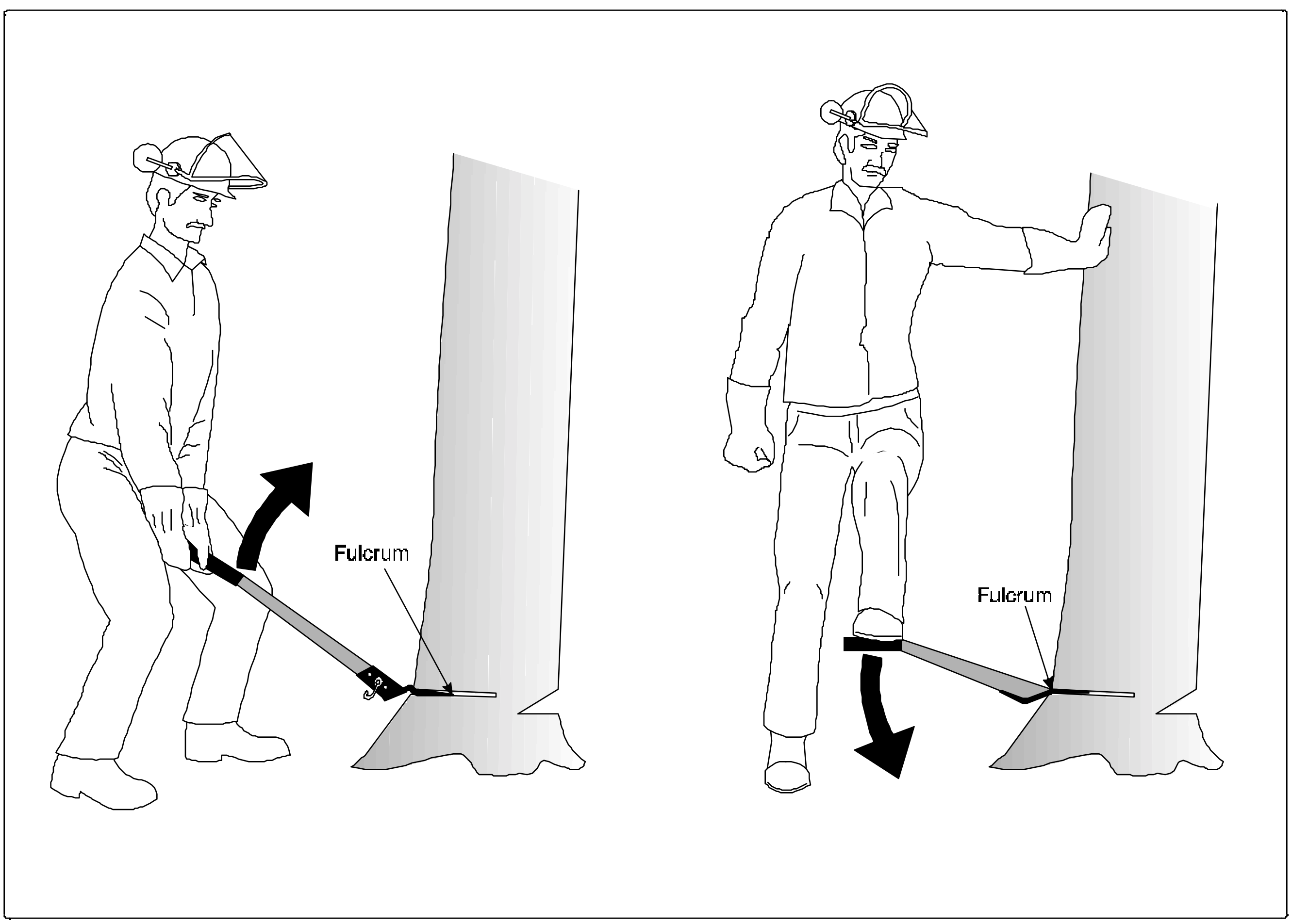

Figure 1. Lifting (left) and step-on (right) felling levers.

