ACTA SCIENTIARUM POLONORUM Acta Sci. Pol.
Silv. Colendar. Rat. Ind. Lignar. 8(2) 2009, 53-60

EFFECT OF LABOUR ORGANISATION ON THE LEVEL OF ENERGY EXPENDITURE AND STATIC LOADS OF A WORKER IN INTERMEDIATE CUTTING

Włodzimierz Stempski
Poznań University of Life Sciences

Abstract. The aim of the performed experiments was to assess energy expenditure and static loads of the operator of a chain sawing machine harvesting timber in a pine stand intermediate cutting. The investigations included two technological variants. In variant I, all technological operations were carried out by one worker – operator of the chain saw, while in treatment II the operations were carried out by a team of three persons – two operators of chain sawing machines and a helper. The energy expenditure was determined on the basis of measurements of the ventilation of lungs, whereas the static load – using the OWAS method. The determined net unit energy expenditures of the chain saw operators in the experimental variants exceeded 20 $kJ \cdot min^{-1}$ and differed statistically significantly between one another. With regard to static loads, a greater proportion of positions negatively affecting the muscle-skeletal system of the operator were found in variant II.

Key words: timber harvesting, intermediate cutting, physical effort

INTRODUCTION

The operational realities of forest service enterprises cause that the selection of timber harvesting technology depends, primarily, on economical considerations. Technological solutions employed in practice are based on a combination of hand-machine labour and are characterized by low efficiencies and, consequently, by relatively high unit costs. Most frequently, they include various variants of the entire bole method involving different proportions of ground skidding conducted by agricultural tractors. Naturally, this does not mean that nothing has changed in the field of technology. Multifunctional machines for timber harvesting (harvesters) and special skidding tractors (forwarders) are becoming increasingly popular in Polish forests. For example, in 2002, there were only 10 harvesters working in our forests [Moskalik 2002], while now there are over 150 of them. Their numbers increased particularly rapidly during the last two years [Kusiak 2008]. This can be attributed, primarily, to the shortage of workers

Corresponding author – Adres do korespondencji: Dr inż. Włodzimierz Stempski, Department of Forest Technology of Poznań University of Life Sciences, Wojska Polskiego 71 C, 60-625 Poznań, Poland, e-mail: stempski@up.poznan.pl

willing to work in forests but partially due to more and more loudly articulated need for the application, in practice, of environmentally friendly technologies. In addition, ergonomic aspects associated with the requirement to eliminate hard work using a chain saw should not be underestimated [Moskalik 2000 a]. Both harvesters and forwarders should be utilized in technologies based on systems of short timber which are characterised by low environmental nuisance and, at the same time, rationalise the functioning of the entire technological chain beginning with timber harvesting and ending with its processing [Motała 2006, Porter and Porter 1998, Suwała 1995].

Timber harvesting technologies employed at present are based, primarily, on the labour of workers equipped in combustion engine sawing machines. The proportion of machine timber harvesting does not exceed 10% of the annual volume harvest, while its potential possibilities are estimated at 40% [Moskalik 2000 b]. Carrying out tree felling and processing operations with the assistance of a chain saw is burdened by a considerable physical effort [Grzywiński 2005, Stempski and Grodecki 2005]. Without the elimination of chain saws, it is difficult to expect major changes in this field. Nevertheless, the introduction of specific technologies differing with regard to organisation or even the technique of work alone can result in load reductions [Sowa and Kulak 1999, 2000, Sowa et al. 2006].

The objective of this study was to assess physical loads of a chain saw operator harvesting timber within the framework of intermediate cutting of a pine stand. The performed measurements comprised unit energy expenditures as well as static effort in the course of the realisation of individual technological treatments and during operational time.

The investigations comprised two technological variants of the assortment method of short timber differing with regard to labour organisation. The first variant (I) assumed work of only one worker – chain saw operator, while the second variant (II) – adopted a different approach in which a team of two chain saw operators and a helper were involved. In variant I, the chain saw operator was responsible for all operations, including the preparation of the timber for skidding. In the case of variant II, the helper did not use the chain saw at all and was only responsible for the preparation of piles from timber cut into lengths situated along the skidding track. The chain saw operators in this variant were responsible for tree felling as well as for their debranching and cross-cutting. Timber was skidded by a Timberjack 1010 forwarder.

