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THE OPERATIVE LABOUR CONSUMPTION OF TECHNOLOGIES OF FUEL WOOD HARVESTING FROM IMPROVEMENT CUTTINGS IN PINE STANDS

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Abstract. The reduction of fuel fossil resources and the tendency to limit emission of harmful substances into the atmosphere have influenced an increase of utilization of wood, especially wood chips. The object of performed investigations was to determine the operative labour consumption of technologies applied in wood chips harvesting that nowadays are used in the PGL State Forests. The technologies analysed, differed in the extent to which machines were used. The assesment comprised work output. The technology based on mechanical skidding and chipping with a chipper with a mechanical feeding system was the least labour-consuming. The technology in which horse skidding was used and the wood was chipped with a chipper with a manual feeding was the most labour-consuming. Manual skidding was the most labour-consuming and chip trucking the least, with the exception of technology with horse skidding, which was the most labour-consuming.

Key words: fuel wood chips, chipping, chips harvesting, operative labour consumption

INTRODUCTION

The energetic utilization of wood is getting more and more significant. The reduction of fuel fossil and the attempts to establishing a configuration: environment-economy have caused in energetic to the explorations of the way to the broadest utilization of renewable resources in energetic [Nilsson 1999, Różański et al. 2002].

Wood, which is destined to produce energy, comes from the coupes, weedings and thinnings. The fuel wood from final fellings is harvested in forms of rolls, split wood, logging residues and branches and from improvement cuttings – in forms of rolls and rods. Moreover, such residues as: bark, shavings, sawdust and cones can be used in the local area. In order to obtain effective harvesting, transport and combustion, fuel wood should be harvested in the form of chips.

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In the PGL State Forests, in 2002, fuel chips were harvested in 3 forest divisions (Kliniska, Wejherowo, Czarna Białostocka). The stands from I and II age class were the basic material resources in the mentioned forest divisions. In Kliniska, fuel wood chips fed a local heat-generating plant for over 7000 m^2 of inhabited surface and a hospital heat-generating plant in Szczecin. A part of chips was used in industry. In Wejherowo all the chips were burnt in a local hospital. In 1997-1999 a part of chips heated a local housing heat-generating plant. In Czarna Białostocka 10 000 m^3 of chips were used in industry and over 20000 m^3 in a heat-generating plant [Taradejna 2002].

The amount of chips harvested in above mentioned forest divisions in the next years and its recipients are shown in Figures 1 and 2.

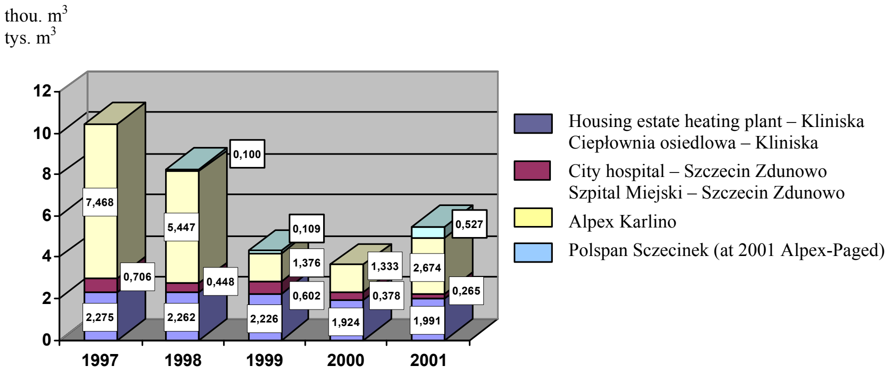

Fig. 1. The amount of harvested chips in the area of forest division in Kliniska, in years 1997-2001, including recipients. Source: Data from forest division of Kliniska
Rys. 1. Ilość pozyskiwanych zrębków na terenie Nadleśnictwa Kliniska w latach 1997--2001, z uwzględnieniem odbiorców. Źródło: dane Nadleśnictwa Kliniska

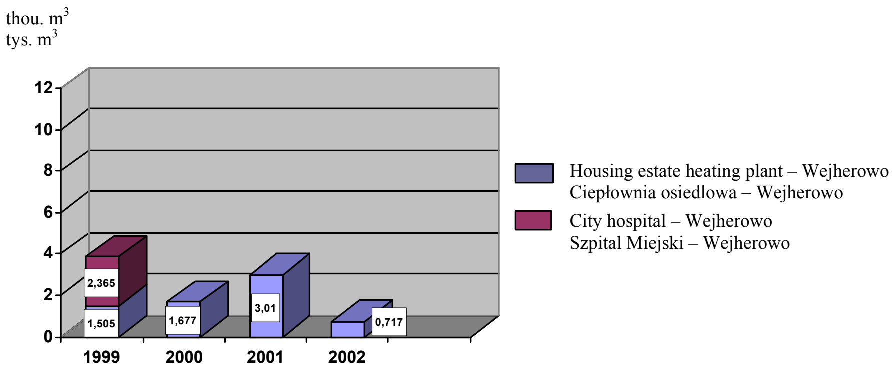

Fig. 2. The amount of harvested chips in the area of forest division in Wejherowo, in years 1999-2002, including recipients. Source: Data from forest division of Wejherowo
Rys. 2. Ilość pozyskiwanych zrębków na terenie Nadleśnictwa Wejherowo w latach 1999--2002, z uwzględnieniem odbiorców. Źródło: dane Nadleśnictwa Wejherowo

