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ANALYSIS OF TIMBER HARVESTING PROCESS BY MEANS OF THE LONG-TIMBER METHOD IN THE TECHNOLOGICAL VARIANT WITH MEASUREMENTS OF THE LENGTH AND DIAMETER OF LOGS BY THE CHAINSAW OPERATOR

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Abstract. Investigations were carried out in a pine stand 80 years of age, 24 cm average diameter of breast height and 22 m tall. Both long-timber and medium-length assortments 1.8 and 2.4 m long were harvested. The performed analyses comprised: mean duration times at individual activities during operating time, structure of the operation time, as well as labour consumption during this time. The impact of the length and diameter of the harvested long timber on the above-mentioned characteristics of the harvesting process was assessed. Measurements of operation times were taken with the assistance of a stopwatch using the method of continuous timekeeping. Times of the following operations were identified and measured: site preparation, felling, fastening of the self wind-up measuring tape, cutting logs into assortments, measurement, returning to the end of the handled bole, cutting into rollers, walking over to the next tree to be felled. The obtained results of the investigations revealed statistically significant differences of mean duration times and mean shares of some operations in groups of trees of differing length and diameters. In the structure of the operating time, the highest shares were recorded for roller cutting and measurements. It was found that the diameter of the handled long timber exerted the strongest influence on the labour consumption of the harvested timber.

Key words: wood harvesting, chainsaw, long timber, measurement of boles

INTRODUCTION

Despite the fact that multi-operational machines are increasingly common in timber harvesting, chainsaws continue to remain basic tools employed for harvesting and processing of timber. The introduction of chainsaws to timber harvesting improved labour

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efficiency but, at the same time, brought in a number of threats which did not occur when simple tools were used [Skarżyński 2002, Sowa 1998, Sowa and Kulak 1999, Więsik 2001, Więsik and Wójcik 2002]. The introduction of multipurpose machines (harvesters) to the process of timber harvesting has resulted not only in dramatic increase of efficiency but has also eliminated majority of threats occurring during work with a chainsaw [Grzywiński 2004, Sowa and Leszczyński 2000, 2007].

The process of timber harvesting with the assistance of chainsaws involves carrying out some operations (processing) using a chainsaw and other activities which, as a rule, do not require the use of this tool. The processing operations include: felling, debranching and cutting into assortments and they are performed serially on each tree [Wójcik 2007 a]. The duration of processing operations depends on two groups of factors. The first group includes chainsaw parameters (volume, power), while the other one comprises tree natural biometric traits such as branching, as well as parameters of bucking assortments [Wójcik 2007 b]. The amount and scope of the remaining operations of the timber harvesting process depend on the adopted technology.

The final effect of timber harvesting in the felling system are large-size wood and stack assortments. Large-sized wood is usually cut into long timber most frequently measured prior to skidding. This requires almost permanent presence of a State Forest worker (forester, ranger) who will carry out current measurements of length and diameter of each worked long timber. In some forest districts, chainsaw operators are additionally commissioned to take measurements. This job, however, apart from auxiliary equipment and skills, requires additional time expenditure which should be taken into consideration in labour-consumption standards of large-size timber harvesting in the form of long timber.

The aim of these studies was to evaluate basic parameters characterising the harvesting process of pine wood with the assistance of a chainsaw in the variant with measurements of long timber length and diameter by the chainsaw operator.

SITE AND METHODS OF EXPERIMENTS

Investigations were conducted in the Oborniki Forest District, compartment 783 c, on which an 80-year old pine stand of II stand quality of 24 cm mean diameter at breast height and 22 m tall was growing.

Tree felling was performed using a Stihl 026 chainsaw and handling and length measurements – with the assistance of a wind-up measuring tape, whereas diameters were measured using a section gauge. Diameter measurements were carried out on debarked logs. Bark was removed by the chainsaw operator with a drawing knife in places where the arms of the section gauge were applied. Ninety trees were felled from which, apart from long timber, 1.8 and 2.4 m long stack wood was worked.

