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Impact of saw chain cutters type on blunting speed of blades and change of cutting efficiency

ADAM MACIAK, URSZULA GÓRSKA, ŻANETA ZACH
Department of Agricultural and Forest Machinery, Warsaw University of Life Science – SGGW

Abstract: *Impact of saw chain cutters type on blunting speed of blades and change of cutting efficiency*. The research was aimed at determining and comparing uniformity and speed of dulling of chainsaw blades with chisels and semi-chisel type of edge during cutting of oak wood. In addition, the change in the cutting capacity of the surface along with the gap surface made for the tested chain saws was examined. The dullness measurement consisted of drawing the blade's imprints in the lead plate and performing measurements of the radius of blade rounding using a station equipped with a microscope connected to a computer. As a result of the tests carried out, it was found that with the increasing area of kerf, the individual cutters undergo uneven blunting. The surface cutting efficiency of the saw with chisel links decreases faster

Key words: cutting of wood, saw chain, chainsaw, cutting efficiency, blunting process

INTRODUCTION

In Poland, wood harvesting is carried out using petrol chainsaws or harvesters. In both cases, the cutting tool is a chainsaw. It is estimated that in Poland about 90% of wood is harvested by petrol chainsaws, and the remaining part by harvesters [Kusiak et al. 2012, Wójcik 2014]. The share of multi-operational machines in acquisition increases every year. The big advantage of chainsaws compared to harvesters is their availability with a low purchase price [Zychowicz 2009, Nurek 2013], the disadvantages are the risks associated with the use of saws [Brzózko and Skarżyński 2014].

Introducing more and more new technical solutions, improves work safety, ergonomics, increases the efficiency of the saw [Gendek and Oktabiński 2012]. Despite the development of chain saw, they use phenomena that reduce productivity. The main one is the blunting of cuts when cutting wood. It is a phenomenon closely related to cutting wood, and even the latest solutions in the geometry of cutting cells are not able to eliminate this phenomenon.

In modern cutting systems of forest machines, two types of cutting edges are most often used: a chisel in which there is no arc at the junction of the vertical and horizontal cutting edge, only a corner and half-chisel with a curve of a certain radius. The blades of the half-chisel-type linkage cut wood fibers several times, while the chisel-type cutters cut each fiber only once. Therefore, according to the afore-mentioned author, a saw with chisel-type links is characterized by greater efficiency than a saw with half-chisel links. It follows that eliminating the arc between the vertical and horizontal blade can increase productivity by 20–30%. Maciak [2000] investigating the cutting resistance stated that the crevice blade with a smaller radius of the arc fragment shows lower cutting resistance at the same chip thickness. Dolny et al. [2003] found the influence of the cutting cell type on the dimensions of chips produced in the cutting process. A saw with chisel type of edge cuts thicker chips than a semi-chisel type. This may indicate differences in the course of the wood cutting process between the two saw types.

Cutting performance is a basic indicator of sawing the saw and operator skills. In the case of wood cross-cutting, we most often use the concept of cutting efficiency related to the surface unit of the cut made [Górski 1993]. Cutting effeciency can depend on many different factors, one is the choice of a chainsaw. In addition, it may depend on the type of wood being treated and even its degree of contamination.

According to research carried out by Kozłowski [2003], semi-chisel edges are characterized by better performance for soft-density, low-density tree species. Chiselling teeth, on the other hand, will show higher cutting performance during the cutting of high density hardwood. According to Kozłowski [2003], chisel cells, despite achieving high efficiency, are characterized by lower durability than semi-chisel cells.

Next decisive factor in the surface cutting efficiency is the blunting of the cutting blades. In this case, the researchers agree that the blunting of the blades negatively affects the results of wood cutting. Bieńkowski [1993] and Maciak [1994], while cutting various species of coniferous and deciduous wood, found that the thickness of the chip and the cutting efficiency decreased as the dullness of the cutting blades increased. This was confirmed by Górski's findings [1996], from which it appears that the change in the radius of the rounding of the cutting edges from 10 to 35 μm resulted in a 30% decrease in cutting efficiency. Maciak [2015] investigating the process of extermination of saw blades with chisel-type links during cutting of pine wood stated that there are significant differences in the speed of blunting of individual cutting links of the tested saw.

