Analysis of operational indices of the electric and internal combustion chain saws

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Abstract: Analysis of operational indices of the electric and internal combustion chain saws. The basic operational indices: wood cutting productivity, electrical energy consumption and cost, fuel consumption were determined and compared for tree operational techniques. There were investigated the two chain saws of Stihl make: electric E180C and internal combustion MS250. The electric power requirement and fuel consumption needed for cross-cutting of wood with the two operational techniques were determined. There were compared the costs of electrical energy and fuel needed for cross-cutting of 1 m³ of firewood in a household.

Key words: operational costs, power, electric chain saw, internal combustion chain saw, cutting productivity.

INTRODUCTION

A basic equipment for timber harvesting in the forest is a sawing machine equipped with the chain saw driven by internal combustion engine. However, in the households where small volumes of firewood are cross-cut for internal purposes, apart from the small unprofessional internal combustion chain saws one can also find the electric chain saws. Application of such machines depends on the power source availability and distance. The hitherto done investigations on timber cutting have been carried out mainly on internal combustion chain saws, while the electric chain saws have been rarely investigated [Gendek 2001, Górski 1993, Maciak 2001].

The basic aim of carried out investigations was determination of basic operational indices for both the chain saws: cutting productivity and cost of wood cross-cutting. The active power needed to overcome the wood cutting resistances and electrical energy consumption were determined for the electric motor, while fuel consumption was determined for the internal combustion chain saw. The cost of cross-cutting of 1 m³ of firewood in a household was calculated for both investigated chain saws.

MATERIAL AND METHODS

The investigations were carried out under laboratory conditions for both the chain saws: electric Stihl E 180 C and internal combustion Stihl MS 250. Both machines were equipped with a standard cutting system, consisted of the guide Rollomatic 13” with the chain saw Picco Micro 3/8”. The pine wood of cross section 24.5 × 26 cm (kerf height 26 cm) were cut. The three operational techniques were investigated:
without spiked bumper and small feed force, resulted from chain saw weight and small operator’s pressure on the front grip, while the guide was maintained parallel to the kerf height and moved vertically;

− without spiked bumper and biggest feed force, when operator pressed down the front grip against the wood with a highest force allowing for operation of the motor, and the guide was maintained parallel to the kerf height and moved vertically;

− with the use of spiked bumper, which supported the chain saw on wood, while the feed force was exerted by the operator with the rear grip, and the guide was moving along the bow.

The electrical quantities were measured with the electric net parameter analyzer WALLY IP+ and recorded every 0.02 sec. During wood cutting with the electric chain saw there were recorded: time of cutting, active, passive and apparent power, phase voltage and phase current.

During wood cutting with the internal combustion chain saw the fuel consumption was measured by titration method and refueling after cross-cutting. The amount of refilled fuel was determined with accuracy ±1 ml. The entire cross-cutting process was recorded with a camera, then the time of particular kerf execution was read off with the use of a special software for image processing, and the wood cutting productivity was determined.

Basing on the time records \((t)\) and cross section of wood \((P)\), the cutting area productivity \((W)\) was determined for both chain saws from the general dependence:

\[ W = \frac{P}{t} \text{ [cm}^2\text{/s]} \]

RESULTS OF INVESTIGATIONS

The mean wood cutting productivity is presented in Figure 1 for various operational techniques. The similar productivity values were found for all investigated techniques and both the chain saws. No statistically significant differences between them were found in the carried out statistical analysis.

Both the chain saws showed the least productivity during operation without the spiked bumper and at minimal feed force exerted by the operator. The productivity amounted to 35.07 cm\(^2\)/s for electric chain saw and 34.32 cm\(^2\)/s for internal combustion chain saw.

At the same operational technique but the highest feed force exerted by operator, the cutting productivity increased by over 30%. The maximal cutting productivity of the chain saws was obtained at this cross-cutting technique, and the maximal value obtained at the highest feed force for chain saw MS 250 is consistent with the results of previous investigations on internal combustion chain saws. Under this condition, the chain saw’s engine operates at rotational speed close to the speed of maximal torque, and a thickest chip is cut [Gendek 2007].