AREA AND RESEARCH METHODS

The intermediate cutting during which the described investigations were carried out was conducted in a pine stand growing on a fresh mixed coniferous forest (BMśw) site. The stand was 39 years of age and was characterised by 0.9 stocking rate, full crown closure, breast height diameter of 15 cm, mean tree height of 15 m and volume of large growing stock of 220 $m^3 \cdot ha^{-1}$.

Energy expenditure

The determination of the energy expenditure on the post of the chain saw operator sustained by him during the operation time T_{02} required the knowledge of duration times of individual technological treatments during this time. The appropriate duration times of those operations were measured using an electronic stop watch with 1 s accuracy.

The following technological operations were classified as effective time T_1:
– preparation of the work station
– cutting-felling
– de-branching, manipulation, cross-cutting
– final de-branching
– preparation of timber piles for skidding.

The preparation of the work station consisted in the assessment of the tree position and selection of the felling direction, while final de-branching – in cutting branches from the bottom part of round timber assortments.

Auxiliary time T_2 included walks between consecutive cut trees – T_{22}.

Investigations of energy expenditure were carried out on a 44-year old worker with over 20-year long experience in this profession.

Energy expenditure was determined with the assistance of a method which involves measurements of lung ventilation which is based on the correlation between the amount of oxygen breathed in and the effort during work [Koradecka and Bugajska 1998]. Measurements were taken with the assistance of an MWE-1 meter which allows direct unit readouts of energy expenditures expressed in $kJ \cdot min^{-1}$. Energy expenditure readouts were carried out in three measurement cycles – at the beginning, in the middle and at the end of the work shift. The duration of each cycle was connected with the time needed to use the full fuel canister increased by the time necessary to prepare the work station in both experimental variants and the time required to form piles for skidding in variant I.

Static effort

The OWAS method was employed to assess work loads of static nature [Łastowiecka et al. 2001]. Field investigations involved observations of the worker at work and recording positions assumed by him during adopted time intervals (every 30 s). The recordings consisted in assigning individual positions appropriate four digit code describing positions of: arms, legs, back and external loads.

In the course of laboratory work, positions adopted during work recorded in the form of four digit codes were allocated to one of four ergonomic categories of work station assessment.

RESULTS AND DISCUSSION

Energy expenditure

The results presented in Table 1 indicate considerable variations of mean unit energy expenditures incurred to perform specific technological operations. The recorded values were contained between 10 $kJ \cdot min^{-1}$ up to nearly 46 $kJ \cdot min^{-1}$. The lowest energy expenditures, at the level of less than 11 $kJ \cdot min^{-1}$, were recorded for the preparation of the

Table 1. Mean values of energy expenditures for technological operations
Tabela 1. Średnie wartości wydatków energetycznych dla zabiegów technologicznych

Technological treatment Zabieg technologiczny	Mean Średnia $kJ \cdot min^{-1}$	Standard deviation Odchylenie standardowe $kJ \cdot min^{-1}$	Coefficient of variability Współczynnik zmienności %
Stand preparation Przygotowanie stanowiska	10.7	5.16	48.29
Cutting, felling Ścinka, obalanie	14.3	4.19	29.26
De-branching, handling, cross-cutting Okrzesywanie, manipulacja, przerzynka	24.5	4.69	19.18
Final de-branching Dokrzesanie	25.6	4.67	18.25
Passes Przejścia	21.1	4.75	22.53
Package formation Formowanie pakietów	45.7	3.74	8.19

work station. Simultaneously, in the course of the realisation of this task, the greatest variations in measurement values were observed. The variability coefficient in this case amounted to 48% and was several times higher than in the remaining operations. Another case of energy expenditure which did not exceed the limit of the so called sustained organism efficiency of 17 $kJ \cdot min^{-1}$ [Löffler 1990] was the cutting-felling operation. For the remaining operations carried out with the aid of the chain saw, mean unit energy expenditures were contained within 20 to 25 $kJ \cdot min^{-1}$ interval. The highest energy expenditures reaching almost 46 $kJ \cdot min^{-1}$ were recorded in the course of the formation of timber piles for skidding. It should also be emphasised that this operation was also characterised by the smallest variations in measurement values; the calculated variability coefficient amounted here to 8%.