The purpose of the described research was to determine and compare the uniformity and speed of blunting of the chainsaw blades with chisel and half-chisel cells and to determine how the dulling of cells affects the surface cutting capacity achieved by the saws under test.

MATERIAL AND METHODS

The measurements were taken at the Forest Experimental Station in Rogów. Elaboration and analysis of results under the microscope were carried out in the laboratory of the Department of Agricultural and Forest Machinery of the Faculty of Production Engineering of WULS-SGGW.

Sawn timber was placed on a goat with a height of 60 cm. For operator safety, timber are additionally secured with a fastening tape.

The study uses oak wood in the form of chock with a diameter of 21–28 cm.

An oak has been chosen due to the fact that it is one of the hardest tree species obtained in Poland. Thanks to this, blunting occurs much faster than in the case of soft tree species. The absolute moisture content of wood (44.51%) was determined using a RAD-WAG WPS 210 S weighting machine with an accuracy of 0.01%.

The measurements were conducted using a Husqvarna sawing machine, model 257. According to manufacturer data, the swept capacity of machine is 57 cm^3, the power – 4.1 kW. The sawing machine was equipped with a guide bar 15 inches long.

Two types of saw chain were tested: semi-chisel and chisel (Fig. 1). They had a different radius connecting the horizontal and vertical blade. It had a size of 1.4 and 0.2 mm, respectively.

The tooth pitch of tested saws was 3/8 in and lowering of the feed limiter was 0.65 mm. The saws had 28 cutters and 56 drive links. Chain with chisel edges marked in the catalog 73LP, chain with semi-chisel 73D.

The preliminary tension of the saw chain was appropriate. To control the tension, a load of 20 N was put on the saw chain at the midpoint of the guide's lenght. Then, the saw deflection arrow should indicate 5 mm. This was measured by a vernier caliper. The accuracy was 0.1 mm.

Two series of measurements were made for both saws. They differed in the diameter of the wood being cut. It was difficult to compare the results for different diameters of cutting wood. The course of measurements for both tested saws was similar. To determine the measurement accuracy of the cutting edge radius. Before performing the actual measurements, 36 prints were made from one place of the cutting edge. A radius was measured under the microscope. As the measurement accuracy of the cutting edge rounding radius, the standard deviation value was taken from 36 measurements which amounted to 1.36 μm. Before each series of measurements, the saw blade was sharpened and imprints of the horizontal cutting edge of all 28 cutting links in lead plates were taken (Fig. 2). The prints were made in the middle of the cutting edge of the horizontal links.

Three prints were taken from each blade. Imprints were collected after every

a

b

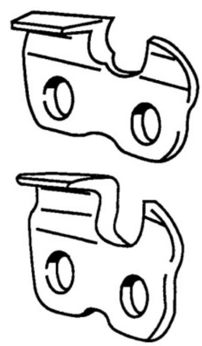

FIGURE 1. Type of cutting edges: a – semi-chisel, b – chisel

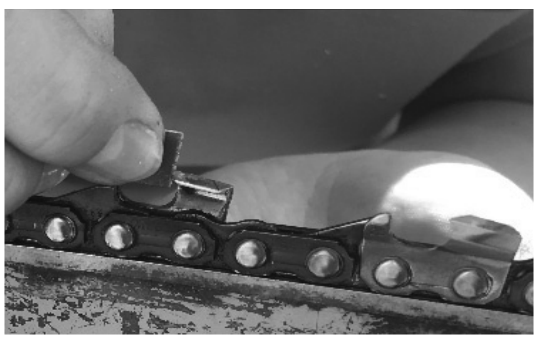

FIGURE 2. The method of taking the cutting edge imprint

10 kerfs. In total, 50 kerfs were made for each saw in each measuring series. During cutting, the cutting time and the diameter of the wood at the cutting point were also measured. The cutting time was measured from the moment the saw touches the wood surface until the slices are cut off. The time was measured by means of a stopwatch, which gives 0.01 s accuracy. The diameter of the sample to calculate the kerf area was measured with a 0.5 cm accuracy using a diameter gauge. Measurement of tasks in two perpendicular planes. For the calculation of recipients values from two diameters. The measured diameter of the sample and the cutting time made it possible to calculate the cutting efficiency. It was determined by the formula:

$$W = \frac{A}{t} \qquad (1)$$

where:

W – cutting efficiency [$cm^2 \cdot s^{-1}$];

A – kerf area [cm^2];

t – time of cutting [s].

The kerf area is determined by the formula:

$$A = \frac{\pi \cdot d^2}{4} \qquad (2)$$

where:

A – kerf area [cm^2];

d – timber diameter [cm].

The radius of rounding the edges was measured in the research laboratory of the Department of Agricultural and Forest Machinery WULS-SGGW. A microscope with a camera connected to a desktop computer was used. Lead plates in which the edges were imprinted were placed on a microscope table and analyzed. The recording of the camera image was carried out using the Cyberlink Power Director 7 program. The sample images are shown in Figure 3.

Then, each of the pre-recorded camera images was loaded into the Multi Scan 18.03 program, which enabled image analysis and radius measurement. Microsoft Excel and the Statistica 13 package were used to analyze the results.

a

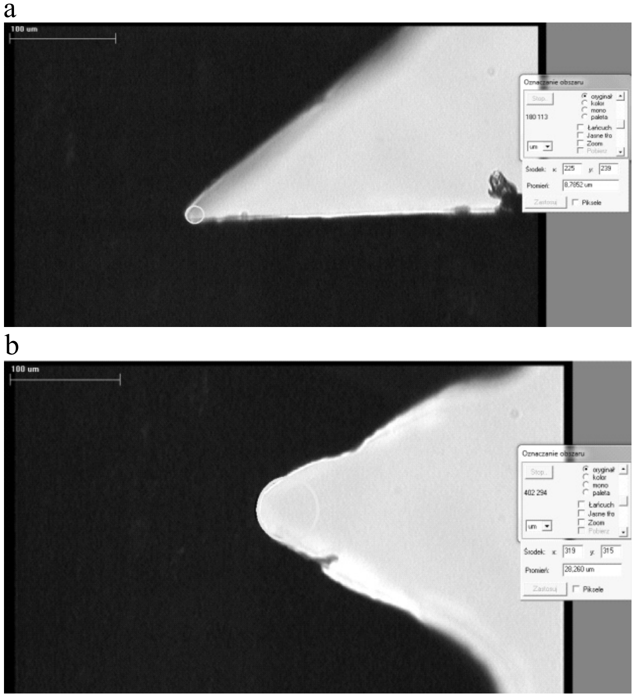

FIGURE 3. Measuring the radius of the cutting edge rounding: a – sharp saw ρ = 8.79 µm, b – blunt saw ρ = 28.26 µm

RESULTS

Statistically evaluated results are presented in the Table, which contains the average values of the radius of the cutting edge rounding obtained for the tested saws in both measurement series and the corresponding values of the standard deviation. After sharpening, the average radius of cutting edge of the chisel type saw blades was 10.05 μm, the semi-chisel was 10.23 μm. The difference was very small and statistically insignificant. After performing in the first series of tests with a saw with chisel cutter surface of 22,365 cm^2, the average radius increased to 27.05 μm, in the second series these values were respectively 21,790 cm^2 and 21.35 μm. For a semi-chisel saw for the first series of tests, these values were 18,545 cm^2 and 19.75 μm, respectively, and for the second series 24,530 cm^2 and 23.8 μm, respectively.

