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WORKER'S PHYSICAL LOAD WHEN HARVESTING LOGS ON CLEAR CUTS

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Abstract. The aim of the study was to investigate the energy expenditure and static load of a worker during harvesting wood in pine stand clear cuttings. The performed experiments involved two technological treatments in which timber was harvested either in the form of large-size logs or medium-size rollers and blocks. The above variants differed with regard to the spatial order on the felling area (organised and unorganised felling). The energy expenditure was determined on the basis of measurements of lung ventilation, while static load – using the OWAS method. The obtained net unit energy expenditures were similar in both variants and reached 30 kJ/min and exceeded the limiting value of the so-called durable efficiency of the organism. With regard to the static loading, in each variant, the worker was found to be loaded moderately.

Key words: timber harvesting, energy expenditure, static effort

INTRODUCTION

Environmentally-friendly model of Polish forestry makes it necessary to apply in wood harvesting, especially in intermediate cutting of technologies which are based on the short wood system as their environmental values are widely known [Grodecki et al. 2000, Porter and Porter 1998, Suwała 1995].

The effect of changes taking place in recent years on the timber market is, among others, the observed increased demand of timber customers for large-sized raw material in the form of logs. This means that technologies based on the short wood system are employed increasingly frequently also on clear cutting areas.

Despite growing numbers of multi-functional machines used in our forests, a significant majority of technologies applied in timber harvesting is based on the combination of manual-machine work which employs power chainsaws for timber processing operations. Working with chainsaws is characterised by considerable physical loads [Grzywiński 2005, Stempski and Grodecki 2005] and perceptible improvement in working conditions will only be possible when chainsaws are completely replaced by harvesters.

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Fig. 1. Organised felling
Rys. 1. Zrąb uporządkowany

Fig. 2. Unorganised felling
Rys. 2. Zrąb nieuporządkowany

Nevertheless, currently applied technologies vary with regard to the loads that workers are exposed to [Giefing 1996, Sowa et al. 2006]. In addition, levels of physical loads can also be influenced by the applied technique of work with the chainsaw [Sowa and Kulak 1999, 2000].

The objective of the performed research project was to determine the level of energy expenditure by a worker during timber harvesting operations involving log formation in the course of felling of pine stands. In addition, an attempt was also made to estimate the level of static loads to which a worker is exposed during the realisation of definite activities and eight-hour working shift. The experiments involved the following two technological variants of timber harvesting from mature pine stands:

1) variant of organised felling,
2) variant of unorganised felling.

RESEARCH AREA AND METHODS

The investigations were carried out in a pine stand in which Ib mode of felling was applied during cutting. Characteristics of the stand were as follows: pine – 100%, age – 105 years, stand density index – 0.8, broken crown closure, mean breast height diameter – 30 cm, mean height – 20 m, stand quality – III, quality – 3, large timber stock 246 m^3/ha, area – 5.70 ha.

The stand was divided into two experimental plots on which appropriate technological variants of timber harvesting scheduled by the management plan were carried out.

Organised felling

In this variant, forest works were carried out on working strips approximately 20-25 m wide and the organisation of the working area resulted from tree felling with their crowns towards the centre of the strip (Fig. 1). Tree tops and branches which remained in this area constituted the so-called branch region and provided a special skidding road. Timber prepared for skidding lay on the right and left sides of this area (in the so-called 'timber zones'). Two types of timber were prepared: long logs 4.10 m in length as well as medium-sized timber assortments: 2.40 and 1.80 m long. There was always only one worker on the working strip who realised all the technological processes. He used a Husqvarna 372 chainsaw and a self-coiling measuring tape to handle the raw material and formed bundles of stacked timber using lifting tongs. Forwarding was realised with the assistance of a special forestry tractor Timberjack 1010.

Unorganised felling

In the case of the unorganised timber felling variant, the same timber assortments as in the organised felling system were harvested. The difference consisted in the fact that the felling work was not carried out on successive working strips but on the entire width of the cutting area and there was more freedom in the selection of the direction of falling trees. The worked assortments as well as after-felling residues were distributed all over the area without special zones for branches and timber (Fig. 2).

Physical load

The level of energy expenditure was assessed employing worker's net unit energetic expenditures.