Handle

The handle of a lifting lever should permit a "hand in front of hand" (baseball) grip, and should have no sharp edges or corners that create pressure points on the hand. Thus, handles often include a plastic or rubber cover. Step-on levers require a suitable surface for the worker to stand on, and this is achieved in several Nordic models by simply adding a non-slip cleat or pad to the end of the lever's shaft.

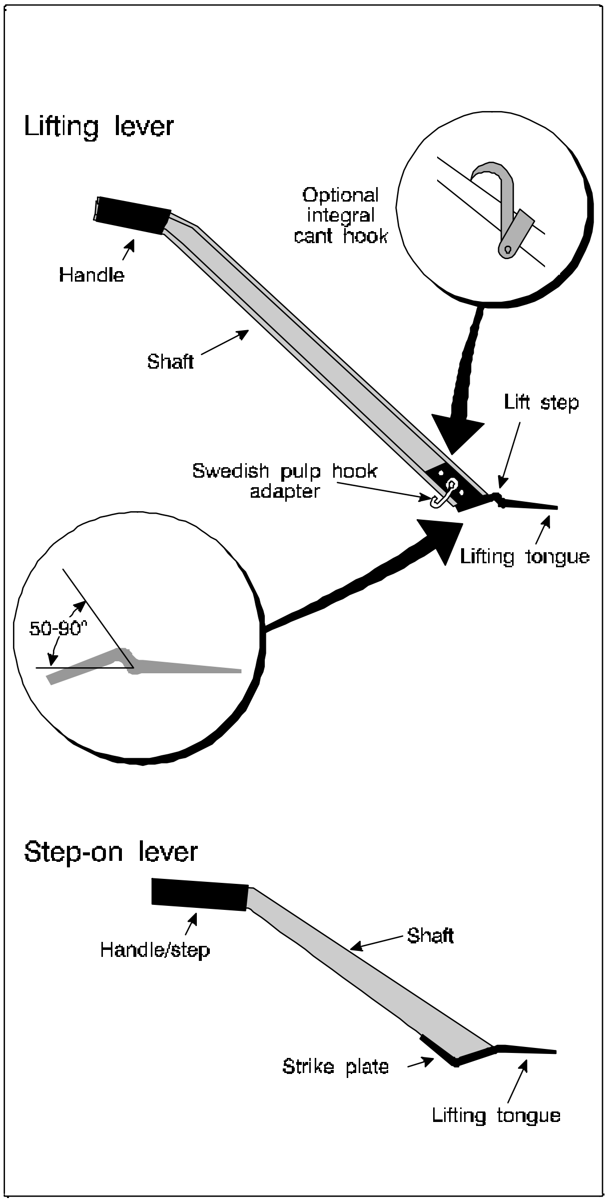

Figure 2. The component parts of felling levers.

Lever Shaft

To minimize weight, several shaft designs and materials are used, including forged steel, tubular box steel, folded steel plate (step-on levers only) and aluminum I-beam. Of these, forged steel appears to be the most durable. Lightweight tubular box steel and aluminum I-beams are prone to bending under lateral forces.

Lift Tongue

Lift tongues, generally built from plate steel, are the portion of the lever inserted into the backcut to create a fulcrum point and to push on the stem. They are often bent to create a lift-step (or heel) that is angled with respect to the lever's shaft to place the handle or step at a convenient height for the worker once the lever has been inserted into the backcut. The lift-step also serves as a wedge: as the tree starts to tip, the lever can be inserted further into the backcut to keep the kerf from closing. This increases the lifting capa- city and permits the worker to rest briefly before final felling, which is particularly helpful with large trees. The tongue is usually tapered both in thickness and in width. A thin leading edge facilitates insertion of the tongue into the backcut, particularly for trees that tend to set back on the stump. A wider leading edge stabilizes the lever during lifting and minimizes the risk of lateral twisting.

Many lifting levers also have teeth on the lift tongue's leading edge. These reduce the risk that the tongue will skate out of the backcut during the lift while felling frozen wood. However, the use of teeth is controversial, and some fallers claim that they impede the lifting process by preventing necessary slippage. This argument appears to be valid for levers with a large lift-step angle or where the lift step comprises a distinct 90° ledge. However, the lift-step angle in most levers is shallow enough to avoid this problem. Levers can also have a flat strike plate welded to the lever's shaft, directly behind the lift tongue, that can be used to drive wedges when felling trees too large for a lever.