TABLE. Average values of the radius of the rounding and values of standard deviations

Kerf area [$cm^2 \cdot s^{-1}$]	Measurement series number	Radius of rounding the cutting edge [μm]	*SD*
Saw with chisel links			
0	1.2	10.05	1.41
4 319	2	13.48	1.88
4 338	1	11.57	1.72
8 584	2	13.64	0.99
8 731	1	15.06	1.48
12 813	2	14.76	1.09
13 200	1	16.92	1.42
17 190	2	17.53	1.55
17 745	1	19.92	2.23
21 790	2	21.35	2.30
22 365	1	27.05	4.59
Saw with semi-chisel links			
0	1.2	10.23	1.38
3 530	1	11.37	0.81
4 929	2	12.45	1.84
7 180	1	13.92	1.55
9 819	2	14.25	1.55
11 177	1	15.94	1.25
14 729	2	17.39	1.27
14 947	1	17.09	1.55
18 545	1	19.75	2.32
19 639	2	21.39	2.63
24 530	2	23.80	2.35

The process of blunting saws for different series proceeded at a slightly different speed. For example, a saw with chisel links after the first series of kerf measures 4,338 cm^2 reached the average radius of the cutting edge of 11.57 μm, while in the second series the values were respectively 4,319 cm^2 and 13.48 μm. In the second series of measurements, despite the 19 cm^2 reduction of the smaller kerf area, the radius of the rounding of the cutting edge of the links will increase by 1.91 μm.

After analyzing the statistical trend of variability in the value of standard deviations obtained, it turned out that along with the increase in the area of the performed kerf, the standard deviation of the rounding radius of the cutting edge of saw chains significantly increases. This testifies to the increasing diversification of the cutting edges of saw chains together with the increase in the surface area of the kerf.

This is in line with the observation made by the author when machining pine wood [Maciak 2015], where also with the increase in the area of kerf made the diversification between the cutting edges of the chainsaw grew.

Figure 4 shows the effect of the surface of the kerf on the radius of rounding the horizontal cutting edge of saws. There is a large variation in the radius of rounding between the saw chains. For a saw with chisel-type links, after the execution of 22,365 cm^2 kerf, the differences in the radius of the rounding of the cutting edge between the cutting links were as much as 17 μm. At an average dulling of 27.05 μm, it was 65% of the average value. The reason for this may be the high variation of the angular position of individual cutting cells in the kerf found by Maciak [2013]. As a result, each of the links can set up at a different angle and machine different chip thicknesses. What causes different load

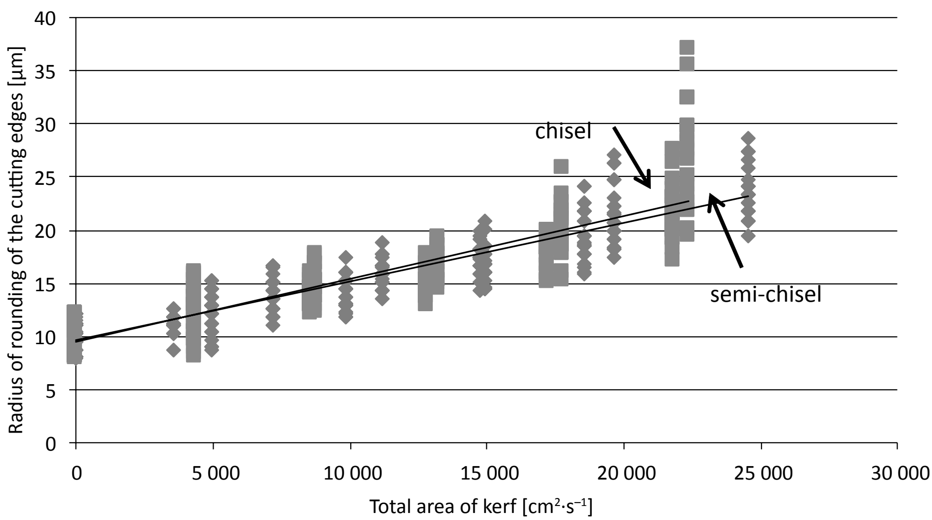

FIGURE 4. The impact of the area of kerf on the radius of rounding the cutting edge of saws with chisel and semi-chisel

of individual links with cutting forces. Statistical analysis showed that there is no statistically significant difference in the speed of blunting of the saw blades.