Times of individual operations were calculated on the basis of the data from the timekeeping of the continuous operating time. Measurements were taken using a stopwatch with 1 s accuracy. The following activities of the operating time were identified:

- preparation of the workstation
- tree cutting and felling
- fastening of the self wind-up measuring tape
- de-branching and cutting of the boles

– measurement of the boles length and diameter and recording the result on the stem cross-cut end
– return to the end of the worked long timber
– de-branching and cutting of rollers from the top-end of the bole
– walking over to the next tree to be cut.

The performed laboratory work included: calculation and analyses of mean duration times and share times of individual actions in the course of operating time, the structure of the operating time, as well as the labour consumption of individual operations and the entire operation of long timber harvesting. Since only the volume of the large-size timber was known, the labour consumption for all operations during the operating time, as well as the entire harvesting operation in this time, were determined in $\text{min}\cdot\text{tree}^{-1}$. Next, evaluation of the effect of the long timber length and diameter on mean duration times and labour consumption of individual actions of timber harvesting and the structure of operating time were carried out. Trees were divided into groups of different lengths and diameters of logs worked from them. The groups comprised trees from which boles with lengths of up to and over 10.5 m were worked and trees of long timber diameters of up to and over 21 cm. The limiting length and diameter values were assumed on the basis of the criterion of a similar number of trees in groups. Mean times of duration of individual operations of timber harvesting, mean proportions of duration times of these operations in the operating time were calculated and the structure of the operating time was determined. The obtained results regarding mean time values of individual operations as well as their mean shares in the operating time were subjected to statistical analysis using for this purpose *t* Student test together with an earlier assessment of the homogeneity of variance.

RESULTS

Table 1 collates mean values of duration times of individual actions of the operating time. The time required to cut rollers was clearly the longest and exceeded 140 s, whereas for long timber cutting, only 55 s were required. The mean time of bole bucking was similar to the time of felling which only slightly exceeded 50 s. The second longest mean time after roller cutting was determined for the operation of long timber measurement and recording its result on the stem cross-cut end. The shortest time, which did not exceed 10 s, was recorded for the action of fastening the self wind-up measuring tape to the stem cross-cut end.

Results of measuring of operation times associated with timber harvesting were characterised by variations on the level from small to large. Small variations were determined only for the action of the measurement together with the recording of the result on the stem cross-cut end. Intermediate variations were observed for tape fastening, as well as for long timber and roller bucking. In the case of the remaining operations, the value of the variability coefficient corresponded to high result variability. In the case of the preparation of the workplace and walking over to consecutive trees to be worked, the value of this coefficient reached almost 90%, while for the cutting and returning to the end of the long timber – it did not exceed 50%.

The analysis of mean values of times of individual operations in tree groups of different stem lengths and diameters demonstrated, for the majority of operations, that

Table 1. Measures of time variability of timber harvesting operations
Tabela 1. Miary zmienności czasów czynności pozyskania drewna

Operation Czynność	Mean Średnia s	Standard deviation Odchylenie standardowe s	Coefficient of variability Współczynnik zmienności %
Workstation preparation Przygotowanie stanowiska	31.6	27.8	87.85
Felling Ścinka	51.1	23.8	46.56
Fastening of measuring tape Zapięcie taśmy	9.1	3.6	39.41
Bole bucking Wyrzynka dłużyc	54.6	17.7	32.46
Measurement, recording Pomiar, zapis	75.2	13.5	17.93
Return Powrót	27.8	11.4	40.90
Roller bucking Wyrzynka wałków	141.1	45.7	32.42
Changing Przejście	27.7	24.8	89.59

trees from which longer and thicker boles were worked were characterised by higher values (Table 2). In the group of trees with shorter long timber, higher values were determined for operations of workplace preparation, roller cutting and walking over, whereas in the group with thinner stems – only for the return of the operator to the end