Cant Hook

Many lifting levers incorporate a retractable cant hook, mounted on the lever's shaft, that allows the lever to be used as a peavey for felling trees that have become hung up. Those without an integral cant hook are fitted with a small hook on the shaft that permits the attachment of a Swedish pulp hook to permit similar use of the lever.

Calculated Tipping Force of Levers

Felling levers differ considerably in their construction and basic dimensions, but the theoretical mechanical advantage (TMA) gained by using the tool can be calculated simply. The TMA for common lever makes is given in Table 1.

Although TMA values permit a quick comparison of felling levers, more calculations are required to determine the actual lifting force and its relationship to the total inertia that must be overcome for a standing tree. For example, some levers that offer a high TMA have significant design errors that reduce their effectiveness. A common problem is a poor combination of heel angle and shaft length. For lifting levers, this places the lever's handle too low or high after insertion in the backcut, forcing fallers to lift from inefficient or potentially harmful positions. A lifting lever's handle should be at mid-thigh. For poorly designed step-on levers, fallers are forced to step too high, or the lever is so close to the ground that insufficient movement occurs before the step pad contacts the ground. A step-on lever's step pad should be at mid-calf (not above the knee) when placed in the backcut.

FERIC developed a simple computer model to examine the capabilities of various lever designs. Based on standardized assumptions, the model quantifies the relative lifting capacity of a lever in terms of tree diameter, height, lean and several variables controlled by the cutter (e.g., notch depth, hinge thickness). The model uses the following assumptions: a backcut through 60% of the tree's diameter, a 10% hinge, and a 30% notch; the lifting tongue is directed through the tree's center of gravity; and the lift (fulcrum) point occurs at the outside edge of the tree for lifting levers and at the tip of the tongue for step-on levers.

Estimates of operator weight and lifting capacity were derived from a sample of 41 male forest workers in Nova Scotia. Their lifting capacity ranged from 495 to 1930 N (average of 1180 N), and their weight ranged from 64 to 126 kg (average of 82 kg). Tree height, weight, diameter, and the bending moment constant used in the model were those for white spruce (Keen 1963).

Although several levers were investigated, modeling of the actual lifting force focused on one step-on and one lifting lever to permit a simple comparison. The model omits several factors that are difficult to quantify (e.g., the effects of wind, snow load, branch distribution, crown interaction with adjacent trees, and shock loadings such as jumping on a lever). The actual maximum tree diameter will also vary for species with characteristics different from those of white spruce, although the relative performance of the lever should remain fairly constant.

Table 1. Theoretical mechanical advantage (TMA) for several felling levers

Make	Lever length (cm)	Tongue length (cm)	TMA[a]
Lifting Levers			
Gripo	53	4.1	12.9:1
Jonsered	70	6.5	10.8:1
Fiskars	66	6.4	10.3:1
Stihl	69	7.0	9.9:1
Sandvik Windsor[b]	45	6.0	7.5:1
Step-on levers			
Sandvik Windsor[b]	39	6.0	6.5:1
Nordic forestry equipment	36	7.4	4.9:1

[a] Lever length ÷ tongue length.

[b] This model is designed as a step-on lever but is also effective as a lifting lever; in these different applications, the effective lever

Table 2. Effect of tree lean on maximum tree size for felling levers

	Maximum DBH (cm)					
	Lifting lever			Step-on lever		
	0° lean[a]	1° lean	2° lean	0° lean[a]	1° lean	2° lean
Operator strength/weight						
Low (min.)	40	18	10	22	<10	<10
Average	50	30	14	26	<10	<10
High (max.)	>50	40	20	38	<10	<10

[a] Adverse lean, opposite to intended felling direction.

Table 2 presents the effect of lean on the maximum diameter of a tree which can be pushed over with step-on and lifting levers.

