Analysis of processing operation time and its percent share in timber harvesting with the chain saws

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Abstract: Analysis of processing operation time and its percent share in timber harvesting with the chain saws. There is presented the analysis of operational time during three timber harvesting operations executed with the chain saws: felling, pruning and cross-cutting, together with the time percent structure. There were analyzed mainly the parameters of trees being harvested and their effect on the time needed to perform particular operations. Knowledge of the share of particular processing operations in timber harvesting is important for determination of arduousness of the chain saw operator’s work. Determination of percent coefficient of j-operation’s share in timber harvesting \( \beta_j \) enables to determine the so called equivalent vibrations, as the basis for permissible time of operator’s work with respect to vibrations.

Key words: internal combustion chain saw, operational time, timber harvesting, felling, pruning, cross-cutting.

INTRODUCTION

The forest work in timber harvesting has been regarded for some time now as the one of most dangerous (Sowa and Leszczyński, 2000). Introduction of chain saws to timber harvesting increased the rate of work, but at the same time created new hazards resulting from a specific system: operator – chain saw – tree being processed. An alternative is application of high-output multi-operational processing machines, which due to high purchase price, high exploitation costs and the need for appropriate scope of tasks have not been widely used in Polish forestry (Wieśik and Nurek, 2002).

Timber harvesting process with internal combustion chain saws includes most often the three processing operations: felling, pruning and cross-cutting. The time of particular operations is connected with the size of harvested trees, and more precisely with their parameters. According to author, they include the following:

- volume of trees being harvested,
- diameter in the place of cutting during felling,
- number of branches cut off in pruning,
- number of bucked elements in cross-cutting.

Knowledge of the time for particular timber harvesting operations, their share and determination of the effect of particular parameters of trees being harvested on this time enables to point out the most dangerous operation from the viewpoint of various stress factors (vibrations, noise, exhaust gases, physical and psychological strain) (Hagen, 1990; Kieser and Wick, 1999).
MATERIAL AND METHODS

The measurements on duration time for particular operations were limited to pine forest stands of tree diameter breast high included in the range \( d_{1.3} = 5.9–61.0 \) cm. Out of the bolt there were made logs (at thinner end \( d \geq 14 \) cm without bark) and round paper wood 1.2 m long from the remaining part or the entire bolt, if its \( d_0 \leq 24 \) cm without bark. The measurements were executed in Forest Inspectorate Chojnów on the two adjacent areas – thinning area of age 20–60 years and felling area of age 60–120 years. During investigations 120 pine trees were processed, three sets of 40 trees for each chain saw (Tab. 1).

There were investigated three professional models of internal combustion chain saws of Husqvarna make (H 246 XP, H 254 XP and H 262 XP), randomly selected from a bigger machine group. The chain saws differed in engine displacement \( V_s \) (46; 54; 62 cm\(^3\)) and represented two size groups of chain saws (medium size and large size) of biggest share in the market (46 and 33%, respectively). The chain saw of pitch 3/8" equipped with chisel-type cutting links and standard guide of length 15 in. was investigated.

The felling duration was measured from the moment of starting the undercutting kerf until termination of the cutting kerf. Measurement and recording of pruning duration was started at the moment of putting the guide bar together with movable chain saw against first branch being pruned and it was finished, when the kerf cutting off the top of thickness 5 cm without bark was completed. The time of assortment cross-cutting was measured from the moment of starting kerf cutting off the first section of tree being processed, till termination of cross-cutting of the last section.

