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Impact of saw chain cutters type on cutting efficiency and fuel consumption in timber cutting

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Abstract: *Impact of of saw chain cutters type on cutting efficiency and fuel consumption in timber cutting*. The aim of the study is to determine the impact of the type of timber and saw chain types on fuel consumption and cutting efficiency during logging. A saw chain with chisel cutters and semi-chisel cutters and a saw chain with sintered carbide edges was used for the tests. The tests were carried out on two types of timber differing in hardness. Pine and oak logs were machined. The best cutting efficiency and the lowest consumption of fuel in chainsaw, cutting pinewood, was achieved with the saw chain with sintered carbide edges and the one with chisel cutters. For oak, the saw with chisel cutters proved to be better.

Key words: chainsaw, cutting efficiency, fuel consumption

INTRODUCTION

The most popular logging machines in Poland are chainsaw (90% of wood is logged in this way) [Wójcik 2014]. This is mainly because of their affordable price and availability [Nurek 2013]. As the devices are cheap, relatively new chainsaw are used, since the users can afford their replacement every 2–3 years [Zychowicz 2009]. With the use of new machines, fitted with cutting-edge systems to diminish any risks related to their operation, the level of safety of the operators has been improved [Brzózko and Skarżyński 2014]. With the introduction of the latest technical solutions, in turn, performance is increased whilst reducing the consumption of fuel [Gendek and Oktabiński 2012]. Lower fuel consumption reduces not only the costs of logging, but also fuel emission to the environment.

Among the basic benchmarking indicators to be taken into account when comparing the output of individual sawing machines are the cutting efficiency and costs of operation (fuel or electricity consumption) [Gendek 2009]. Cutting efficiency is the main indicator to be considered when assessing the machine and skills of the operator [Górski 1993]. The above-mentioned parameters may vary depending on several factors, such as the selected saw chain, the type of the timber processed or the level of its contamination.

Fuel consumption depends on a large variety of factors, and is strongly connected with performance. Sometimes they coincide with the factors determining of cutting efficiency. Among the key factors that affect the amounts of fuel consumed are: the characteristics of the stand structure, types of economic procedures, cutting intensity, tree sort, the technical measures used, operator's skills or weather conditions [Kusiak et al. 2012].

Average fuel consumption depends on the type of the economic operation (i.e. the type of felling or thinning). The indicator differs for different economic operations and is for felling than for thinning. Among the significant attributes that successfully describe the consumption of fuel are the height and thickness of the tree and the sorts obtained [Kusiak et al. 2012]. Additionally, the indicator also depends on the tree species. As shown by the research by Gałęzia of 2014, the consumption of fuel equalled 0.07 $dm^3 \cdot m^{-3}$ for pine and up to 0.24 $dm^3 \cdot m^{-3}$ for birch. The results concerning fuel consumption for pine are similar to those received by Więsik and Wójcik [2007], but lower than Kusiak's [2012]. Yet another factor affecting the consumption of fuel is contamination of the active surface in the air filter [Maciak 2007]. Finally, fuel consumption also depends on the sawing machine's engine cubic capacity [Bągart 2016]. The bigger the cubic capacity the more fuel the machine consumes (and the bigger its power).

The engine's horsepower has a significant impact on the cutting efficiency. Its increase induces growth in the performance and, thus, the usable feed rate and thickness of the chips. Nevertheless, the feed rate must not be too big, as this leads to a sudden growth in the chip thickness and cutting resistance [Maciak 2001]. If a chainsaw's operator applies too much feed force, the driving system may get overloaded. As Gendek [2009] noted, the best cutting efficiency is achieved within the range of rotational speeds corresponding to the highest torque.

The wood cutting efficiency of a chain saw is also affected by numerous factors related to the construction of the cutting edges (e.g. link type), their condition and direction of the machining in relation to the fibres of the wood processed [Maciak 2007]. To obtain high machining performance, the saw chain must be properly tightened, the blades should have the appropriate angles and the cutting edges must be in a good condition [Maciak 2001]. The blunter the cutting edges, the smaller the thickness of the chips cut. Additionally, the performance deteriorates if the saw chain is improperly tensioned (too loose), while excessive tension, in turn, leads to high energy losses (friction) and increased wearing of the cutters [Maciak 2013]. Kozłowski [2003] noted that for softwood with low density, semi-chisel cutters are more efficient, while chisel cutters are more suitable for hard, dense wood.

The research covered by the study was carried out in order to determine the impact of the type of wood and the saw chain used on fuel consumption and performance of the chainsaw during the logging.

