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Effect of sawmen' professional experience on working time structure in pine-timber harvesting under conditions of the clear felling

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Abstract: *Effect of sawmen' professional experience on working time structure in pine-timber harvesting under conditions of the clear felling.* Times of particular operations in timber harvesting with the use of an internal combustion chain saw were analyzed depending on professional experience of the fellers. Investigations were carried out on the two groups of sawmen: of many years' experience and the beginners in the feller profession. The both groups were compared in consideration of the felling and debranching times. Basing on carried out investigations and their analysis it was found that the percent time structure of operations executed by both the experienced sawmen and the beginners was similar. The longest time was taken by debranching, the shortest time was spent on preparatory and additional operations. However, the experienced sawmen usually execute all the operations in timber harvesting quicker, with the exception of debranching of trees with less branches; here the beginners were more effective.

Key words: internal combustion chain saw, sawman, timber harvesting, felling, debranching, time of operation.

INTRODUCTION

In spite of huge technological development in the materials that can substitute timber, this natural material has been still used in various fields of economy; sometimes it is even indispensable. Therefore, the key task for the State Forests is such management of Polish forests that could prevent from a decrease in harvested timber; it should increase every year with the increased timber stand. In the planning of operations connected with forest planting and felling, the knowledge on execution times of particular operations in silviculture and timber harvesting. As a result, such situation facilitates planning of the manpower demand and technical means used in these operations, as well as their time schedule. Therefore, carrying out investigations and observations connected with structure of the sawman working time has theoretical and practical significance.

According to Bojarewicz [1981], the diameter at the place of cutting or the breast height diameter affect most of all the time of tree processing (felling, debranching, crosscutting); the percent time structure of particular operation execution is similar for various breast height diameters. According to this author, tree felling takes less than 16% of total time, while debranching 37% and crosscutting 47%.

Giefing and Maćkowiak [1998] maintain that the experience and physical condition of workers are important, together with previous site preparation that greatly

affect the possible reduction of time consumption during felling and tree processing. Muszyński and Muszyński [1999] presented the same opinion.

Although according to investigations of Grzywiński et al. [2000] the effective working time of a sawman does not exceed 40% of nominal time, medical examinations [Hagen 1990; Koradecka, Bugajska 1998] point out that too long work with the use of internal combustion chain saw causes deterioration of quality and productivity of timber harvesting.

Sztyber and Wójcik [2007] found that the real working time of a chain saw in assortment crosscutting was almost inversely proportional to the length of cut assortments. In harvesting of pile assortments it is advisable to crosscut rolls of length above two meters. The labour consumption of such roll crosscutting is 2.2–2.8 times lower than of one-meter rolls. The least labour consumption is characteristic for crosscutting of the whole stem wood over 7 cm diameter at the smaller end: perches and long logs.

According to Wójcik [2005; 2007a; 2007b] the working time structure of a sawmen is greatly influenced by the size of chain saws used as well as parameters of harvested trees, i.e. diameter at the place of cutting, number of cut off branches and number assortments bucked.

According to investigations of Wójcik [2007a] the highest percent share in timber harvesting fell on debranching operation (regarded as most labour consuming and dangerous) and amounted to about 57%. The felling operation took on the average about 25% of time, while crosscutting of assortments about 18% of total time of timber harvesting of a single tree. At the same time, the author maintains that along with an increase in the size of processed trees (volume) the percent share of felling operation and crosscutting of assortments can increase to about 30% in felling and to about 25% in crosscutting; therefore, the percent share of debranching in the time structure decreases to about 45%.

This elaboration aimed at analysis of data on the time of performing the particular operations in timber harvesting with the use of internal combustion chain saw in the pure pine stand under conditions of clear felling, and at comparison of working time structure of the experienced sawmen and the beginners.

The scope of investigations included:

- Time measurements on preparation of chain saw and work-place;
- Time measurements on execution of particular kerfs during felling together with tree felling;
- Time measurements on debranching together with cutting off the tree top and the number of cut off branches;
- Time measurements on crosscutting of pulp wood rolls and the number of cut off rolls (in the case of experienced sawmen only);
- Measurements on characteristic features of harvested trees (breast height diameter, diameter at place of cutting diameter at half of length, height) and calculating on that basis the volume of a single tree.

MATERIAL AND METHODS

Investigations were carried out in Forest Inspectorates Chojnów and Wipsowo in the pine stand aged 100–120 years (Chojnów) and 90–110 years (Wipsowo).

These were the clear fellings of area 2.5 and 3.5 ha, respectively. Prior to harvesting operations both the site were prepared by cutting off the shrub layer and second storey. The forest stands' characteristic parameters of both forest inspectorates are presented in Table 1.