The change of the radius of the cutting edge rounding depending on the surface of the cut made for both saw blades can be described by the following relationship:

$$\rho = 0.00057 \cdot A + 9.61; r = 0.88 \quad (3)$$

where:

ρ – radius of rounding the cutting edge [μm];

A – total area of kerf [cm^2].

The high value of the correlation coefficient shows a significant relationship between the radius of the cutting edge of the saws' cells and the surface of the kerf.

Figure 5 shows the impact of the area of kerf on the cutting efficiency (*W*) obtained by the saws. There is a large spread of the obtained cutting efficiency. This is due to the fact that during the study the saw was operated by the operator and was not placed on a special test stand, as was the case in other studies [Bieńkowski 1993, Górski 2001, Gendek 2005, Maciak 2013]. As a result, it was not possible to achieve exact reproducibility of the value of the feed force and position of the guide to the wood being processed.

The conditions of the experiment were similar to the conditions of actual work.

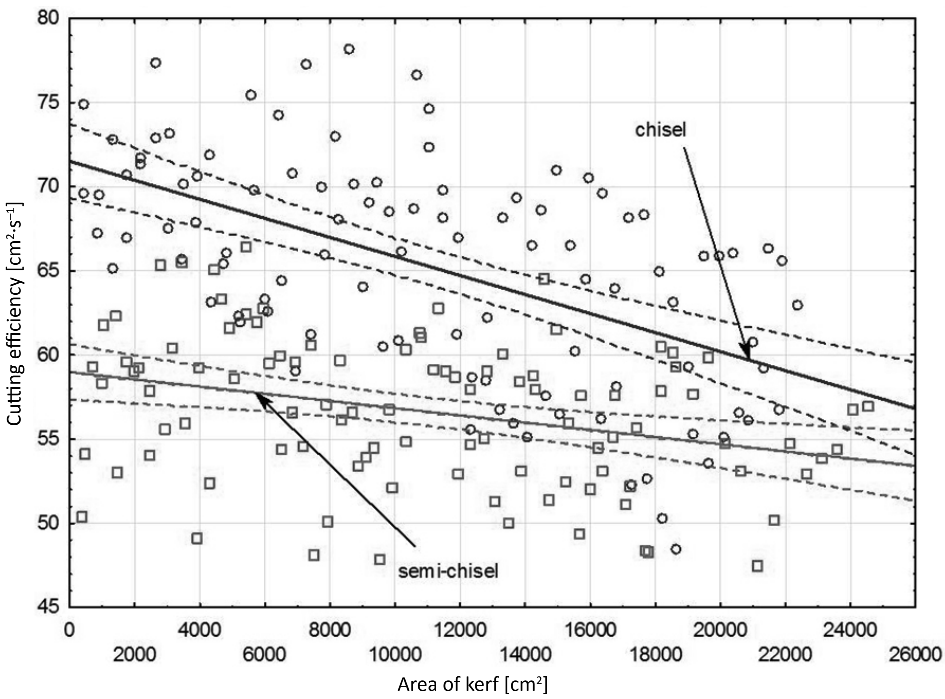

FIGURE 5. The impact of the area of the kerf on the obtained values of the cutting capacity of saws with chisel and semi-chisel type

Fastening the saw on a research bench changes the working conditions of the saw and the cutting process. The reason for this is that the operator–saw system is a massively elastic-damping system, which has a certain natural frequency of vibrations on which the course and continuity of the wood cutting process depends. It is a system with many degrees of freedom and has many natural frequencies [Engel 2001]. The frequency of these vibrations is in the range of the natural frequency of human upper limbs. The human–machine system has a complex dynamic form and is a non-linear, stochastic and non-stationary system containing parameters that change over time. Researchers agree [Engel 2001, Cieślikowski 2007] that the natural frequency of the operator–machine system depends on the operator's individual physical characteristics, working position, fatigue, etc. Attaching the saw to a laboratory bench would make the obtained results difficult to relate to actual conditions.