Table 2. Mean times of timber harvesting operations in tree groups of different bole length and diameters, s
Tabela 2. Średnie czasy czynności pozyskania drewna w grupach drzew o różnych długościach i średnicach dłużyc, s

Operation Czynność	Bole length Długość dłużyc		Bole diameter Średnica dłużyc	
	≤ 10.5 m	> 10.5 m	≤ 21 cm	> 21 cm
1	2	3	4	5
Workstation preparation Przygotowanie stanowiska	34.3	27.8	26.9	37.3
Felling Ścinka	47.0	56.9	46.5	56.4
Fastening of measuring tape Zapięcie taśmy	8.9	9.5	9.1	9.1
Bole bucking Wyrzynka dłużyc	46.5	67.0	49.9	58.9

Table 2 – cont. / Tabela 2 – cd.

1	2	3	4	5
Measurement, recording Pomiar, zapis	70.6	82.3	71.5	78.4
Return Powrót	26.9	29.3	30.5	25.5
Roller bucking Wyrzynka wałków	146.6	130.9	115.8	161.0
Changing Przejście	28.6	26.2	27.2	28.5

of the long timber. In this tree group, fastening of the measuring tape, on average, required the same amount of time as in the group of thicker trees, while the remaining operations were characterised by lower mean times. Statistically significant differences between mean duration times of individual operations, in all groups of trees, were found for bucking long timber and for measurement with recording. In the groups of trees with differing diameters of long timber, such differences also occurred in the case of the return of the operator to the end of the trunk and bucking of rollers (Table 3).

Table 3. Results of the *t* Student test for mean times of individual timber harvesting operations in tree groups of different bole length and diameters

Tabela 3. Wyniki testu *t* Studenta dla średnich czasów poszczególnych czynności pozyskania drewna w grupach drzew o różnych długościach i średnicach dłużyc

Operation Czynność	Length Długość		Diameter Średnica	
	statistic *t* value wartość statystyki *t*	critical $t_{0.05}$ value wartość krytyczna $t_{0,05}$	statistic *t* value wartość statystyki *t*	critical $t_{0.05}$ value wartość krytyczna $t_{0,05}$
Workstation preparation Przygotowanie stanowiska	1.117	1.993	–1.662	1.992
Felling Ścinka	–1.827	1.992	–1.850	1.992
Fastening of measuring tape Zapięcie taśmy	–0.884	1.998	–0.039	1.988
Bole bucking Wyrzynka dłużyc	–6.457	1.998	–2.431	1.988
Measurement, recording Pomiar, zapis	–4.390	1.998	–2.449	1.988
Return Powrót	–0.937	1.990	2.023	1.990
Roller bucking Wyrzynka wałków	1.632	1.993	–5.083	1.990
Changing Przejście	0.459	1.992	–0.230	2.004

Bucking of medium-sized timber assortments was characterised by the highest, nearly 30% share in the operating time (Fig. 1). When analysing the share of this operation in the experimental tree groups, its highest values were determined for trees from which shorter and thicker merchantable logs were obtained (Table 4). The proportion of measuring time and recording the result on the stem cross-cut end constituted over 19% of the operating timer. The highest share of this operation in tree groups was observed in the trees from which longer and thinner boles were harvested. More than 10% share in

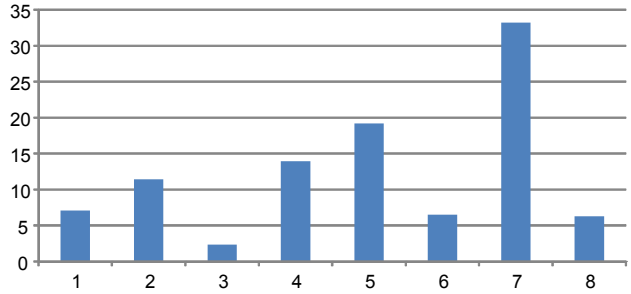

Fig. 1. Structure of operating time, %: 1 – workstation preparation, 2 – felling, 3 – fastening of measuring tape, 4 – bole bucking, 5 – measurement, recording, 6 – return, 7 – roller bucking, 8 – changing

