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Effect of kerf execution correctness during felling with internal combustion chain saw on direction of tree fall

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Abstract: *Effect of kerf execution correctness during felling with internal combustion chain saw on direction of tree fall.* To maintain proper direction of tree fall as well as from the viewpoint of sawman safety, proper execution of kerfs during tree felling is very important. This refers to both the under-cut (that determines direction of tree fall) and the felling cut with properly formed hinge and maintenance of safety threshold. Parameters of particular kerfs depend mainly on tree diameter in the place of felling kerf execution, while the proper form of kerfs depends also on assumed direction of felling, inclination and height of tree, size and shape of its crown, tree habit, shape of trunk and of adjacent trees. Basing on carried out investigations, the obtained results and their later analysis there was found a significant dependence between the way of execution of particular kerfs (under-cut kerf and felling kerf with properly formed hinge and maintenance of safety threshold), with consideration to suitable parameters of a tree subjected to felling (diameter, inclination and height, shape and size of crown, tree habit and shape of trunk), and direction of the tree fall (felling). It was assumed during investigations, that 20° deflection of lying tree to the left or right from the expected felling direction is not regarded as discordant with the expected one, and can be caused by such factors like: rebounding tree from the ground or the remaining stump, rolling of tree, turning round of tree on branches etc.

Key words: internal combustion chain saw, timber harvesting, kerf, tree felling

INTRODUCTION

In spite of constantly increasing share of highly-productive machines in the process of timber harvesting, an internal combustion chain saw with has been still commonly used in felling, branching and cross-cutting; with its use over 90% of timber mass is annually harvested in Poland. Therefore, it will be for a long time a basic implement used in timber harvesting on hand-machine operation level [Wójcik 2005, 2007a].

It is well known that internal combustion chain saw is a machine regarded as particularly dangerous and most dangerous in the group of hand-operated working tools. Apart from dangers connected directly with the chain saw as a device itself (vibrations, noise, rebound, contact with sharp edges, contact with hot surfaces etc.), the hazard during its utilization results also from specific and hard conditions of work and the specified technological limitations of timber harvesting process [Sowa 1989, Wójcik 2007b]. These include, first of all, the specified requirements that should be considered by chain saw operator in organization of work on the cutting area. For that matter it is the selection of suitable method for timber harvesting (e.g. entire stem method, long wood method, short wood method etc.), as well as assuring of maximal productivity of logging means (clambunks, skidders, forwarders etc.), by proper determination of tree fall direction and, more important, proper felling of harvested trees. One should also take into consideration the site configuration, inclination of majority of trees, course of operation roads, direction of skidding, type of skidding means, but also necessity of protecting natural regenerations, and also protecting trees from damage (trees on the felling site and adjacent); in the case of clear felling it is fairly easy, but in the case of pocket felling or thinning it is rather difficult [Laurow 1999, Więsik et al. 2005, Nurek 2013].

To maintain proper direction of tree fall as well as from the viewpoint of sawman safety, proper execution of kerfs during tree felling is very important. This refers to both the under-cut (that determines direction of tree fall) and the felling cut with properly formed hinge and maintenance of safety threshold. Parameters of particular kerfs depend mainly on tree diameter in the place of felling kerf execution (Fig. 1), while the proper form of kerfs depends also on assumed direction of felling, inclination and height of tree, size and shape of its crown, tree habit, shape of trunk and of adjacent trees [Wójcik 2013].

MATERIAL AND METHODS

The investigations were carried out in August/September 2011 on the ground of Forest Inspectorate Wipsowo (forest district Borek). The felling area was situated in a pure pine stand (90%) of age 110–120 years, with addition of spruce and birch (10%). Felling area was divided into two plots (felling pockets), surrounded from three sides with forest walls, and from one side with an improved forest road. Part of trees of the main stand (first story) and the whole of shrub layer (second story) were removed from felling pockets the year previous to investigations; it allowed for free determination of tree fall direction, with no possibility of suspending cut trees during carried out measurements.

Majority of investigated trees were straight and of small branching (from 12 to 34 branches) and of uniform distribution of branches on the trunk; this made easier carrying out measurements due to small effects of branch distribution and crown shape on expected felling direction, it enabled to use the classical technique of felling trees (Fig. 2).

