Performance of the small tracked harvesters in spruce stands

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Abstract: Harvester technologies represent the second most common logging system in Czech Republic. The high productivity of this technology is very necessary to cover its acquisition and operational cost. The aid of this study is the monitoring of the operation time and shift time of tracked harvester Neuson 8002. The chronometry was analysed during the felling works in premature forest stands. This paper is worked up for tree-volume of coniferous species from 0.05 to 0.35 m³/tree, which require for manufacturing total time from 65 to 128 sec. Total standards lie for intermediate (improvement, advanced) fellings within the interval 0.10 - 0.36 working h/m³.

Key words: tracked harvester, performance, work stages, harvester technology

INTRODUCTION

Use of cut-to-length system via harvester technologies is still increasing in Czech Republic. We estimate that at present time there are about 220 harvesters (about 15 tracked harvesters) and c. 350 forwarders in Czech forestry. This technology is on the second place – just after the manual logging by power chainsaw as it participates in the annual planned timber production in Czech Republic by c. 25% (Malík, Dvořák, 2005). Also for the future we expect a progressive trend in the use of logging and haulage machinery and similar development as in West Europe, where the percentage of cut-to-length system is even 60% (Germany). The most expended use of harvesters and forwarders is in Scandinavian with c. 90% (Moskalík, 2004; Zychowicz, 2005).

There are many advantages for using these machines: saving of wage cost, ergonomics and work hygiene, prompt reaction to the customer requirements, minimal pollution of logged wood and high grade of ecological quality of logging and hauling activities. On the other hand, there are also
disadvantages: to organise work is quite demanding, staffs training and obtaining of qualified operators is time-consuming and expensive.

The productivity of these machineries is always analyses in relation to the production factors as volume of fell stems, cutting percentage, human factor and other (Dvořák et al., 2007; Erler, 2000; Kärhä et al., 2004; Forbrig, 2001; Ulrich et. al., 2002; Valent et al., 2003).

The neglect of work organisation leads to a disparagement of time demanded by felling skidding machines. Continuous work ensures maximal volume of timber production. The investment returns growths hand in hand with increasing timber production. There have already been worked out norms for the purposes of different ways of felling but not yet for harvesters. The application of these norms serves the purposes of work planning, preparation of rolling stock and manpower planning.

Market research demonstrates heavy time utilization of felling and skidding machines (Dvořák, 2001), but it does not however give optimal utilization of annual time fund and its distribution between general and operative time. Harvesters are used for 273 working days in Czech Republic from which transfers among workplaces take 5%, and non-standard servicing take 17%. This presents an average 2.2 h of 9.8 h, which is the average daily working time of an operator. If we consider the minimal safety break, which is given by law, and the blackout time, the general time (not representing major efficient time) is 27.5% of 1 shift. Average number of forwarder working days is 255 a year. Analogical annual utilization of forwarder Timberjack 1010 is also mentioned in Poland (up to 267 days a year) (Zychowicz, 2005).

**MATERIAL AND METHODOLOGY**

The aim of this research was to verify the productivity of tracked harvester in spruce forests.

**Working conditions**

The research is focused on elaboration of time snapshot of harvesters working in intermediate fellings. Premesuring includes performance observation, working procedure and working efficiency per a time unit. The felling is convenient also for the “task giving” because it presents unchangeable regular working procedure within the marked trees is felled and manufactured. The monitored harvester was Neuson 8002 (Fig. 1, Table 1).

The operator for small-class harvester Neuson 8002 has been working with his harvester for 2 years. Before that he had been working with skidders LKT and John Deer for 30 years.

The work has been monitored in forest compartment on the area 14.87 ha, spruce stands age-range 25-96 years (mean age is 41 years), spruce
distribution 65-100%, spruces breast height diameter 14-32 cm, mean height 15-31 m and mean stem volume 0.12-1.18 m³ (average is 0.24 m³). Stand density is 10. Intermediate felling was realised in conditions of terrain type 11 (gradient of the slope up to 10%, ride able and carrying terrain). The stand was made accessible via hauling lines with the average width 3 m and distance 20-25 m.

**Power cycle time**
Observation of working assignment is divided into 2 sections, which are in consonance with time studies carried out in forestry:

- Time snapshot of the operator’s working day includes:
  - a) Setting of working orders, work preparation and work termination within the shift ($T_s$);
b) Logging ($T_L$);
c) Hygienic and biological breaks ($T_B$);
d) Machine service and repair ($T_S$);
e) Others ($T_o$) – e.g. stand monitoring, sanitation of damaged trees, harvester transit into new stand, telephoning and other.