The lines shown in Figure 5 can be described by the following equations:

- for a saw with a chisel type of edge:

$$W_d = -0.0006 \cdot A + 71.51;\ r = -0.56 \quad (4)$$

- for a saw with a semi-chisel type of edge:

$$W_p = -0.0002 \cdot A + 58.99;\ r = -0.34 \quad (5)$$

After sharpening the links, the average efficiency of the saw with chisel and semi-chisel type of edge, calculated from equations (4) and (5), was 71.51 and 58.99 $cm^2 \cdot s^{-1}$, respectively. The average performance of the chisel-type saw was higher than the saw with semi-chisel edge by 12.52 $cm^2 \cdot s^{-1}$, i.e. by 21.2%.The critical value of the regression coefficient at the significance level $\alpha = 0.05$ is in both cases $rkr = 0.29$. For both equations, the values of the regression coefficient are higher than the critical value. The dependence of the cutting efficiency on the area of the kerf for both saw blades is statistically significant. In both cases, along with the increase in the radius of the rounding of the cutting edge, the value of the obtained surface cutting capacity significantly decreases. Based on the value of the linear correlation coefficient, it can be concluded that for the chisel type saw there is a moderately strong negative correlation between the cutting efficiency and the total area of kerf. For a semi-chisel type saw, the correlation is poor. It can be stated that a saw with chisel-type links is characterized by a faster decrease in the obtained values of surface cutting capacity together with the surface of the cut, and thus with the increase of the cutting edge radius. The average value of the obtained cutting efficiency for a saw with chisel-type links after the execution of 22,000 cm^2 of the saw area was 58.31 $cm^2 \cdot s^{-1}$. For saw with half-chisel links 54.59 $cm^2 \cdot s^{-1}$. The initial difference of 12.52 $cm^2 \cdot s^{-1}$ decreased to 3.72 $cm^2 \cdot s^{-1}$, i.e. to 6.8%.

It follows that for a saw with chisel type of edge, the surface's cutting efficiency decreases faster than the saw blades with the semi-chisel type of edge. This may be the reason for the observation made by Kozłowski [2003] about the greater durability of the saw with semi-chisel type of edge.

The practical conclusion from the research is that a chisel-type saw is more efficient, but requires more precise sharpening. So it should be recommended for professional users. Determining the reasons for a faster decline in the performance of a chisel requires further research and analysis.

CONCLUSIONS

- A large unevenness in the rate of blunt cutting edges between the saw chains has been found. Differences in the value of the rounding radius of the saw blades increased with the area of the kerf and even up to 17 μm.
- The high variability of blunt blunt process is also evidenced by differences in the speed of this process for different measurement series made with the same saw. On this basis, it can be concluded that the development of general relationships describing the process of blunting the saw requires many repetitions of the experiment.
- There were no significant differences in the speed of the process of blunting of the saw with chisel and semi-chisel type of edge.
- Saw with chisel type of edge turned out to be more efficient than saw with semi-chisel type of edge. However, the saw chain with chisel type of edge is characterized by a faster decrease in the cutting efficiency with the increase of the radius of the rounding, than the saw with the semi-chisel type of edge.

REFERENCES

BIEŃKOWSKI J. 1993: Wpływ stępienia ostrzy tnących na opory i wydajność skrawania piłą łańcuchową. Przegl. Tech. Roln. Leś. 12: 17–20.

BRZÓZKO J., SKARŻYŃSKI J. 2014: Proceeding algorithms for difficult trees as the basis for expert system to increase sawmen' safety on post-disaster sites. Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 64: 77–87.

CIEŚLIKOWSKI B. 2007: Procesy drganiowe w diagnostyce maszyn rolniczych. Polskie Towarzystwo Inżynierii Rolniczej, Kraków.

DOLNY S., KUSIAK W., STEMPSKI W. 2003: Charakterystyka wymiarowa wiórów powstałych przy przecinaniu drewna piłami łańcuchowymi. Przegl. Tech. Roln. Leś. 11: 20–22.

ENGEL Z. 2001: Ochrona środowiska przed drganiami i hałasem. Wydawnictwo Naukowe PWN, Warszawa.