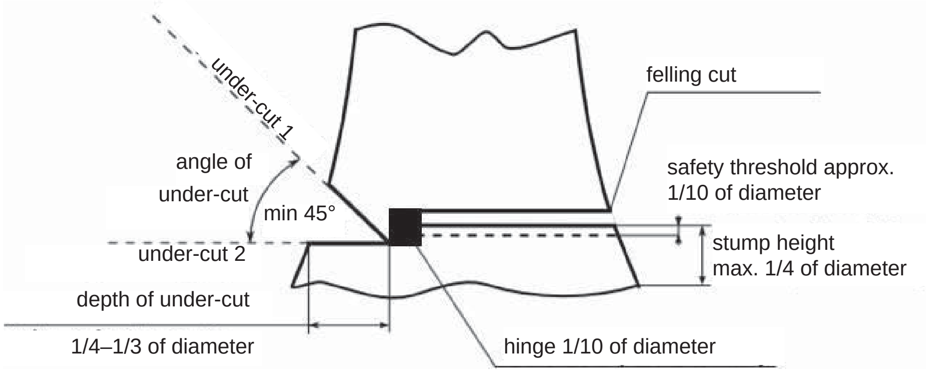

FIGURE 1. Rules of proper kerfs' execution in felling trees [Więsik et al. 2005]

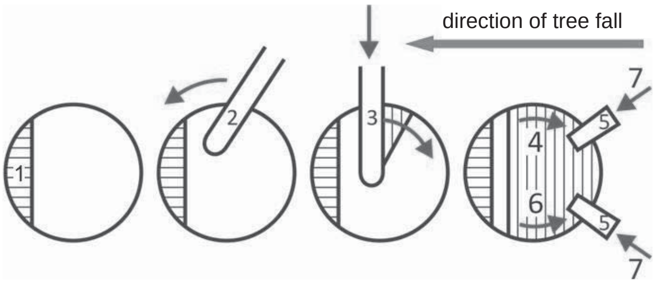

FIGURE 2. Sequence of operations in felling of straight tree, thicker than guide length: 1 – under-cut with possible shortening of hinge, 2 – boring felling cut, beginning of hinge forming, 3 – boring felling cut, hinge forming on right side of tree, 4 – execution of felling kerf (around tree), 5 – inserting wedges into slit of felling kerf, 6 – completing of felling kerf and final hinge forming on left side of tree, 7 – possible striking of wedges to fall the tree [Więsik et al. 2005]

Some of trees on research sites were slightly inclined in direction of tree fall – deflection of tree tip in vertical projection (measured from the trunk) did not exceed 3 m; this resulted in the need of tree felling with so-called supporting slat (Fig. 3).

During measurements the weather was windless (it did not call for a change in expected direction of tree fall), with moderate cloudiness and temperature 18°C. During measurements over 100 pine trees were harvested; 60 of them were selected (their parameters are presented in Table 1).

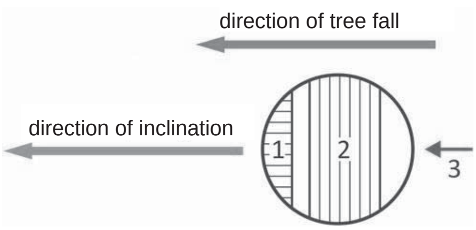

FIGURE 3. Felling of tree inclined in direction of tree fall – method with supporting slat: 1 – under--cut, 2 – parts of kerf made by boring cut, 3 – cutting of supporting slat [Więsik et al. 2005]

Timber harvesting was executed with the use of internal combustion chain saw Stihl MS 440 of engine displacement V_s = 70.7 cm^3, power N_s = 4.0 kW, weight m = 6.3 kg, guide length l = 18 in. and chain saw pitch t = 3/8 in.

Height of tree was measured after its felling with the use of 30-meters-long measuring tape, with accuracy of 1 cm. The same accuracy was used in measurements on breast height diameter of tree and diameter of cut (prior to felling), while half-length diameter (and again diameter of cut) on a lying tree with the use of a tree caliper of measuring range of 1 m. Volume of a single tree was calculated with Newton (Riecki) formula with consideration to previous measurements and was compared to the volume of recording device, determined during timber acceptance procedure.

Angle of cut wedge, created during making of under-cuts (oblique and horizontal), was measured after its complete cutting out from the cut tree (in the center of meeting the oblique and horizontal kerfs edges) with the use of bevel protractor with accuracy of 1°.