Tree lean was found to have a dramatic effect on the capabilities of both step-on and lifting levers. When a 1° lean (away from the intended felling direction) was introduced in the model, the step-on lever was found to be incapable of generating sufficient lifting force to fell even a 10-cm DBH tree. Lifting levers also exhibited a reduction in the maximum diameter (Table 2).

As shown in Table 3, doubling the hinge thickness from 10% of tree diameter to 20% effectively reduces the maximum felling diameter from 50 cm DBH to approximately 36 cm DBH for an average faller. Again, step-on levers are incapable of generating sufficient lifting force to fell merchantable trees when hinge thickness is doubled.

Decreasing the notch depth while increasing the hinge size (a common error) greatly reduces a lifting lever's capacity (Table 4). However, decreasing notch depth while maintaining hinge wood at 10% and increasing backcut depth with a 1° tree lean increased lifting capacity slightly for lifting levers (Table 4). Although this was also true for step-on levers, the increase was insufficient to permit felling of merchantable trees. Note that reducing hinge thickness below the accepted norm (i.e., 10%) is not a recommended practice because it reduces both faller safety and the amount of control in directional felling.

Felling levers were also compared with the ability of an average faller to push over a tree manually (Table 5). Lifting levers offer a significant advantage to the faller, but step-on levers generate a marginally greater lifting capacity and only under ideal conditions. However, step-on levers require much less strain to use and are thus more appropriate in thinnings of small-diameter trees that require regular use of a lever.

Table 3. Effect of hinge thickness on the maximum tree size for a lifting lever

	Maximum DBH (cm)[a]		
	10% hinge	20% hinge	30% hinge
Operator strength			
Low	40	24	20
Average	50	36	28
High	>50	46	40

[a] Hinge thickness represents % of diameter.

Table 4. Effect of lean, notch depth and hinge thickness on maximum tree size capacity for a lifting lever

	Proportion (%)[b]		Maximum DBH (cm)
	Notch	Hinge	
0° lean[a]			
Operator strength			
Low	30	10	40
	20	20	20
Average	30	10	50
	20	20	32
High	30	10	>50
	20	20	40
1° lean[a]			
Operator strength			
Low	30	10	18
	10	10	22
Average	30	10	30
	10	10	36
High	30	10	40
	10	10	46

[a] Adverse lean, opposite to felling direction.
[b] % of diameter.

Table 5. Maximum tree size (DBH) that can be felled using lifting levers, step-on levers or hand pushing on a tree stem at shoulder height for an average faller

Proportion (%)[a]			Maximum DBH (cm)		
Notch	Hinge	Lean (degrees)[b]	Lifting lever	Step-on lever	Hand pushing[c]
30	10	0	50	26	24
30	10	1	30	<10	14
30	20	0	36	<10	14
20	20	0	32	<10	12

[a] % of diameter.
[b] Adverse lean, opposite to felling direction.
[c] Data for manual pushing derived from Koroleff (1947).

Field observations indicated that lifting levers often crush the bark directly above the lever's tongue, significantly decreasing the tipping force. This effect can be reduced by removing the bark where the lever will be inserted, thus ensuring contact with firm wood. The same observation holds true for step-on levers, but in this case bark directly below the lever tongue must be removed.

Conclusions

Felling levers are simple and effective tools in manual felling operations. They are particularly useful for relatively small trees (DBH <50 cm for lifting levers and <25 cm for step-on levers) and where crowns are uniform, as in plantation thinnings.

Heavier fallers will benefit more from step-on levers than will lighter workers. Where conditions permit their use, step-on levers require less effort for fallers than lifting levers, and are easily carried on a tool belt.

Tree lean and hinge thickness are the most significant factors that affect a lever's ability to fell trees. For the most part, the faller cannot significantly change tree lean. However, hinge thickness is readily controlled and must be kept to the 10% guideline. Fallers should only modify the notch or backcut proportions (thus, the proportion of hinge wood) if they fully understand the consequences, particularly the safety implications. Felling levers do not replace the use of wedges or pushing with a skidder's fairlead or blade in felling problem trees; they are simply another tool available to the professional forest worker for use in certain felling conditions.

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