On both research sites the sawmen used a chain saw Stihl model MS 440. This is a professional chain saw of the big chain saws group, of displacement 70.7 cm^3 and power 4.0 kW. In debranching the sawmen used a chain saw MS 260 of medium size chain saws group, also professional one but of lower power – 2.6 kW and displacement 50.2 cm^3.

The investigations on tree harvesting time for the experienced sawmen were carried out in Chojnów forest in June and July 2008. Average air temperature during measurements amounted to 20ºC, with cloudless sky. The wind speed did not exceed values admissible for safe work in felling.

The investigations in Forest Inspectorate Wipsowo (sawmen without professional experience) were executed in September 2008. Average air temperature during measurements amounted to 18ºC, with cloudiness from overcast and broken sky cover to bright intervals, no rainfalls. The wind speed did not exceed values that could make the work on felling site impossible.

To facilitate measurements and to decrease the measurement error, the harvesting process was recorded with the use of digital video camera JVC model GR-D200. The time of particular operations was measured with the real time clock, and additionally with an electronic stop-watch, with accuracy 0.1 s.

The height of every tree was measured with the use of measuring tape of length 30 m and graduation of 1 cm. The height of every tree was recorded in cumulative Tables with accuracy 0.1 m.

The subsequent characteristic features of a tree are its cross-sectional diameters in the selected places. The following diameters were measured: in the place of cutting kerf, in half of height, in the place of top cutting off, and breast height diameter (diameter of tree at height 1.3 m from the ground). These measurements were executed with the use of tree caliper with accuracy 1 cm.

The total time of timber harvesting with internal combustion chain saw t_c [s] is equal to the sum of particular times of the cycle, i.e. time of preparation t_p [s], time of felling operation t_{os} [s], time of

TABLE 1. Comparison of various parameters characteristic for stands in Forest Inspectorates Chojnów i Wipsowo

Forest Inspectorate		Height of tree [m]	Diameter [cm]			Volume of tree [m^3]	Number of branches [pcs]
			Trunk	Breast height	At half of length		
Chojnów	Mean	27.84	46.33	38.85	27.67	2.11	49.83
	Max	34	68	60	38	4.44	112
	Min	20.5	31	20	19	0.68	17
Wipsowo	Mean	27.79	47.22	38.67	26.77	2.03	56.62
	Max	33	68	52	38	4.09	103
	Min	22.4	34	27	18	0.8	17

debranching operation t_{oo} [s] and time of crosscutting operation t_{op} [s]:

$$t_c = t_p + t_{os} + t_{oo} + t_{op} \quad (1)$$

Above there are presented the mathematical equations for calculating the time of execution for particular stages of timber harvesting with internal combustion chain saw.

Time of preparation:

$$t_p = t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7 + t_8 + t_9 \quad (2)$$

where:
t_1 – time of chain saw preparation;
t_2 – time of preparation of implements and equipment;
t_3 – time of clearing area around tree;
t_4 – time of determination the walk-away path;
t_5 – time of pruning and barking;
t_6 – time of root swellings cutting off;
t_7 – time of approach to tree;
t_8 – time of determination of throwing down direction;
t_9 – other.

Time of felling:

$$t_{os} = t_{10} + t_{11} + t_{12} \quad (3)$$

and

$$t_{10} = t_{10a} + t_{10b} + t_{10c} \quad (4)$$

where:
t_{10} – time of felling;
t_{11} – time of throwing down;
t_{12} – time of trunk edging and cutting off crest;
t_{10a} – time of undercutting kerf execution;
t_{10b} – time of undercutting hinge execution;
t_{10c} – time of cutting kerf execution.

Time of debranching:

$$t_{oo} = \sum_{i=2}^{n} t_{13} + \sum_{i=1}^{m} t_{14} \quad (5)$$

where:
t_{13} – time of walking and saw setting against trunk;
t_{14} – time of cutting off branches;
n – number of saw setting against trunk;
m – number of cut off branches.

Time of crosscutting:

$$t_{op} = \sum_{i=2}^{p} t_{13} + \sum_{i=1}^{s} t_{15} \quad (6)$$

where:
t_{13} – time of walking and saw setting against trunk;
t_{15} – time of crosscutting;
p – number of saw setting against trunk;
s – number of crosscut sections (assortments).