Measurement on deflection from expected tree fall direction was executed in the ways presented in Figure 4. At

TABLE 1. Characteristic parameters of harvested trees

Tree parameter	Minimum value	Maximum value	Mean value
Breast height diameter, $d_{1,3}$ [cm]	30.0	60.0	42.0
Diameter of cut, d_s [cm]	38.0	68.0	49.3
Half-length diameter, $d_{1/2}$ [cm]	20.0	39.0	30.0
Height, h [m]	18.8	30.8	26.9
Volume, V_d [m^3]	0.76	3.67	1.91

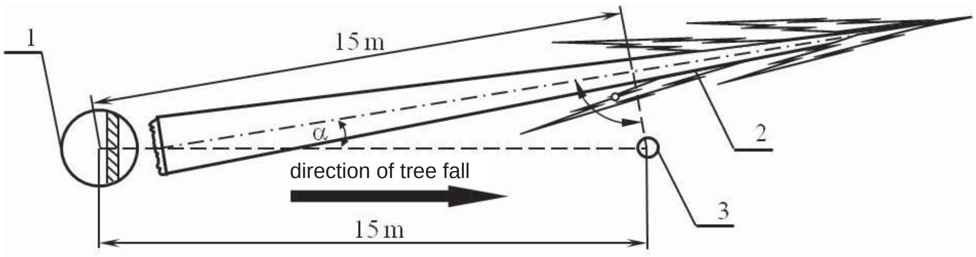

FIGURE 4. Measurement on lying tree deflection from expected direction of tree fall: 1 – stump of cut tree, 2 – cut tree, 3 – measuring slat, α – angle of cut tree deflection from expected direction of tree fall

distance of 15 m from the cut tree a measuring slat 1.5 m long was set in the place determined by the sawman as the expected tree fall direction. After tree felling, a distance from the center of cut tree to measuring slat was measured at right angle to direction assumed by the sawman, with accuracy of 1 cm. When linear measurements were executed with the use of a wind-up measuring tape, the deflection angle was calculated.

It was assumed during investigations, that 20° deflection of lying tree to the left or right from the expected direction of tree fall would not be regarded as discordant with the expected felling direction, and can be caused by such factors like: rebounding tree from the ground or the remaining stump, rolling of tree, turning round of tree on branches etc.

Then, the characteristic parameters of hinge were measured: length, width and height (Fig. 5), as well as the stump parameters after felling: length of under-cut (depth of undercut), length of felling cut and width of felling cut (diameter of felling) – Figure 6.

FIGURE 5. Exemplary measurement on hinge parameters: a – length, b – width, c – height

FIGURE 6. Exemplary measurement on stump after felling: a – length of under-cut (depth of under--cut), b – length of felling cut, c – width of felling cut (diameter of felling)

RESULTS OF INVESTIGATIONS

The results of carried out investigations were compared to the values of stump parameters after felling (of the hinge and the stump itself), calculated according to rules of appropriate execution of kerfs during felling.

In the case of hinge width (Fig. 7a), 37% of measurement results were consistent with optimal value obtained in calculations that considered the diameter of harvested trees in the points of kerfs during felling, but 38% of results differed slightly from the optimal hinge width value. Unfortunately, 25% of hinges were made incorrectly, including 10% too thin hinges (danger of out-of-control fall of tree), and 15% of too thick (longer time of felling and additional fatigue of worker connected to striking of wedges, lower productivity and higher fuel consumption during felling on additional undercutting of the hinge).

Only 10% of hinge length values (Fig. 7b) were not consistent with the standard values. Too short hinges were measured in 8% of cases, however, no hinge was shorter than half of tree diameter in the place of cut; therefore, they could be regarded as appropriate. The hinge was sometimes too long (2%), because it was not shortened in the place of buttresses