In order to estimate static loading, time proportions of individual technological processes in a work shift were determined. These proportions were assessed on the basis of continuous timekeeping. The measurements were carried out using a stopwatch with 1 s accuracy and they comprised the following technological operations:

- preparation of the workstation,
- tree cutting and felling,
- de-branching and handling,
- cross-cutting,
- formation of bundles of stacked timber for skidding,
- passages,
- servicing (refuelling, sharpening, regulation, small repairs),
- breaks for rests and physiological needs.

In addition, measurements of the parameters of harvested trees (diameter, length) were also conducted which made it possible to determine position statistics of the obtained raw material and verify the hypothesis about the lack of differences between tree parameters harvested on organised and unorganised fellings.

Energetic expenditure

Energy expenditure for each technological operation was determined on the basis of measurements of lung ventilation using, for this purpose, an MWE-1 energy expenditure device. In each of the experimental technological variants, series of measurements were carried out between 8-9 o'clock, 11-12, 13-14, 15-16, and 17-18. On the basis of the obtained results, mean minute energy expenditures were calculated for each technological operation. The knowledge of the time proportions of individual operations in the 8-hour work shift allowed the determination of the mean weighted net unit energy expenditure for the entire work shift.

Statical load

The OWAS method [Łastowiecka et al. 2001] was employed to determine static loads. During field work, all positions adopted by the worker during work were recorded using, for this purpose, a 4 digit code. The codes were registered every 30 s; the total of 990 recordings was carried out on the organised felling and 1036 recordings – on the unorganised one.

In the course of further studies, all coded positions were assigned into one of the four categories of the workstation assessment (OWAS categories) dividing them into either forced or unforced group (e.g. 2f, 1u). Next, on the basis of the structure of a working day, the percentage proportion of the time of occurrence of the recorded positions (expressed as OWAS category) during the realisation of individual technological operations and the entire timber harvesting operation was determined. This allowed determining the loading category with the static effort of the examined technological variants.

RESULTS AND DISCUSSION

Energetic expenditure

The results of the net unit energy expenditures obtained during the performed experiments showed that operations involving the application of power chainsaw as well as manual preparation of the raw material for skidding required considerable physical effort (Table 1).

Table 1. Results of measurements of net energy expenditure
Tabela 1. Wyniki pomiaru wydatku energetycznego netto

Technological variant Wariant technologiczny	Mean Średnia kJ/min	Standard deviation Odchylenie standardowe kJ/min	Coefficient of variability Współczynnik zmienności %
Organised felling Zrąb uporządkowany	29.9	1.48	4.94
Unorganised felling Zrąb nieuporządkowany	30.6	1.52	4.97

Both in the case of the organised and unorganised clear cutting, mean unit energy expenditure reached, approximately, 30 kJ/min. In both variants, only slight differences in the obtained results were found. The calculated coefficients of variance were at the level of 5%.

The obtained mean unit energy expenditures significantly exceeded 17 kJ/min, i.e. the value which is treated as the limiting value (so-called durable efficiency of the organism) [Löffler 1990]. The calculated confidence intervals of 29.9 ±1.8 for the organised felling and 30.6 ±1.9 for the unorganised felling indicate that it is practically impossible for the energetic expenditure to come close to the limiting value.

Statistical analysis revealed lack of significant differences between mean weighted unit energetic expenditures of the worker in the examined technological variants (Table 2).

Table 2. Results of Student's t-test for unit energy expenditure
Tabela 2. Wyniki testu t-Studenta dla jednostkowego wydatku energetycznego

Variables Zmienne	F-Snedecor's test Test F-Snedecora		Student's t-test Test t-Studenta	
	statistic F value wartość statystyki F	critical $F_{0.025}$ value wartość krytyczna $F_{0,025}$	statistic t value wartość statystyki t	critical $t_{0.05}$ value wartość krytyczna $t_{0,05}$
Organised felling Zrąb uporządkowany Unorganised felling Zrąb nieuporządkowany	1.06	6.39	0.718	2.306

Table 3. Results of the significance of differences of traits of harvester timber
Tabela 3. Wyniki testu istotności różnic cech pozyskanego drewna

Timber trait Cecha drewna	Statistic D value Wartość statystyki D	Critical $D_{0.05}$ value Wartość krytyczna $D_{0,05}$
Central diameter, cm Średnica środkowa, cm	0.177	0.265
Large timber volume, m^3 Miąższość grubizny, m^3	0.219	

In the case of the energetic expenditure investigations on the organised felling, it was found that the worker harvested timber of the mean volume of 0.5784 m^3, whereas the worker on the unorganised felling – 0.4807 m^3. Mean central diameters of harvested trees amounted to: 20.55 cm and 18.95 cm, respectively. In order to ascertain whether the parameters of the harvested timber could have acted as factors differentiating the level of the used energy in the examined technological variants, the significance of differences of the diameter and volume of the cut trees was checked. The obtained results of the applied Kołmogorov-Smirnov test (Table 3) showed lack of statistically significant differences between:

– large timber volume of individual felled trees,
– central diameter of individual felled trees.