Rys. 1. Struktura czasu operacyjnego, %: 1 – przygotowanie stanowiska, 2 – ścinka, 3 – zapięcie taśmy, 4 – wyrzynka dłużyc, 5 – pomiar, zapis, 6 – powrót, 7 – wyrzynka wałków, 8 – przejście

Table 4. Time shares of timber harvesting operations in tree groups of different bole length and diameters, %

Tabela 4. Udziały czasów czynności pozyskania drewna w grupach drzew o różnych długościach i średnicach dłużyc, %

Operation Czynność	Bole length Długość dłużyc		Bole diameter Średnica dłużyc	
	≤ 10.5 m	> 10.5 m	≤ 21 cm	> 21 cm
1	2	3	4	5
Workstation preparation Przygotowanie stanowiska	7.5	6.5	7.3	7.0
Felling Ścinka	10.2	13.3	12.7	10.6
Fastening of measuring tape Zapięcie taśmy	2.3	2.4	2.5	2.2
Bole bucking Wyrzynka dłużyc	11.9	17.2	13.9	14.0
Measurement, recording Pomiar, zapis	18.0	21.1	20.0	18.6

Table 4 – cont. / Tabela 4 – cd.

1	2	3	4	5
Return Powrót	6.7	6.2	7.7	5.7
Roller bucking Wyrzynka wałków	36.7	27.8	29.2	35.9
Changing Przejście	6.7	5.5	6.7	6.1

the operating time was also determined for bole bucking and for felling. The highest time shares of these operations were determined in the case of trees from which boles over 10.5 m long were worked. In the groups of trees of different bole lengths, statistically significant differences between mean proportions of times of individual operations were determined for: felling, bucking of boles, measurement with recording, as well as bucking of rollers. In the groups of trees of different bole diameters, such differences were found for the action of return and bucking of rollers (Table 5).

Table 5. Results of the *t* Student test for mean time shares of individual timber harvesting operations in tree groups of different bole length and diameters
Tabela 5. Wyniki testu *t* Studenta dla średnich udziałów czasów poszczególnych czynności pozyskania drewna w grupach drzew o różnych długościach i średnicach dłużyc

Operation Czynność	Length Długość		Diameter Średnica	
	statistic *t* value wartość statystyki *t*	critical $t_{0.05}$ value wartość krytyczna $t_{0,05}$	statistic *t* value wartość statystyki *t*	critical $t_{0.05}$ value wartość krytyczna $t_{0,05}$
Workstation preparation Przygotowanie stanowiska	0.048	1.998	0.621	1.988
Felling Ścinka	–2.362	1.998	1.915	1.998
Fastening of measuring tape Zapięcie taśmy	–1.240	1.998	1.624	2.002
Bole bucking Wyrzynka dłużyc	–5.799	1.998	–0.035	1.988
Measurement, recording Pomiar, zapis	–3.310	1.998	1.052	1.998
Return Powrót	1.488	1.998	2.236	1.992
Roller bucking Wyrzynka wałków	4.303	1.998	–2.540	1.988
Changing Przejście	1.230	1.998	–0.016	1.998

The highest labour consumption of harvesting the entire timber was determined for bucking assortments of medium-sized timber (Table 6). Also in groups of trees, this operation required the highest unit expenditure of labour time but higher results were observed for trees from which thicker and shorter boles were worked. In the case of trees from which longer and thinner boles were obtained, labour consumption of roller bucking was lower by 18.5% and 20%, respectively. For majority of the examined operations, the recorded labour consumptions did not exceed 1 min·tree^{-1}, with the exception of the bucking of boles with the length exceeding 10.5 m and measurement of the diameter in all groups of trees. Distinctly lowest labour consumption – less than 0.2 min·tree^{-1} – was ascertained for the action of fastening the measuring tape on the stem cross-cut end of the bole.