Snapshot of the working day was carded on special observation sheet for no determinable sequence of working operations or work interruptions during a shift in contrast to chronometry.

Chronometry – time snapshot of the harvester operator’s work stages includes:

a) Machine movement to a new position ($t_{A121}$);
b) Approaching of the felling head to the trunk ($t_{A122}$);
c) Tree felling ($t_{A123}$);
d) Processing of tree ($t_{A124}$).

The separation of the operative and general time is shown in Fig. 2.

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**Fig. 2.** Scheme of the shift time
RESULTS AND DISCUSSION

Harvester technology

Harvesters are used in conifer stands. Broad-leaved trees are processed in young stands, where a branchinees and a high curvature are not (e.g. beech or birch). The slope should be to 45% for wheel-harvester and more for tracked-harvester. The machinery is not used on the poor load-bearing soil.

Foresters mark trees and skidding lines in the stands. This work cannot do harvester operators. Stands are sectioned to workspaces, which are 20-25 m wide. The width of the workspaces depends on the boom length of the harvester. Skidding lanes go in the middle of the workspace and they are 3-3.5 m wide. They are wider about one meter on a turn or in an obstacle terrain. The skidding lanes are straight and readable.

The operator has to process a felled tree on the skidding line and he cannot go in the stand by harvester. Tree-branches stay on lines and they decrement the pressure of the machinery on the soil. Products assortments (2-6 m) are saved on the edge of the lines.

Performance measuring of tracked harvester

We can the function of the performance define as follows:

\[ W = f(V, HF, SC), \]

where:
- \( W \) is performance (m\(^3\)/h);
- \( V \) is stem volume (m\(^3\));
- \( HF \) is human factor – operator’s education and experiences;
- \( SC \) is working conditions (above all work organisation, terrain conditions).

We think of factors as constant. Felled trees are spruce, terrain type has the symbol 11 (the slope to the 10% and snagfree) and the operator is only one. The variably factor is volume tree of the spruces for us. In this paper dependence is monitored between performance and work time.

There was measured the time processing of the 1290 felled trees in 11 premature stands. Harvesting work stage was divided into 4 segments. Major part of the work stage takes the processing of tree with 54% (39.8 sec) of the total working time. Average time periods of the previous work stages are similar – from 11.1 sec to 11.7 sec. Average work operation time is summarized with its share of the total operating time sum in Table 2.

We can see that the time for the parts of stage works is increased. The maximal difference is between the minimal tree volume and maximal tree volume (0.05 m\(^3\)/tree and 0.35 m\(^3\)/tree). The time for machine movement to a new
position decreases from 7.9 sec to 15.2 sec (Fig. 3); the time for approaching of felling head to the trunk decrease from 10.0 sec to 12.9 sec (Fig. 4); the time for machine movement to a new position from 10.3 sec to 13.5 sec (Fig. 5) and the time for processing of tree – from 22.9 sec to 58.4 sec (Fig. 6).

Respective production process is connected not only with operative time (major and secondary) even with next general times whether eliminable or non-eliminable. This time is summarized in the daily snapshot (Table 3). The work of harvester operator was being measured for twenty-two working days. Average work of the harvester is 8.6 hours a shift in premature stands.

**Table 2**

<table>
<thead>
<tr>
<th>Work operations</th>
<th>Average operation time</th>
<th>Operation time share</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine movement to a new position</td>
<td>11.1</td>
<td>15</td>
</tr>
<tr>
<td>Approaching of the felling head to the trunk</td>
<td>11.5</td>
<td>15</td>
</tr>
<tr>
<td>Tree felling</td>
<td>11.7</td>
<td>16</td>
</tr>
<tr>
<td>Processing of tree</td>
<td>39.8</td>
<td>54</td>
</tr>
<tr>
<td>Total time of a working cycle</td>
<td>74.1</td>
<td>100</td>
</tr>
</tbody>
</table>

**Fig. 3.** Time for machine movement to a new position

**Fig. 4.** Time for approaching of felling head to the trunk

Average work of the harvester is 8.6 hours a shift in premature stands.