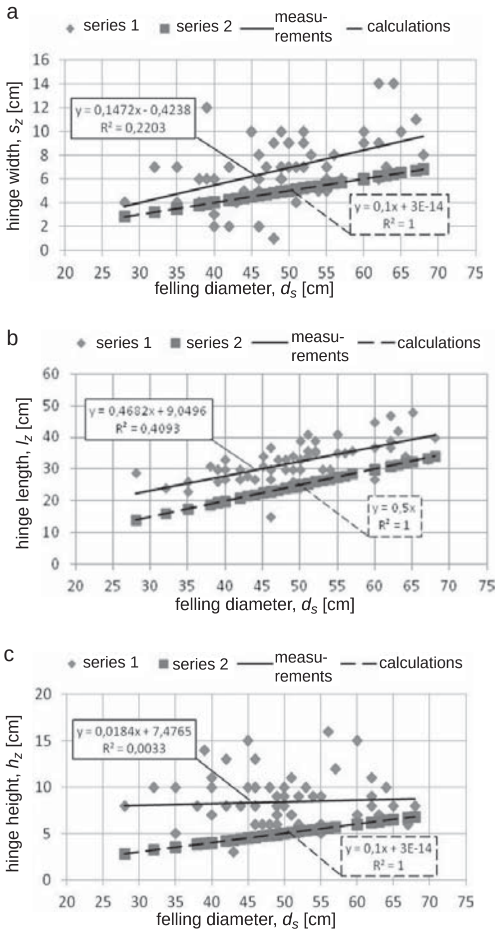

FIGURE 7. Comparison between hinge parameters measured and calculated according to rules of appropriate execution of kerfs during felling: a – measurement on hinge width, b – measurement on hinge length, c – measurement on hinge height

during execution of under-cut. The remaining 90% of results were almost consistent with calculated values (27% exactly and 63% slightly above).

Considering the hinge height (Fig. 7c) one can find, that it was safe almost in 100% of cases; 35% of hinge heights were exactly equal to the calculated ones, 30% were slightly bigger, and 35% were considerably bigger than the value determined according to rules of execution of kerfs during felling. In this last case, too high threshold increases time of tree felling, or sometimes calls for striking wedges.

The measured under-cut lengths (Fig. 8a) coincided with calculated values in 43% of cases. In 22% of cases they could be accepted as admissible, but in 9% of cases they were too big and exceeded half of cut tree diameter; that might be especially dangerous in terms of too fast and out-of-control breaking of the hinge and also impossibility of inserting wedges into the felling cut. The remaining 20% of cases included too short under-cuts; although they do not create such danger as in the previous case, but result in the decreased productivity by long-lasting operation of chain saw in the kerf.

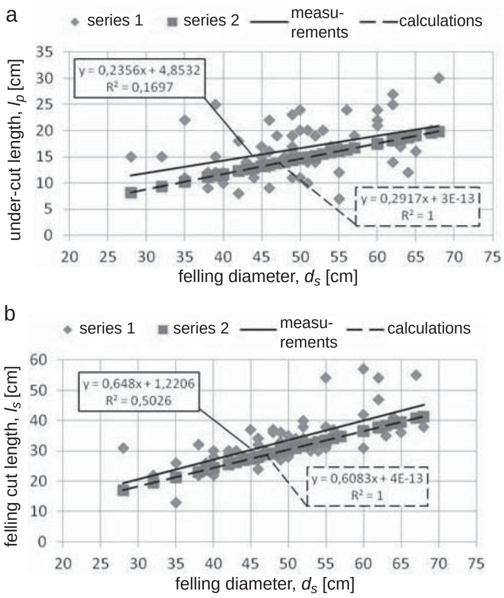

FIGURE 8. Comparison between stump parameters measured and calculated according to rules of appropriate execution of kerfs during felling: a – measurement on under-cut length, b – measurement on felling cut

The measured felling cut lengths coincided with calculated correct values in 63% of cases (Fig. 8b). In 20% of cases it can be regarded as sufficiently good, in 15% as admissible, and in 2% only as inadmissible and dangerous (possibility of tree fall into the zone of operator's work, in direction opposite to the expected one, cutting of hinge, impossibility of inserting wedges).

It was found during measurements on the angle of wedge cut out by under-cut, that only in 4 cases out of 60 it was lower than recommended (45°) and in 7 cases higher than the boundary angle (65°); it does not cause the increased losses in the butt part of harvested raw material (Fig. 9a).

During measurements on the angle of deflection from the expected direction of tree fall it was found, that in 47 cases out of 60 values of this angle did not exceed 10°, while in 20 cases this angle amounted to 0°, and in 33 cases did not exceed 5°. In 10 cases it was included in the range between 10 and 20°, and only in 3 cases it was higher than the assumed in methodics (Fig. 9b).