The obtained mean values of unit energy expenditures in the course of performed operations indicate that timber harvesting in intermediate cutting using chain saws requires considerable effort (Table 2). In the case of both analysed technological variants, energy expenditure exceeded 20 $kJ \cdot min^{-1}$, i.e. the above-mentioned limiting value of organism sustained efficiency. In variant I, the fact that the chain saw operator also had to prepare timber piles for skidding increased the mean energy expenditure by over 7 $kJ \cdot min^{-1}$ reaching the level of nearly 30 $kJ \cdot min^{-1}$. Variations in measuring values were greater in variant II; in this variant the variability coefficient reached 16%, while in variant I – 10.5%. The calculated 95% confidence intervals for the mean amounted to 29.8 ±5.9 in variant I and to 22.3 ±7.4 in variant II. The range of the confidence interval in variant II indicates that it is probable to reduce the energy expenditure in this variant to the limiting value, whereas in the case of variant I – it is practically impossible.

In order to check the significance of differences of the chain saw operator's energy expenditures, a Student's t-test was conducted in both experimental variants with the earlier evaluation of variance. The obtained results indicate statistically significant

Table 2. Mean-weighted energy expenditure of a chain saw operator during operational time
Tabela 2. Średnioważony wydatek energetyczny operatora pilarki w czasie operacyjnym

Method of work organisation Sposób organizacji pracy	Mean Średnia $kJ \cdot min^{-1}$	Standard deviation Odchylenie standardowe $kJ \cdot min^{-1}$	Coefficient of variability Współczynnik zmienności %
Only chain saw operator Tylko operator pilarki	29.8	2.85	9.56
Two chain saw operators and helper Dwóch operatorów pilarek i pomocnik	22.3	3.60	16.13

Table 3. Results of Student's t-test for unit energy expenditure of a chain saw operator
Tabela 3. Wyniki testu *t* Studenta dla jednostkowego wydatku energetycznego operatora pilarki

Variables Zmienne	*F* Snedecor's test Test *F* Snedecora		T-Student's 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 $t_{0,05}$
Variant I Wariant I Variant II Wariant II	1.38	1.91	8.274	2.010

diversification of mean-weighted unit energy expenditures of the chain saw operator in the analysed variants (Table 3).

Static load

In the course of the realisation of technological operations, the worker assumed positions from all the categories from the list of evaluation of the work station (Table 4). The only operation carried out in a position which failed to exert any negative impact on the muscle-skeletal system (category 1) was associated with walking. A very high proportion (90% or higher) of category 1 positions was also recorded in the course of the work station preparation in both variants as well as during the cutting-felling operation in variant II. In variant I, the proportion of category 1 positions during the cutting-felling operations amounted only to 75%. The remaining 25% of observations were associated with categories 2 and 3, with a greater share of the latter one. In variant II, the proportion of category 3 operations was recorded at the level of 4%, while no positions from category 2 were recorded. Among operations which required considerable static effort was debranching combined with handling and cross cutting. In both experimental variants, the proportion of category 2 positions exceeded here 75% which can be attributed to the fact that the worker carrying out operations on the trunk of a cut tree lying directly on the ground had to bend all the time. A similar situation was

Table 4. Results of static load assessment of a worker during realisation of operations
Tabela 4. Wyniki oceny obciążenia statycznego robotnika w czasie realizacji zabiegów