Table 6. Labour consumption of timber harvesting, min·tree^{-1}
Tabela 6. Pracochłonność pozyskania drewna, min·drzewo^{-1}

Operation Czynność	All trees Wszystkie drzewa	Trees of bole length Drzewa o długości dłużyc		Trees of bole diameter Drzewa o średnicy dłużyc	
		≤ 10.5 m	> 10.5 m	≤ 21 cm	> 21 cm
Workstation preparation Przygotowanie stanowiska	0.53	0.57	0.46	0.45	0.62
Felling Ścinka	0.86	0.78	0.95	0.78	0.94
Fastening of measuring tape Zapięcie taśmy	0.15	0.15	0.16	0.15	0.16
Bole bucking Wyrzynka dłużyc	0.91	0.78	1.12	0.83	1.00
Measurement, recording Pomiar, zapis	1.25	1.18	1.37	1.19	1.33
Return Powrót	0.46	0.45	0.49	0.51	0.43
Roller bucking Wyrzynka wałków	2.35	2.44	2.18	1.93	2.75
Changing Przejście	0.46	0.48	0.44	0.45	0.49
Total Razem	6.97	6.83	7.17	6.29	7.72

The obtained labour consumptions of the entire operation of harvesting in the course of the operating time indicate that they were influenced strongest by the diameter of the worked trees. The largest and the smallest labour consumptions were recorded in the groups of trees of different bole diameters where larger diameters were accompanied by greater labour consumption. In groups of trees with different lengths of boles, higher labour consumption was observed in trees from which longer boles were harvested. The difference of results for tree groups of different bole lengths amounted only to 0.34 min whereas for trees of different diameters – 1.43 min.

DISCUSSION

The analysis of time structure during timber harvesting using chainsaws frequently refers only to processing operations carried out with the assistance of these machines. In such investigations, indices of felling, de-branching and bucking in a different condition of realisation of these operations are assessed [Sztyber and Wójcik 2005, 2007, Wójcik 2007 a, b]. In the case of the presented paper, the operation of de-branching was not treated as a separate action because it was not carried out in one cycle but each time it was combined with the bucking of boles and rollers which constituted separate operations (among others, measurement and registration of its result was recorded on the bole cross-cut end).

In the performed investigations, the highest labour consumption was determined for roller bucking; it was more than twice higher in comparison with the labour consumption of bole bucking. Similar results were reported by Sztyber and Wójcik [2007] who analysed indices characterising time of work of a chainsaw in the course of bucking of assortments from pine stems. In addition, the above researchers reported that the real time of work of a chainsaw during assortment bucking was almost inversely proportional to the length of those assortments.

Knowledge of the working day structure is indispensible for the assessment of labour consumption and efficiency of technological processes during timber harvesting [Suwała 2002 a, b, 2006]. This problem is particularly important in the case of timber harvesting in conditions differing from those prevailing when realising planned fellings (e.g. removal of consequences of natural disasters). Such studies in stands affected by damages were conducted by Sowa et al. [2009] who analysed the structure of a working shift of a chainsaw operator employed to remove damages caused by snowbreaks and also carrying out planned treatments of late thinning. The results of these studies revealed a statistically significantly higher share of passes during working time on the area with snowbreaks in comparison with the work done during thinning. The passes were caused by impediments that occur on areas hit by disasters consisting mostly in recognising threats and their elimination (e.g. separating piled-up trees).