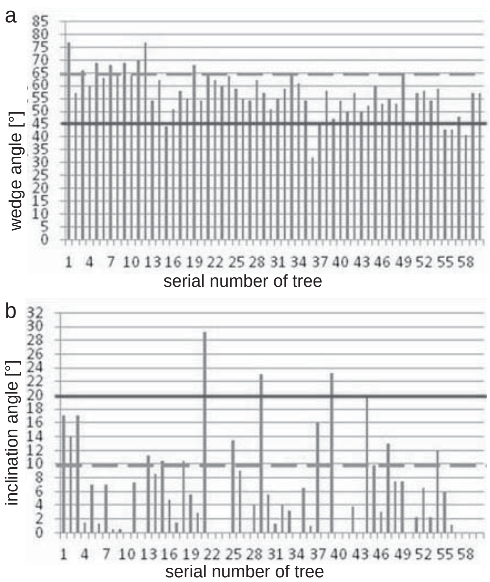

FIGURE 9. Measurements on angle cut out by under-cut of wedge – a, angle of deflection from expected direction of tree fall – b; boundary value – solid line, maximal deflection proposed – broken line

SUMMARY

The carried out investigations aimed at demonstration of the effect of proper execution of kerf during felling on direction of tree fall. The main parameters were dimensions of the stump after felling, i.e. dimensions of hinge (length, width and height) and dimensions of kerfs (under-cut and felling cut) as well as the angle of cut wedge in the under-cut. These parameters greatly affected the angle of tree fall in relation to the expected one. The investigated tree stand consisted of trees that did not call for application of special felling techniques. As a result of carried out investigations, their analysis, calculations and direct observations, one can find that:

- The highest effect on direction of tree fall has the properly made hinge;
- Making the hinge one should bear in mind its proper forming, i.e. maintaining its uniform width throughout its length, unless its different form is required (e.g. execution of a triangular hinge);
- It is important to maintain the proper hinge length, equal at least to half of cut tree diameter; it is sometimes inconvenient due to execution of additional kerfs to shorten the hinge;
- Equally important hinge parameter (as its width and length) is the height of threshold (too small height may result in out-of-control change in tree fall direction, while too high threshold increase the time needed for tree felling);
- One should pay special attention to maintain the proper length of under-cut (from 1/4 to 1/3 of diameter), in respect of the need to form the hinge of appropriate width and to maintain possibility of inserting felling wedges into the felling cut, to protect tree against felling in direction opposite to the expected one, especially when the hinge has been cut;
- Making the felling cut one should bear in mind the final stage of forming hinge, when its non-uniform width often causes change in tree fall direction;
- Angle of under-cut wedge should be such, that both kerfs (oblique and horizontal) meet in the same place; otherwise, the hinge may be under--cut (decreased hinge width);
- In majority of cases (almost 80%) the tree fall direction coincided with the expected one, or the deflection amounted to 5–10° and was sometimes caused by rebounding tree from the ground or the remaining stump,

rolling of tree, turning round of tree on branches etc.;

- The error that caused the highest deflection from the expected tree fall direction was improperly forming of the hinge, mainly too small or non-uniform width of the hinge.

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Streszczenie: *Wpływ prawidłowości wykonania rzazów podczas ścinki pilarką spalinową na kierunek padania (obalania) drzewa.* Zarówno w przypadku zachowania właściwego kierunku obalania, jak i zachowania bezpieczeństwa samego pilarza bardzo ważne jest odpowiednie wykonanie rzazów podczas ścinki drzew. W tym przypadku ważne jest właściwe wykonanie zarówno rzazu podcinającego (odpowiadającego przede wszystkim za kierunek obalania), jak i rzazu ścinającego z odpowiednio uformowaną zawiasą i zachowaniem progu bezpieczeństwa. Parametry poszczególnych rzazów zależą przede wszystkim od średnicy drzewa w miejscu wykonywania rzazu ścinającego, ale właściwe ich uformowanie zależy również od założonego kierunku obalania, pochylenia i wysokości drzewa, wielkości i kształtu korony, pokroju drzewa, ukształtowania pnia i sąsiadujących drzew. Na podstawie przeprowadzonych badań i uzyskanych wyników oraz ich późniejszej analizy wykazano istotną zależności między sposobem wykonania poszczególnych rzazów (podcinającego i ścinającego z odpowiednio uformowaną zawiasą i zachowaniem progu bezpieczeństwa) z uwzględnieniem odpowiednich parametrów ścinanego drzewa (średnica, pochylenie i wysokość, kształt i wielkość korony, pokrój, kształt pnia) a kierunkiem jego padania (obalania). Podczas badań przyjęto, że 20° odchylenie leżącego drzewa na lewo lub prawo od założonego kierunku obalania nie jest traktowane jako niezgodne z założonym, a może być spowodowane czynnikami, takimi jak odbicie się drzewa od powierzchni lub pozostałego na niej pniaka, przetoczenie się drzewa, obrócenie się drzewa na gałęziach itp.

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