During wood cutting with application of the spiked bumper the obtained productivity of the electric chain saws (36.25 cm\(^2\)/s) is close to productivity without the spiked bumper at small feed force (difference of 3%), but is considerably lower than that obtained without spiked bumper at maximal feed force (productivity decreased by 20.6%). The similar dependence was found for internal combustion chain saw, but the difference in productivity values related to cutting without the spiked bumper at small feed
force amounts to 12%, and a decrease in productivity is equal to 15% when related to cutting without the spiked bumper at maximal feed force.

The wood cutting productivity obtained in investigations are included in the range for electric chain saws [Górski 1993] and for small internal combustion chain saws. However, with respect to designation of the investigated unprofessional models, these productivity values are substantially lower than for professional internal combustion chain saws [Gendek and Maciak 2007, Maciak 2001].

The power requirement for wood cutting without the spiked bumper at minimal pressure on the front grip of chain saw (extorting the feed force) averaged to 1757.57 W (Fig. 2), thus, it is close to the value of 1800 W given by manufacturer. At the same operational technique but at maximal feed force, the power requirement increased by 34% to average value of 2355.83 W, while the cutting area productivity increased by 30% (Fig. 1). An average active power requirement for cutting with application of the spiked bumper amounted to 2087.40% (Fig. 2). This is an increase by 18.7% when related to operation of the chain saw without the spiked bumper at small feed force (an increase in cutting productivity by 3.3%), and a decrease when related to operation without the spiked bumper at maximal feed force (a decrease in cutting productivity by 20.6%).

Basing on the results of stand investigations there was determined the approximate costs of electrical energy and fuel for the three operational techniques investigated, excluding the oil consumption, cost of labour, depreciation, and other. There was assumed in calculations, that average diameter of firewood rollers amounted to 20 cm. The firewood rollers of length 1.2 m were cross-cut into 4 pieces of 30 cm each (3 cross-cuttings), thus, to cross-cut 1 m³ of wood in rollers
one should make 80 kerfs. The results of calculations are presented in Table 1.

The least cost of electrical energy was obtained in chain saw operation without the spiked bumper at minimal feed force (0.16 pln/m³), while it was slightly higher (0.17 pln/m³) in the same technique at maximal feed force. The highest cost of

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**TABLE 1. Approximate cost of wood cross-cutting for various operational techniques**

<table>
<thead>
<tr>
<th>Type of chain saw</th>
<th>Item</th>
<th>W/o spiked bumper, small feed force</th>
<th>W/o spiked bumper, max feed force</th>
<th>W/ spiked bumper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric chain saw Stihl E180C</td>
<td>Mean productivity of wood cutting [cm²/s]</td>
<td>35.07</td>
<td>45.66</td>
<td>36.25</td>
</tr>
<tr>
<td></td>
<td>Mean time of 1 kerf execution [s]</td>
<td>8.95</td>
<td>6.88</td>
<td>8.66</td>
</tr>
<tr>
<td></td>
<td>Chain saw power requirement [W]</td>
<td>1757.57</td>
<td>2355.83</td>
<td>2087.4</td>
</tr>
<tr>
<td></td>
<td>Energy consumption for 1 kerf execution [kWh]</td>
<td>0.00437</td>
<td>0.00450</td>
<td>0.00502</td>
</tr>
<tr>
<td></td>
<td>Cost of 1 kerf execution* [pln]</td>
<td>0.0021</td>
<td>0.0021</td>
<td>0.0024</td>
</tr>
<tr>
<td></td>
<td>Cross-cutting cost per 1 m³ of wood* [pln]</td>
<td><strong>0.16</strong></td>
<td><strong>0.17</strong></td>
<td><strong>0.19</strong></td>
</tr>
<tr>
<td>Int. combustion chain saw Stihl MS250</td>
<td>Mean productivity of wood cutting [cm²/s]</td>
<td>34.32</td>
<td>46.06</td>
<td>39.12</td>
</tr>
<tr>
<td></td>
<td>Mean time of 1 kerf execution [s]</td>
<td>9.15</td>
<td>6.82</td>
<td>8.03</td>
</tr>
<tr>
<td></td>
<td>Mean fuel consumption [ml/s]</td>
<td>0.56</td>
<td>0.50</td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>Fuel consumption for 1 kerf execution [ml]</td>
<td>5.1</td>
<td>3.4</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Fuel consumption for cross-cutting of 1 m³ of wood [l]</td>
<td>0.4087</td>
<td>0.2724</td>
<td>0.2888</td>
</tr>
<tr>
<td></td>
<td>Cross-cutting cost per 1 m³ of wood** [zł]</td>
<td><strong>1.72</strong></td>
<td><strong>1.14</strong></td>
<td><strong>1.21</strong></td>
</tr>
</tbody>
</table>