MATERIAL AND METHODOLOGY

Two types of wood, of different density, were tested, i.e. pinewood and oak wood. The tests were performed on oak logs (diameter from 21 to 21.5 cm, moisture content: 44.51%) and pine logs (diameter from 21.5 to 23 cm, moisture content: 29.94%).

The tests were carried out with the use of the chainsaw Stihl MS 250 and a Stihl guide bar, length: 14” fitted with a sprocket nose. Width of the guide groove: 1.3 mm.

Three types of saw chain were tested, with different types of cutting edges (Fig. 1), that is, saw chains with chisel and semi-chisel cutters, and a saw chain with sintered carbide edges (usually used for logging wood contaminated with sand, e.g. after skidding). The saw chain used in the tests were all new. Before the tests, each cutters was sharpened with a file. The preliminary tension of the saw chains was appropriate. To control the tension, a load of 2 kg was put on the saw chain, at the midpoint of the guide’s length (then, the saw deflection arrow should indicate 5 mm). The parameters of the saw chains used for the tests are presented in Table 1.

At the time of the measurements the chainsaw was fed with fuel from the measuring burette (measurement accuracy: 1 mm^3). Before the measurement, the chainsaw was warmed up, whereupon the burette was filled up with fuel from the tank above the ‘zero’ level. Before each kerf, the wood diameter was measured at the cutting site with a section gauge (accuracy: 0.5 cm).

a b c

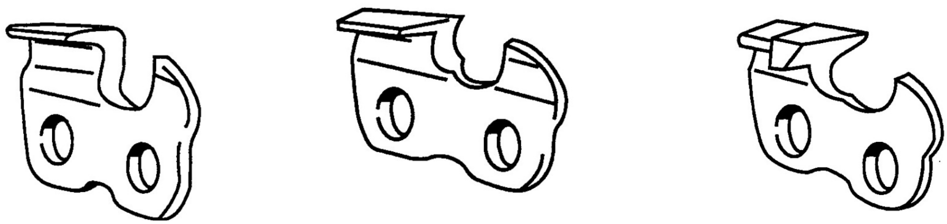

FIGURE 1. Type of cutting edges: a – chisel, b – semi-chisel, c – sintered carbide

TABLE 1. Parameters of saws used for the tests

Name	Picco Super 3 (PS3)	Picco Micro Super 3 (PMC3)	Picco Duro (PD3)
Number of drive links	50	50	50
Pitch [inch]	3 / 8”	3 / 8”	3 / 8”
Weight [g]	172.06	172.35	177.54
Cutting edge type	chisel	semi-chisel	sintered carbide edges

The engine was started and cutting was commenced when the fuel reached the ‘0’ level, which made it easier to read the fuel consumption from the burette scale. The cutting was made using the lower edge of the guide. In the process of sawing, the time of cutting of each kerf was measured with a stop-watch (accuracy: 0.01 s). After each kerf, the chainsaw was switched off and the time and fuel consumption was recorded. The measurements were made in series (1 series = 30 kerfs) for individual wood types and saw chains. Three cutting series for oak wood and three series for pine wood were performed in overall. After each cutting, the burette was filled up with fuel and the saw chain cutting edges were sharpened.

The measurements of the cutting time and the wood diameter made it possible to calculate the cutting efficiency per area (W), as the quotient of the lateral area of the kerf and the time of cutting:

$$W = \frac{\pi \cdot d^2}{4 \cdot t} \ [\mathrm{cm^2 \cdot s^{-1}}] \qquad (1)$$

where:
d – timber diameter [cm];
t – time of cutting [s].

The consumption of fuel (G_s) per unit of the area, was calculated based on the following formula:

$$G_S = \frac{G}{A} \ [\mathrm{cm^3 \cdot cm^{-2}}] \qquad (2)$$

where:
G – volume of fuel consumed [cm^3];
A – kerf area [cm^2].

The results obtained were compared and subjected to statistical analysis in Statistica v. 10. Statistical analysis was to calculate average, standard deviations and the statistical significance of differences between data sets. The level of significance $\alpha = 0.05$.

RESULTS AND DISCUSSION

Table 2 presents the results of measurements of the cutting efficiency per area, for three types of saw chains in the process of oak wood and pinewood machining.