### RESULTS AND DISCUSSION

The times of chain saw operation in felling, depending on the tree size (diameter in the place of cut) and the chain saw model, varied from 5 to 574 seconds. The highest felling time and biggest range of felling time interval was found for the smallest chain saw (H 246 XP): from 5 to 574 seconds (on the average 112.2 sec/tree); for the chain saw H 254 XP it ranged from 24 to 252 seconds (on the average 72.5 sec/tree),

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Set 1 for H 246 XP</th>
<th>Set 2 for H 254 XP</th>
<th>Set 3 for H 262 XP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume ([\text{m}^3])</td>
<td>0.55</td>
<td>0.53</td>
<td>0.63</td>
</tr>
<tr>
<td>Diameter breast high ([\text{cm}])</td>
<td>25.15</td>
<td>25.01</td>
<td>27.11</td>
</tr>
<tr>
<td>Height ([\text{m}])</td>
<td>22.32</td>
<td>20.22</td>
<td>21.20</td>
</tr>
<tr>
<td>Diameter in the place of cutting ([\text{cm}])</td>
<td>28.28</td>
<td>30.27</td>
<td>32.11</td>
</tr>
<tr>
<td>Sum of dimensions of cut branch bases ([\text{cm}])</td>
<td>224.49</td>
<td>238.40</td>
<td>302.29</td>
</tr>
<tr>
<td>Sum of diameters of cut bolt elements ([\text{cm}])</td>
<td>192.78</td>
<td>88.86</td>
<td>142.66</td>
</tr>
<tr>
<td>Number of pruned branches ([\text{pcs}])</td>
<td>37</td>
<td>34</td>
<td>38</td>
</tr>
<tr>
<td>Number of cut sections ([\text{pcs}])</td>
<td>6</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
and for the biggest chain saw H 262 XP it varied from 20 to 161 seconds (on the average 60.4 sec/tree) (Tab. 2).

The time of pruning was longer than the felling time and ranged from 33 to 620 seconds, depending on the number and thickness of cut branches and chain saw model. In the case of smallest chain saw (of engine displacement 46 cm$^3$) the time for bolt pruning varied from 37 to 370 seconds (on the average 174.2/tree and 0.11 sec/branch). The time of cutting off branches with medium size chain saw varied from 45 to 620 seconds (on the average 155.5 sec/tree and 0.11 sec/branch). As it is evident, the average time of cutting off the single branch is the same for all chain saw models (0.11 sec/branch).

The cross-cutting time was shortest among all investigated timber harvesting operations and varied from 7 to 395 seconds. For the chain saw Husqvarna 246 XP it varied from 8 to 364 seconds (on the average 75.4 sec/tree and 0.31 sec/karf, for the chain saw Husqvarna 254 XP from 7 to 225 seconds (on the average 48.4/tree and 0.27 sec/karf), while for Husqvarna 246 XP from 8 to 395 seconds (on the average 64.2/tree and 0.27 sec/karf). It was found that chain saws of bigger engine displacement required considerably shorter time for cross-cutting of assortments.

Since no statistically significant differences between the investigated trees were found, they were regarded as one set. It is evident from analysis, that the most decisive tree parameter in felling is diameter of tree in the place of cut, in pruning it is number of cut branches, and in cross-cutting it is number of bucked elements. The dependences between the times for felling, pruning and cross-cutting and the above mentioned parameters can be described with the following equations:

- felling: \( y = 1.0847x^{1.2175}, r = 0.7743 \), where \( x \) – diameter at the place of cut,
- pruning: \( y = 5.3049x^{0.9425}, r = 0.7646 \), where \( x \) – sum of dimensions of bases of cut off branches,
- cross-cutting: \( y = 5.1827x^{1.3253}, r = 0.8013 \), where \( x \) – sum of diameters of cut off bolt elements.

The values of particular correlation coefficients enabled to find a significant dependence between the felling time and diameter in the place of cut, the time of tree pruning and number of branches, and the time of assortment cross-cutting and number of bucked assortments. They are statistically significant for all the chain saw models at level \( \alpha = 0.01 \) (99%), since at \( r_{\text{tab}, \alpha = 0.01} = 0.3982 \) the relation \( r > r_{\text{tab}} \) was found in all the cases.
In Figures 1–3 there was presented the percent share of the times for particular operations included in timber harvesting with chain saw models on the investigated tree sets. Determination of share coefficient $\beta_j$ for felling, pruning and cross-cutting enables to determine the so called equivalent vibrations, as the basis for permissible time of chain saw operator’s work with respect to vibrations during all three processing operations (Wójcik, 2004).