*According to price list ZEWT Konstancin-Jeziorna, September 2008 – 0.4712 pln/kWh
**Average price of petrol E95 – 4.20 pln/l
electrical energy (0.19 pln/m³) was found during operation with the spiked bumper application.

Slightly different is the cost of fuel needed for cross-cutting of 1 m³ of wood. The highest value (1.71 pln) was obtained in operation without spiked bumper at minimal feed force, when the chain saw operated at high rotational speed with lowest productivity. The least fuel cost (1.14 pln) occurred in cross-cutting operation without the spiked bumper at the highest feed force, when the chain saw motor operated at speed close to the point of maximal torque and maximal wood cutting productivity was obtained.

Comparison of electrical energy and fuel consumption for cross-cutting of 1 m³ of wood is presented in Figure 3.

Basing on the obtained results one can find that depending on operational technique applied the cost of fuel needed for cross-cutting of 1 m³ of wood with the use of chain saw Stihl MS250 is by 6 to 11 times higher than the cost of electrical energy consumed by chain saw Stihl E180C.

SUMMARY AND CONCLUSIONS

The carried out measurements showed that the highest wood cutting productivity was obtained for both the chain saws in operation without spiked bumper, when operator exerted the highest feed force.

At small feed force the active power requirement of the chain saw electric motor, needed to overcome the wood cutting resistance, is close to the manufacturer’s value. At big feed forces and high wood cutting productivity the active power requirement is higher by about 40%. The least cost of electrical energy needed for wood cross-cutting with the chain saw Stihl E180C was obtained in operation without spiked bumper at minimal feed force, while the highest value was found in operation with spiked bumper. Since the difference in electrical energy cost per 1 m³ of cross-cut wood with the chain saw E180C (0.16–0.19 pln), and with assumption of unprofessional use of such chain saws in the households, the type of operation selected by operator is not important.

FIGURE 3. Comparison of electrical energy and fuel cost
For the chain saw Stihl MS 250 the least fuel consumption and the least fuel cost per 1 m³ of cross-cut wood were found in operation without spiked bumper at maximal feed force. The highest consumption and cost of fuel were obtained in operation without spiked bumper at maximal feed force. In the case of this chain saw, the selection of type of operation may be important for the user. To decrease the cost of fuel, the operation without spiked bumper at maximal feed force or operation with the spiked bumper can be recommended.

The substantially higher cost of fuel than that of electrical energy needed to cross-cut 1 m³ of wood may suggest, that in household operations more economic is the electric chain saw Stihl E180C. However, its main disadvantage is dependence on the power source and lower durability. From the user’s viewpoint, in spite of higher cost of fuel, the internal combustion chain saw is more mobile and can have wider application.

REFERENCES


Streszczenie: Analiza wskaźników pracy pilarki elektrycznej i spalinowej. Przy zastosowaniu trzech różnych technik pracy określone zostały podstawowe wskaźniki pracy – wydajność skrawania i koszt przerzynki drewna dwiema pilarkami firmy Stihl: elektryczną E180C i spalinową MS250. Porównano koszt energii elektrycznej i paliwa potrzebnych do przerzynki 1 m³ drewna przeznaczonego na opał w gospodarstwach domowych. najlepsze efekty skrawania drewna uzyskano przy zastosowaniu techniki bez ostrogi, gdy operator wywiera największą siłę posuwu. Niższy koszt przerzynki ale zarazem mniejszą wydajność uzyskała pilarka elektryczna. Jednak mimo wyższych kosztów paliwa i ze względu na niezależność od źródła zasilania, z punktu widzenia użytkownika pilarka spalinowa jest bardziej uniwersalna i może mieć szersze zastosowanie.

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