**Table 3**

<table>
<thead>
<tr>
<th>The time for</th>
<th>Shift time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(min)</td>
</tr>
<tr>
<td>Operative work (logging)</td>
<td>375</td>
</tr>
<tr>
<td>Preparation and termination time</td>
<td>1</td>
</tr>
<tr>
<td>Machine maintenance and reparation</td>
<td>66</td>
</tr>
<tr>
<td>Hygienic and biological breaks</td>
<td>8</td>
</tr>
<tr>
<td>Others</td>
<td>68</td>
</tr>
<tr>
<td>Total time</td>
<td>518</td>
</tr>
</tbody>
</table>
Production time needs to be extended by general time, which includes: e.g. work preparation time, breaks, machine service and repair. With respect to wide variability of this general time in intermediate and main fellings the proposed time standard is divided and defined for each felling individually. The intermediate felling time consist of 0% for preparation works, 2% for hygienic and biological breaks and 13% for machine maintenance and 13% for other time (stand monitoring, sanitation of damaged trees, harvester transit into new stand, telephoning and other), Table 3. All these times represent 28% of the harvester operator’s shift time (except the time for operative work). That’s why a lot of studies take into account that 15 min of one operating hour are used for this necessary fault time. It is the gross effective time – $E_{15}$ (machine production time including delays shorter than 15 min).

Operative time (from Fig. 7) was extended by general times (from Table 3) and all together represents proposed ‘working hours’ necessary for processing of conifers by harvester technology considering tree-volume of processed tree and intermediate and main felling (Table 4).

Measured efficiency of the tracked harvester Neuson 8002 ranges from 2.7 to 10 m$^3$/h in premature stands.
Time values in Table 4 graduate depending on tree-volume of felled conifers. For the use of standards based on distinct tree-volume levels it is necessary to ascertain mean tree-volume of felled trees.

This harvester has come out to be universal for felling in premature stands and is only limited by the width of tree base up to 40 cm. Machinery performance is elaborated for a lowland terrain with the maximal slope of 10%, accessible with no obstacles exceeding 50 cm or spacing among obstacles is wider than 5 m and bearable ground. Snow cover should not exceed 20 cm. Technical and technological conditions are also set by average spacing among trees which is not wider than 10 m. As the normal felling cannot be considered such a felling in which trees not growing in the canopy closure and border trees are cut. Working time is allowed to be used in incidental felling as well if set forth above conditions is met and cutting resembles planned felling. Standards don’t include the time devaluating operator’s efficiency in such cases where the protection of young-growth stand or self-seeding is required.

### Table 4
Work hours for processing of spruce-wood

<table>
<thead>
<tr>
<th>Stem volume (m³/stem)</th>
<th>Operative time (sec./m³)</th>
<th>Total time (hours/m³)</th>
<th>One solid cubic meter (m³)</th>
<th>Operative time (sec./m³)</th>
<th>Total time (hours/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>1020</td>
<td>0.28</td>
<td>1306.0</td>
<td>0.36</td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td>684</td>
<td>0.19</td>
<td>875.8</td>
<td>0.24</td>
<td></td>
</tr>
<tr>
<td>0.15</td>
<td>524</td>
<td>0.15</td>
<td>670.8</td>
<td>0.19</td>
<td></td>
</tr>
<tr>
<td>0.20</td>
<td>429</td>
<td>0.12</td>
<td>549.3</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>0.25</td>
<td>366</td>
<td>0.10</td>
<td>468.2</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>0.30</td>
<td>320</td>
<td>0.09</td>
<td>409.7</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>0.35</td>
<td>285</td>
<td>0.08</td>
<td>365.3</td>
<td>0.10</td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSION**

Time values in Table 4 graduate depending on tree-volume of felled conifers. For the use of standards based on distinct tree-volume levels it is necessary to ascertain mean tree-volume of felled trees.

This harvester has come out to be universal for felling in premature stands and is only limited by the width of tree base up to 40 cm. Machinery performance is elaborated for a lowland terrain with the maximal slope of 10%, accessible with no obstacles exceeding 50 cm or spacing among obstacles is wider than 5 m and bearable ground. Snow cover should not exceed 20 cm. Technical and technological conditions are also set by average spacing among trees which is not wider than 10 m. As the normal felling cannot be considered such a felling in which trees not growing in the canopy closure and border trees are cut. Working time is allowed to be used in incidental felling as well if set forth above conditions is met and cutting resembles planned felling. Standards don’t include the time devaluating operator’s efficiency in such cases where the protection of young-growth stand or self-seeding is required.

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Работа на малки верижни харвестери в насаждения от смърч

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(Резюме)

Верижните харвестери са технологии на второ място в системата за събиране на сортименти в Чешката република. Високата продуктивност на тази технология покрива изискванията и операционните разходи. Целта на това изследване е да се направи мониторинг на операционното време и смените на верижен харвестер Neuson 8002. Анализирана е хронометрията по време на работите по сечи в незрели горски насаждения. Статията е посветена на обема на иглолистни видове от 0,05 до 0,35 м³/дърво, което изисква за работа общо време от 65 до 128 сек. Общите стандарти за средни сечи са в интервала 0,10-0,36 работни h/м³.

Ключови думи: верижен харвестер, работа, работни етапи, технология

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