Technological treatment Zabieg technologiczny	Variant I – Wariant I				Variant II – Wariant II			
	category of work station assessment kategoria oceny stanowiska pracy							
	1	2	3	4	1	2	3	4
	percentage of observations – procent obserwacji							
Stand preparation Przygotowanie stanowiska	95.24	4.76	–	–	90.00	10.00	–	–
Cutting, felling Ścinka, obalanie	75.76	10.10	14.14	–	96.00	–	4.00	–
De-branching, handling, cross-cutting Okrzesywanie, manipulacja, przerzynka	22.08	76.42	0.94	0.57	22.42	77.58	–	–
Final de-branching Dokrzesanie	41.30	58.70	–	–	36.59	63.41	–	–
Passes Przejścia	100	–	–	–	100	–	–	–
Package formation Formowanie pakietów	62.93	35.73	1.33	–				

Table 5. Results of static load assessment of a worker during operational time
Tabela 5. Wyniki oceny obciążenia statycznego robotnika w czasie operacyjnym

Technological variant Wariant technologiczny	Category of work station assessment Kategoria oceny stanowiska pracy	Percentage of observations Procent obserwacji
Variant I Wariant I	1	49.07
	2	48.65
	3	2.02
	4	0.25
Variant II Wariant II	1	45.17
	2	54.28
	3	0.56
	4	–

observed in the case of additional debranching where the proportion of category 2 positions was found to be at the level of 60%. In the course of pile formation, an operation carried out only in variant I, nearly 36% of observations involved category 2 positions, about 1% – category 3, while the remaining 63% – to the first category of work station assessment.

Taking into consideration the entire operation time, positions unfavourable from the point of view of static loads were assumed more often in variant II (Table 5). The joint proportion of categories 2 and 3 positions reached here almost 55%, whereas in variant I – 51%. Even greater differences can be noticed analysing only the proportion of the category 2 positions which was found to be about 48% and over 54% for experimental variant I and II, respectively.

CONCLUSIONS

1. Unit energy expenditures of the chain saw operator during operation time, in both analysed technological variants, exceeded the value accepted as the boundary of the sustained efficiency of organism (17.6 $kJ \cdot min^{-1}$).

2. The work of the operator in variant I was characterised by statistically significantly higher unit energy expenditure. This was due to the fact that the operator also had to prepare timber piles for skidding.

3. With regard to static loads to which the chain saw operator was exposed, the first experimental variant turned out to be a more advantageous organisational solution. In the case of variant II, a greater proportion of positions classified as the category of loads negatively affecting human muscle-skeletal system was recorded.

REFERENCES

Grzywiński W., 2005. Obciążenia fizyczne drwala [Physical loading of a feller]. Drwal 6, 10-11 [in Polish].

Koradecka D., Bugajska J., 1998. Ocena wielkości obciążenia pracą fizyczną na stanowiskach roboczych [Assessment of the level of loads with physical work on individual work stations]. Centr. Inst. Ochr. Pracy Warszawa [in Polish].

Kusiak W., 2008. Rynek harwesterów i forwarderów w Polsce w 2008 roku [Harvester and forwarder market in Poland in 2008]. Przegl. Leśn. 8, 14-15 [in Polish].

Löffler H., 1990. Arbeitswissenschaft für studierende der Forstwissenschaft. Uniw. Monach. Monachium.

Łastowiecka E., Bugajska J., Liu D., Konarska M., 2001. Metody badania i oceny obciążenia pracą fizyczną [Research methods and assessment of loading with physical work]. In: Obciążenie fizyczne i psychiczne pracą w rolnictwie. Eds F. Bujak, J. Zagórski. IMW Lublin, 21-32 [in Polish].

Moskalik T., 2000 a. Pozyskiwanie drewna w drzewostanach trzebieżowych z wykorzystaniem maszyn firmy Timberjack [Timber harvest in stands with intermediate cutting using Timberjack machines]. Las Pol. 12, 14-15 [in Polish].

Moskalik T., 2000 b. Zalety maszynowego pozyskiwania drewna [Advantages of machine timber harvesting]. Las Pol. 18, 18-19 [in Polish].

Moskalik T., 2002. Rozwój technik i technologii maszynowego pozyskiwania drewna [Development of techniques and technologies of machine timber harvesting]. Sylwan 10, 31-37 [in Polish].