TABLE 2. Average oak wood and pinewood cutting performance (*AVG*) obtained with the use of three types of saw chains plus the respective standard deviations (*SD*)

Saw chain type	*AVG* [cm^2·s^{-1}]	*SD* [cm^2·s^{-1}]
Pine		
Chisel	74.31	4.92
Semi-chisel	68.43	4.34
Sintered carbide edges	76.35	5.26
Oak		
Chisel	66.91	4.47
Semi-chisel	65.22	1.60
Sintered carbide edges	64.13	2.32

The best cutting efficiency per area for pinewood was achieved by the saw chain with sintered carbide edges (76.35 cm^2·s^{-1}). The chisel saw chain proved to be slightly less efficient

(74.31 $cm^2 \cdot s^{-1}$), yet no statistically significant differences were found between these two. The performance of the semi-chisel chain saw, in turn, was much worse (68.43 $cm^2 \cdot s^{-1}$). The best average cutting efficiency for oak tree was achieved with the chisel saw chain (6.91 $cm^2 \cdot s^{-1}$), which turned out to be much better than the semi-chisel saw chain (65.22 $cm^2 \cdot s^{-1}$) and saw chain with sintered carbide edges (64.13 $cm^2 \cdot s^{-1}$). The statistical comparison of the average values obtained did not show any significant differences between the average cutting efficiency per area obtained with saw chains with the semi-chisel and with sintered carbide edges for oak wood. Nevertheless, the results obtained do not correspond with Kozłowski's findings [2003]. In the tests described in this study, saw chain with chisel cutters proved better for both softwood (pine) and hard wood (oak), while Kozłowski maintained that semi-chisel edges are better for softwood. Table 3 presents the average fuel consumption per unit of the area for both oak wood and pinewood, obtained with the three types of saw chains.

For pinewood, the lowest average unit fuel consumption was obtained when working with the saw chain with sintered carbide edges (0.0061 $cm^3 \cdot cm^{-2}$), while higher values were achieved using the chisel saw chain (0.0065 $cm^3 \cdot cm^{-2}$). Similarly as with the previous parameter, in the case of unit fuel consumption, there are no significant differences between the values obtained with both saw chains. Much higher average unit fuel consumption was obtained with the semi-chisel saw chain (0.0069 $cm^3 \cdot cm^{-2}$).

TABLE 3. Average fuel consumption per unit of the area for both oak wood and pinewood (*AVG*), obtained with the tree types of saw chains plus the respective standard deviations (*SD*)

Saw chain type	*AVG* [$cm^3 \cdot cm^{-2}$]	*SD* [$cm^3 \cdot cm^{-2}$]
Pine		
Chisel	0.0065	0.00042
Semi-chisel	0.0069	0.00038
Sintered carbide edges	0.0061	0.00028
Oak		
Chisel	0.0069	0.00059
Semi-chisel	0.0073	0.00022
Sintered carbide edges	0.0071	0.00023

For oak wood, the lowest average unit fuel consumption was obtained when working with the saw chain with chisel edges (0.0069 $cm^3 \cdot cm^{-2}$), while the results obtained with the saw chain with sintered carbide edges and the semi-chisel saw chain were much higher (0.0071 and 0.0073 $cm^3 \cdot cm^{-2}$, respectively). No material differences were noted between the average values of these two. In both cases, the saws with the best performance consume the least fuel.

In Wójcik's research [2015] when similar chainsaw was tested fuel consumption was bigger and cutting efficiency was lower. The reason for the differences may be a diameter of timber or worker (lumberman).

CONCLUSIONS

For pine wood, the best cutting efficiency and the lowest fuel consumption was obtained with the saw chain with sintered carbide edges and the chisel saw chain.

For oak wood, the best cutting efficiency and the lowest fuel consumption was obtained with the chisel saw chain.

The saw chains with the best cutting efficiency consume the least fuel.

Saw chains with chisel cutters can be recommended for the cutting of both wood types, as they are the most universal of the three compared in this study.

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Streszczenie: *Wpływ rodzaju ogniw tnących piły łańcuchowej na wydajność i zużycie paliwa podczas skrawania drewna.* Piły łańcuchowe są narzędziem szeroko stosowanym do pozyskania drewna. Stosowane są zarówno w pilarkach przenośnych, jak i w maszynach wielooperacyjnych. W artykule przedstawiono wyniki badań powierzchniowej wydajności skrawania oraz jednostkowego zużycia paliwa podczas skrawania drewna piłami łańcuchowymi o różnych rodzajach ogniw tnących. Do badań wykorzystano piły z ogniwami typu dłuto, z ogniwami typu półdłuto oraz piłę z nakładkami z węglików spiekanych. Badania przeprowadzono na dwóch gatunkach drewna różniących się twardością. Skrawano wyrzynki sosnowe oraz dębowe. Najlepszą powierzchniową wydajnością skrawania i najmniejszym zużyciem paliwa podczas skrawania drewna sosny charakteryzowała się piła z nakładkami z węglików spiekanych oraz piła z ogniwami typu dłuto. Dla dębu najlepsza okazała się piła z ogniwami typu dłuto.

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