For every harvested tree the time measurement began and ended in the determined and same moment in all runs, i.e.:

- time of undercutting kerf execution – measured from the moment of setting chain saw guide bar against tree, till the moment, when the fragment being cut was separated from the tree;
- time of hinge shortenning – measured from the moment of setting chain saw guide bar against tree on one side of hinge, till the moment of setting off chain saw guide bar on other side of hinge;
- time of cutting kerf execution – measured from the moment of setting chain saw guide bar against tree, till the moment of removing it off the kerf;
- time of throwing down – measured from the moment of removing chain

saw off cutting kerf, till the moment of tree fall on the ground;
- time of trunk edging and cutting off crest – measured from the moment of setting chain saw guide bar against crest being cut, till the moment of trunk edging completion;
- time of debranching – measured from the moment of setting chain saw guide bar against the first branch being cut, till cutting off the top;
- time of crosscutting – measured from the moment of setting chain saw guide bar against the place of first crosscutting kerf, till execution of the last one;
- total time of single tree harvesting – measured from the moment of undertaking decision on beginning of a given tree felling, till the moment of last kerf execution during crosscutting of the same tree;
- time of preparation – time difference between total felling time and the sum of times for all operations listed above;
- time of felling – measured from the moment of beginning the undercutting kerf execution, till the moment of trunk edging completion.

Number of cut branches was calculated on the felling site, independently by two persons; afterwards, the results were verified on the basis of recorded film material.

RESULTS OF INVESTIGATIONS

During investigations there were harvested 60 trees by both the groups of sawmen of various professional experience. The obtained results of investigations were subjected to statistical analysis. To compare the collected data, the similarity of tree sets of both forest inspectorates was analyzed with the use of a statistical method for testing differences between mean values. There were compared the characteristic parameter values of investigated trees. The statistics $z_{\alpha/2} = 1.96$ was determined for significance level $\alpha = 0.05$ from Tables of cumulative distribution functions. Upon calculating the mean value and variance for every sample, the statistics $|Z|$ was calculated for each tree characteristic parameter (Tab. 2). If inequality $z_{\alpha/2} \geq |Z|$ was true for a given tree characteristic parameter, in the last column the sign „+" was put; if it was not true – the sign "–". According to calculations, for each characteristic parameter inequality $z_{\alpha/2} \geq |Z|$ is valid. It means that the null hypothesis on equality of mean values of both populations can't be rejected. Therefore, one can't find that populations of both stands differ from each other; it can be assumed that both stands are similar in respect of mentioned parameters, they can be regarded as one population, and they can be compared.

The timber was harvested in the entire tree stem system (felling and cutting off branches and top at diameter 5 cm without bark or 7 cm with bark). The crosscutting was performed directly at receiving of raw material by a forester; it not allowed for direct time measurement of this operation for particular trees, therefore, the time of bucking was not considered in the structure being compared.

Figure 1 presents the percent time share for execution of particular process operations in timber harvesting by the experienced sawmen and the beginners. It is distinctly evident that in the case

TABLE 2. Verification of null hypothesis on similarity of tree sets investigated

Characteristic parameters of trees	Mean Forest Inspect. Wipsowo	Mean Forest Inspect. Chojnów	Statistics$_{tab}$ $z_{\alpha/2}$	Statistics$_{calc}$ $\lvert Z\rvert$	$z_{\alpha/2} \geq \lvert Z\rvert$
Volume [m^3]	2.03	2.11	1.96	0.50	+
Height of tree [m]	27.79	27.84	1.96	0.08	+
Number of branches [pcs]	56.62	49.83	1.96	1.86	+
Diameter in place of cut [cm]	47.22	46.33	1.96	0.56	+
Breast height diameter [cm]	38.67	38.85	1.96	0.13	+
Diameter at half length [cm]	26.77	27.67	1.96	1.05	+

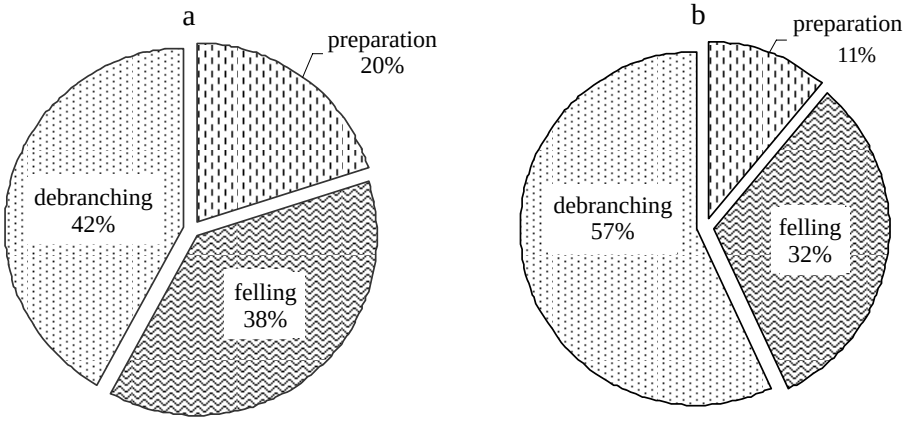

FIGURE 1. Percent time share of particular operations execution by sawman: a – beginner, b – experienced one

of unexperienced sawman (Fig. 1a) the preparatory and additional operations take 20% of total time. The biggest share makes debranching (42% of total time), the rest of time is taken by felling (38%). In the case of experienced sawman (Fig. 1b), the smallest time share (11%) is spent for preparatory operations, te biggest share of total time for debranching (57%), while the percent time share of felling amounts to 32%; it slightly differs from the results of beginners.