GENDEK A. 2005: Wpływ parametrów sprzęgła na wydajność skrawania drewna pilarką spalinową. Doctorial thesis SGGW, Warszawa [manuscript].

GENDEK A., OKTABIŃSKI P. 2012: Engine power losses on resistance of chain saw motion over the guide. Ann. Warsaw Univ. Life Sciences – SGGW, Agricult. 60: 111–117.

GÓRSKI J. 1993: Wpływ siły posuwu i wysokości rzazu na wydajność skrawania piłą łańcuchową. Przegl. Tech. Rol. Leśn. 4: 13–15.

GÓRSKI J. 1996: Analiza wpływu podstawowych czynników na wydajność i energochłonność procesu skrawania drewna piłą łańcuchową żłobikową. Doctorial thesis SGGW, Warszawa [manuscript].

GÓRSKI J. 2001: Proces cięcia drewna elektryczną pilarką łańcuchową. Wydawnictwo SGGW, Warszawa.

KOZŁOWSKI R. 2003: Wpływ typu piły łańcuchowej i gatunku drewna na wydajność skrawania i zużycie paliwa. Przegl. Tech. Roln. Leś. 4: 19–21.

KUSIAK W., MOLIŃSKI K., WALKOWIAK R. 2012: Model zużycia paliwa przy pozyskaniu drewna sosnowego. Sylwan 3: 218–224.

MACIAK A. 1994: Badania oporów i wydajności skrawania drewna bukowego łańcuchową piłą żłobikową. Przegl. Tech. Roln. Leś. 11: 17–19.
MACIAK A. 2000: Forces acting on cutter of saw chain during wood cutting. Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 36: 15–20.
MACIAK A. 2013: Wpływ czynników konstrukcyjnych i eksploatacyjnych na przebieg procesu i wydajność skrawania drewna pilarką spalinową. Rozprawy Naukowe i Monografie 410.
MACIAK A. 2015: The impact of initial tension on rapidity of dulling of saw cutting chains during cross-cutting of pine wood. Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 66: 89–98.
NUREK T. 2013: Structure of the harvester's operation time utilization under conditions of Polish forests. Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 62: 57–63.
WÓJCIK K. 2014: Effect of kerf execution correctness during felling with internal combustion chain saw on direction of tree fall. Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 64: 89–96.
ZYCHOWICZ W. 2009: Analysis of age and size structure of chain saws used in the selected regions of Poland. Ann. Warsaw Univ. Life Sci. – SGGW, Agricult. 53: 55–61.

Streszczenie: *Wpływ rodzaju ogniw tnących piły łańcuchowej na szybkość tępienia się ostrzy oraz zmienność wydajności skrawania drewna*. Celem badań było wyznaczenie i porównanie równomierności oraz szybkości tępienia się ostrzy łańcucha piły z ogniwami typu dłuto z łańcuchem z ogniwami typu półdłuto podczas przerzynki drewna dębowego. Ponadto przebadano zmianę powierzchniowej wydajności skrawania wraz z wykonaną powierzchnią rzazu dla badanych rodzajów pił łańcuchowych. Badania stępienia polegały na pobieraniu odcisków ostrza w płytce ołowianej, a następnie wykonaniu pomiarów promienia zaokrąglenia ostrza na stanowisku wyposażonym w mikroskop połączony z komputerem. Przeprowadzone badania pozwoliły stwierdzić, że wraz ze wzrastającą powierzchnią rzazu poszczególne ogniwa ulegają nierównomiernemu tępieniu się. Zaobserwowano również, że szybciej następuje spadek powierzchniowej wydajności skrawania dla piły z łańcuchem z ogniwami typu dłuto.

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Authors' addresses:
Adam Maciak, Urszula Górska, Żaneta Zach
Wydział Inżynierii Produkcji SGGW
Katedra Maszyn Rolniczych i Leśnych
02-787 Warszawa, ul. Nowoursynowska 164
Poland
e-mail: adam_maciak@sggw.pl
ug.urszula.gorska@gmail.com
zaneta.zach94@wp.pl