**FIGURE 1.** Percent share of felling, pruning and cross-cutting in timber harvesting with chain saw H 246 XP (from tree set 1)

**FIGURE 2.** Percent share of felling, pruning and cross-cutting in timber harvesting with chain saw H 254 XP (from tree set 2)
Considering the work of chain saw H246 XP ($V_s = 46 \text{ cm}^3$) in timber harvesting from the set 1 it was found, that the share of felling time varied from 4 to 49% (on the average 26.5%) of total timber harvesting time (the sums of times for felling, pruning and cross-cutting of a single tree). The percent share of pruning varied from 20 to 85% (on the average 54.5%), while for cross-cutting this value varied from 4 to 47% (on the average 19%) of total time.

In the case of timber harvesting from tree set 2 with the chain saw H 254 XP ($V_s = 54 \text{ cm}^3$) the share of felling time varied from 14 to 60% (on the average 25.5%), for pruning time it varied from 27 to 80% (on the average 58.5%), and for cross-cutting from 6 to 64% (on the average 16%) of total time for the three operations on a single tree.

In the case of timber harvesting from tree set 3 with the use of biggest chain saw H 262 XP ($V_s = 62 \text{ cm}^3$) the following percent shares of times were found: for felling from 12 to 53% (average 23%), for pruning from 34 to 72% (average 58.5%), and for cross-cutting from 4 to 41% (average 18%).

To recapitulate one can find that the biggest percent share in timber harvesting has pruning operation (regarded as the one most labour-consuming and dangerous), which amounts about 75%. The felling operation takes on the average about 25% of time, while cross-cutting about 18% of total time for timber harvesting from a single tree. Figure 4 presents average values of timber harvesting operational times for particular chain saw models.

**CONCLUSIONS**

- The time of performing timber harvesting operations (felling, pruning and cross-cutting) depends on size of chain saws used in the process, as well as on parameters of trees being processed (mainly on...
diameter at the place of cut, number of cut off branches and number of bucked assortments).

- The most dangerous operation in timber harvesting (with respect to its duration) is pruning, which takes on the average about 57% of total processing time for a single tree.

- Less dangerous (with respect to their duration) are the remaining processing operations, namely felling and cross-cutting, of average shares about 25 and 18% of total timber harvesting time for a single tree, respectively.

- It should be noted that if the size (volume) of trees being processed increases, the percent share of felling and cross-cutting of assortments can increase to about 30% in felling and 25% in cross-cutting, thus, the percent share of pruning can decrease in time structure to about 45%.

**REFERENCES**


Streszczenie: Analiza czasu wykonywania operacji obróbczych i ich procentowy udział w procesie pozyskiwania drewna pilarkami spalinowymi. W artykule omówiono analizę czasu pracy oraz wpływ poszczególnych parametrów obrabianych drzew na czas ich obróbki podczas wykonywania ściinki, okresywania i wyrzynki. Poznanie struktury czasu pracy przy pozyskiwaniu drewna ma znaczenie przy określaniu stopnia uciążliwości pracy operatora pilarki spalinowej. Określenie procentowego współczynnika udziału j-tej operacji pozyskiwania drewna (β_j) pozwala na wyznaczenie tzw. drgań ekwiwalentnych, będących podstawą do określenia dopuszczalnego czasu pracy operatora ze względu na drgania. Czas wykonywania operacji pozyskania drewna zależy od wielkości pilarek, a także od parametrów pozyskiwanych drzew (główne średnicy w miejscu cięcia – przy ściincie, liczby odcinanych gałęzi – przy okresywaniu i liczby wyrabianych sortymentów – przy wyrzynce). Za najbardziej niebezpieczną (ze względu na czas jej trwania) można uznać operację okresywania, gdzie jej udział wynosi około 57%. Mniej niebezpiecznymi wydają się operację ściinki i wyrzynki, których udział można średnio szacować odpowiednio na 25 i 18%.

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