Comparing both Figures one can find that the experienced sawmen spent far more time on debranching and less on felling and additional operations, when compared to beginners. The time share for debranching was bigger by 25% than for felling tree. The experienced sawmen spent almost by half less time on preparatory operations then the sawman without experience. However, the time spent on debranching by the beginning sawmen is almost the same as the time spent on felling.

Comparing mean times of execution of processing operations by the beginning and experienced sawmen (Fig. 2) one can find far longer times for the beginners. The total mean time of execution of all operations is higher by 91% in the case of beginners. The highest difference

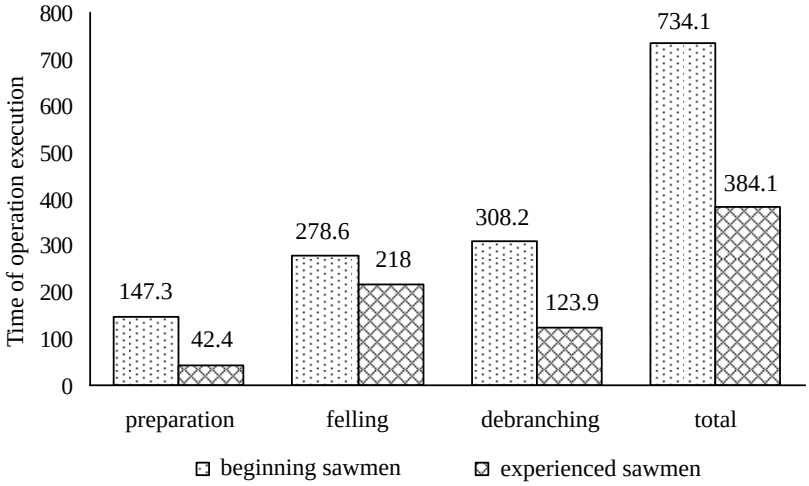

FIGURE 2. Comparison between mean time value of particular operations execution by the beginning and experienced sawmen

was recorded for preparatory operations, where the mean divergence amounted to 247% (149% for debranching). The least mean difference was found for felling (28%).

SUMMARY

- The percent time share of operations execution by the beginning and experienced sawmen has the similar structure. Most of the time is spent on debranching, regardless of experience, the least time is spent on preparatory and additional operations.
- All operations connected with timber harvesting were performed slower by the beginners. The highest difference was found for preparatory and additional operations, the least difference for felling.
- In the case of beginners, the time of felling increase considerably with an increase in trunk diameter of the tree being cut. The experienced sawmen cut the tree quicker, and this difference increases with an increase in trunk diameter, when compared to the beginners.
- The beginners quicker perform debranching of trees with smaller number of branches (to about 40 pcs), while the experienced sawmen manage better trees of bigger number of branches. In debranching, the number of branches on the same trunk does not affect much the time of cutting off a single branch by the beginners, however, this time increases with the increased number of branches. In the case of experienced sawmen, the time of cutting off a single branch decreases significantly with an increase in number of branches.

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Streszczenie: *Wpływ doświadczenia zawodowego pilarzy na strukturę czasu pracy przy pozyskiwaniu drewna sosnowego w warunkach zrębu zupełnego.* W opracowaniu przedstawiono analizę czasów wykonywania poszczególnych operacji pozyskania drewna pilarką spalinową w zależności od doświadczenia pilarzy. Badania zostały przeprowadzone na dwóch grupach pilarzy: doświadczonych, z wieloletnim stażem i początkujących, którzy stawiają dopiero pierwsze kroki w zawodzie drwala. Obie grupy porównane zostały pod względem czasu wykonywania ścinki i okrzesywania. Na podstawie wykonanych badań i ich analizy można stwierdzić, że procentowa struktura czasu wykonywanych czynności przez pilarzy doświadczonych i początkujących jest podobna. Najdłużej wykonywaną czynnością jest okrzesywanie, a najmniej czasu zajmują czynności przygotowawcze i dodatkowe. Jednak pilarze doświadczeni przeważnie szybciej wykonują wszystkie czynności związane z pozyskaniem drewna. Wyjątkiem jest okrzesywanie drzew z mniejszą liczbą gałęzi, gdzie lepiej radzą sobie pilarze początkujący.

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