The research results presented in this article were obtained in conditions of planned cuttings and the only specific hindrance for the chainsaw operator was the measurement of the bole length and diameter made by him and recording of the results on the stem cross-cut end. The share of these operations constituted, on average, 19% of the operating time ranging, in the analysed groups of trees, from 18 to over 21%. It should be stressed that actions of measurement and recording were every time accompanied by the attachment of the measuring tape to the stem by the operator and his return (after recording it on the stem cross-cut end) to the end of the worked stem in order to cut medium-sized timber assortments. Even though labour consumption of the measuring tape attachment was the lowest (0.15-0.16 $min \cdot tree^{-1}$) and that of the return did not exceed 0.5 $min \cdot tree^{-1}$, the total time share of these operations constituted from 7.9 to over 10% of the operating time and together with taking measurements and recording – from 26.5 to 30.2% (28.35% on average). The above values should be taken into account when costing works associated with harvesting timber of varying size in situations when the chainsaw operator is also expected to measure boles. In practice, this should not pose serious difficulties because the "Catalogue of time standards of forest works" makes it possible to increase labour consumption by up to 30% in cases of occurrence of hindrances or conditions not included in this Catalogue.

CONCLUSIONS

1. The operation of stack wood assortment bucking was characterised by the longest mean duration time. It was nearly three time longer in comparison with the bole bucking time and twice as long as measurement actions which lasted, on average, 1 minute and 15 seconds.

2. Both the length and the diameter of the bucked boles differentiated mean duration times of individual operations of timber harvesting in operating time. In all groups of trees, statistically significant differences between mean duration times were determined for bole bucking as well as for measurement with recording. In the case of groups of trees of different bole diameters, such differences were also observed for the walking back and bucking of rollers.

3. Bucking of medium-sized timber rollers was characterised by the greatest (over 30%) share in the operating time. In the groups of experimental trees, the highest time share of this operation was recorded for trees from which short and thick boles were worked. Measurement of boles together with the recording of the result occupied, on average, slightly more than 19% of the operating time. The proportion of this operation reached higher values in the case of trees from which longer and thinner boles were worked.

4. The obtained research results indicate that bole diameters exerted the strongest impact on labour consumption of timber harvesting. The highest labour consumption was recorded for trees of greater diameter. Higher labour consumption was also observed in the group of trees from which longer boles were obtained and the difference, in relation to trees from which shorter boles were worked, was almost five times smaller in comparison with trees of different bole diameters.

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ANALIZA PROCESU POZYSKIWANIA DREWNA METODĄ DŁUŻYCOWĄ W WARIANCIE TECHNOLOGICZNYM Z POMIAREM DŁUGOŚCI I ŚREDNICY DŁUŻYC PRZEZ OPERATORA PILARKI

Streszczenie. Badania przeprowadzono w drzewostanie sosnowym, w wieku 80 lat o przeciętnej pierśnicy 24 cm i wysokości 22 m. Pozyskiwano dłużyce i sortymenty średniowymiarowe o długości 1,8 i 2,4 m. Analizowano średnie czasy trwania poszczególnych czynności w czasie operacyjnym, strukturę czasu operacyjnego oraz pracochłonność w tym okresie. Oceniono wpływ długości i średnicy pozyskiwanych dłużyc na w.w. charakterystyki procesu pozyskiwania. Czasy czynności mierzono stoperem, zastosowano metodę chronometrażu ciągłego. Wyodrębniono i pomierzono czasy następujących czynności: przygotowanie stanowiska, ścinka, zapięcie taśmy samozwijającej, wyrzynka dłużycy, pomiar, powrót do końca wymanipulowanej dłużycy, wyrzynka wałków, przejście do kolejnego ścinanego drzewa. Wyniki badań wykazały statystycznie istotne różnice

średnich czasów trwania i średnich udziałów niektórych czynności w grupach drzew o różnych długościach i średnicach. W strukturze czasu operacyjnego najwyższe udziały odnotowano dla wyrzynki wałków i pomiaru. Stwierdzono, że największy wpływ na pracochłonność pozyskiwania drewna miała średnica wyrabianych dłużyc.

Słowa kluczowe: pozyskiwanie, pilarka, dłużyce, pomiar dłużyc

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