Static loads

Table 4 presents the level of loading with static work of a worker in the course of realisation of the examined technological operations.

Table 4. Results of assessment of static loading for technological treatments
Tabela 4. Wyniki oceny obciążenia statycznego dla zabiegów technologicznych

Technological treatment Zabieg technologiczny	Load – Obciążenie	
	organised felling zrąb uporządkowany	unorganised felling zrąb nieuporządkowany
Stand preparation Przygotowanie stanowiska	small – małe	small – małe
Cutting, felling – Ścinka, obalanie	large – duże	large – duże
De-branching, handling Okrzesywanie, manipulacja	large – duże	large – duże
Cross-cutting – Przerzynka	large – duże	moderate – średnie
Package formation – Formowanie pakietów	moderate – średnie	moderate – średnie
Passes – Przejścia	small – małe	small – małe
Servicing – Obsługa	small – małe	small – małe
Breaks – Przerwy	small – małe	small – małe

Table 5. Assessment results of static loading for technological variants
Tabela 5. Wyniki oceny obciążenia statycznego dla wariantów technologicznych

Technological variant Wariant technologiczny	OWAS category Kategoria OWAS	Times of position maintenance (percentage of working shift) Czas utrzymywania pozycji (procent zmiany roboczej)	Static load Obciążenie statyczne
Organised felling Zrąb uporządkowany	1n	52.01	moderate średnie
	1w	1.44	
	2w	46.59	
	3w	2.40	
Unorganised felling Zrąb nieuporządkowany	1n	52.48	moderate średnie
	1w	2.21	
	2w	45.59	
	3w	3.13	

Considerable work static load in both experimental variants was determined for felling, de-branching and handling and resulted from over 50% of the position time proportion of the forced category 2 during carrying out of these operations. Different levels of static loading occurred in the case of cross-cutting; high level was found on the organised felling and moderate – on the unorganised felling. Package formation for timber skidding was associated with a moderate level of loading with static work. The realisation of this operation in both experimental variants required the highest proportion of the category 3 forced position (about 13%).

Low levels of static loading were observed for the remaining technological operations. Taking into account the entire working shift, the degree of load of the worker with static effort in both experimental variants was moderate (Table 5). This was due to the time of maintenance of the forced 2 category position up to 50% of the work shift and the presence of the forced 3 category position up to 30% of the work shift.

CONCLUSIONS

1. Net unit energy expenditures of the worker in both technological variants were at the level of 30 kJ/min, consequently, exceeded the value of the so-called durable efficiency of the organism.

2. Small variability of the obtained values of the workers' energetic expenditure in the examined technological variants indicates the same character of the incurred effort.

3. Medium levels of static loads were recorded. A higher level during work shift of positions negatively affecting the muscular-skeletal system was recorded in the case of the unorganised variant of felling.

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OBCIĄŻENIA FIZYCZNE ROBOTNIKA PRZY POZYSKIWANIU DREWNA KŁODOWANEGO NA ZRĘBACH ZUPEŁNYCH

Streszczenie. W pracy badano wydatek energetyczny i obciążenie statyczne robotnika pozyskującego drewno w cięciach rębnych drzewostanów sosnowych. Badaniami objęto dwa warianty technologiczne, w których pozyskiwano drewno wielkowymiarowe w postaci kłód oraz drewno średniowymiarowe w postaci wałków i wyrzynków. Warianty te różniły się ładem przestrzennym na powierzchni cięć (zrąb uporządkowany i nieuporządkowany). Wydatek energetyczny określono na podstawie pomiaru wentylacji płuc, a obciążenie statyczne metodą OWAS. Uzyskane jednostkowe wydatki energetyczne netto były zbliżone w obydwu wariantach, na poziomie 30 kJ/min, przekraczając wartość graniczną tzw. trwałej wydolności organizmu. Pod względem obciążeń statycznych stwierdzono w każdym wariancie obciążenie robotnika w stopniu średnim.

Słowa kluczowe: pozyskiwanie drewna, wydatek energetyczny, wysiłek statyczny

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