Motała R., 2006. Proces transportu drewna z perspektywy międzynarodowego koncernu StoraEnso [Timber transport process from the perspective of the international Concern StoraEnso]. In: Materiały Forum Leśnego „Człowiek–Las–Drewno". Poznań 13 października 2006. Ornatus Poznań, 61-64 [in Polish].

Porter B., Porter K., 1998. Wpływ sposobu pozyskania i zrywki na środowisko leśne [Impact of the harvesting method and skidding on forest environment]. Przegl. Techn. Roln. Leśn. 6, 20-22 [in Polish].

Sowa J.M., Kulak D., 1999. Analiza wydatku energetycznego pilarza przy wykonywaniu czynności obróbczych związanych ze ścinką i wyróbką drzew [Analysis of the sawman's energy expenditure in the course of carrying out operations associated with tree felling and cutting into lengths]. In: Materiały Sympozjum „Tendencje i problemy mechanizacji prac leśnych w warunkach leśnictwa wielofunkcyjnego". Poznań 23-24 czerwca 1999. Prodruk Poznań, 165-172 [in Polish].

Sowa J.M., Kulak D., 2000. Związki techniki z poziomem wydatku energetycznego operatorów pilarek spalinowych [Relationships between technique and level of energy expenditure of power chainsaw operators]. In: Materiały III Konferencji Leśnej „Stan i perspektywy badań z zakresu użytkowania lasu". Sękocin Las 30-31 marca 2000. IBL Warszawa, 425-432 [in Polish].

Sowa J.M., Leszczyński K., Szewczyk G., 2006. Human energy expenditure in late thinning performed in mountain spruce stands. Wydatek energetyczny pracowników w trzebieży późnej w górskich drzewostanach świerkowych. Acta Sci. Pol. Silv. Colendar. Rat. Ind. Lignar. 5(1), 73-80.

Stempski W., Grodecki J., 2005. Effects of work methods on physical load of a logger in wood harvesting operations. Zesz. Nauk. AR Krak. 419, 91, 383-389.

Suwała M., 1995. Wpływ wybranych metod i środków pozyskiwania drewna na uszkodzenia nadziemnych części drzew oraz powierzchniowych warstw gleby w późnych trzebieżach drzewostanów sosnowych [Effect of selected methods and means of timber harvesting on damages of the over ground tree parts and surface soil layers in late fellings of pine stands]. Pr. Inst. Bad. Leśn. Ser. A, 786, 60-71 [in Polish].

WPŁYW ORGANIZACJI PRACY NA POZIOM WYDATKOWANEJ ENERGII I OBCIĄŻENIA STATYCZNE ROBOTNIKA W TRZEBIEŻY

Streszczenie. W pracy oceniono wydatek energetyczny i obciążenie statyczne operatora pilarki pozyskującego drewno w trzebieży drzewostanu sosnowego. Badaniami objęto dwa warianty technologiczne, różniące się organizacją pracy. W wariancie I wszystkie zabiegi technologiczne wykonywał jeden robotnik – operator pilarki, w wariancie II pracowało dwóch operatorów pilarek i pomocnik. Wydatek energetyczny określono na podstawie pomiaru wentylacji płuc, a obciążenie statyczne metodą OWAS. Uzyskane jednostkowe wydatki energetyczne netto operatora pilarki w wariantach przekraczały 20 $kJ \cdot min^{-1}$ i różniły się między sobą statystycznie istotnie. W obciążeniach statycznych w wariancie II stwierdzono większy udział pozycji niekorzystnie wpływających na układ mięśniowo-szkieletowy operatora.

Słowa kluczowe: pozyskiwanie drewna, trzebież, wysiłek fizyczny

Accepted for print – Zaakceptowano do druku: 10.02.2009

For citation – Do cytowania: Stempski W., 2009. Effect of labour organisation on the level of energy expenditure and static loads of a worker in intermediate cutting. Acta Sci. Pol., Silv. Colendar. Rat. Ind. Lignar. 8(2), 53-60.