The technologies of the fuel wood chips harvesting in the area of the above mentioned forest divisions have had different degrees of mechanization and technique, which were used in individual operations. The purpose of the conducted research was to determine labour consumption of technologies, which were applied in the analysis. The obtained results can allow introducing modifications, which would significantly reduce the labour consumption of specific operations that were undertaken.

MATERIAL AND METHODS

The research was carried out in pine stands (II and III age classes). The experimental sites were situated in forest divisions of: Kliniska (1-2) and Wejherowo (3). The basic features of test areas are presented in Table 1.

Table 1. The basic features of research areas
Tabela 1. Podstawowe cechy taksacyjne powierzchni wybranych do badań

Specification Wyszczególnienie	Area* – Powierzchnia*		
	1	2	3
Dimension of area, ha – Wielkość powierzchni, ha	1.00	1.40	5.10
Natural station – Siedlisko	Bśw	Bśw	BMśw
Participation of species – Udział gatunków	So	So	7So2Św1Md
Age – Wiek	41	41	22
Stand quality class – Bonitacja	II	II	I
Average d.b.h., cm – Przeciętna pierśnica, cm	10	10	11
Average height, m – Przeciętna wysokość, m	12	12	9
Afforestation – Zadrzewienie	0.9	0.9	0.8
Stand quality – Jakość	22	22	22

Area 1: Regional State Forest Directorates – Szczecin, Forest Division – Kliniska, Forest District – Załom, Compartment – 450c/449c.
Area 2: Regional State Forest Directorates – Szczecin, Forest Division – Kliniska, Forest District – Załom, Compartment – 449c.
Area 3: Regional State Forest Directorates – Gdańsk, Forest Division – Wejherowo, Forest District – Rekowo, Compartment – 180a.
Powierzchnia 1: RDLP – Szczecin, Nadleśnictwo – Kliniska, Leśnictwo – Załom, Oddział – 450c/449c.
Powierzchnia 2: RDLP – Szczecin, Nadleśnictwo – Kliniska, Leśnictwo – Załom, Oddział – 449c.
Powierzchnia 3: RDLP – Gdańsk, Nadleśnictwo – Wejherowo, Leśnictwo – Rekowo, Oddział – 180a.

The fuel wood chips were harvested in two basic variants of rods, namely:
A – rods conversion (length about 4.50 m – M_1, S_{3a}) to chipping,
B – rolls conversion (length 2.40 m – S_{2a}) and rods conversion (M_1) to chipping (for thick trees).
Variant A was applied only in area 2 (all the wood for chipping), whereas variants A and B in areas 1, 3.

The following operations were specified in conducted analysis:
– felling,
– limbing and conversion,
– skidding of individual assortments (M_1, S_{3a}, S_{2a}),
– chipping,
– chip trucking.

On surface 1 and 3 the harvesting was carried out by two-person groups comprising of a power saw operator and an assistant. A power saw operator made felling, limbing and conversion. The assistant simultaneously accomplished manual skidding of wood. The wood was taken out to skidding roads, compartment line or main road. On experimental surface 2 harvesting was carried out single (all the actions were made by power saw operator).

To decrease harvesting labour consumption, on surface 2, the limbing consisted of the cutting of tree crowns and thicker branches. On surface 1, and 3, limbing included cutting of tree crown and all branches.

The wood was taken away at a distance of: 5 m on surfaces 1 and 2, and 3 m on surface 3.

To ensure skidding, roads were prepared during harvesting. On surface 3, 6 roads for horse skidding at distance of approximately 70 m, which was 2.5-3 m wide, were prepared. Owing to a good localization of experimental areas 1 and 2 no skidding roads needed to be prepared.

Skidding was carried out with an agricultural tractor with a trailer (1, 2) and a horse (3).

Chipping was being proceeded at the main road. The chips were transported to the nearby heating plant at a distance of 7 km (1, 2) and 5 km (3).

The operation of chip trucking included full riding, unloading and empty riding.

The types of machines, which were used in each technologies are collated in Table 2.

Table 2. The types of machines, which were used in each technologies
Tabela 2. Rodzaje maszyn i urządzeń stosowanych w poszczególnych operacjach analizowanych procesów technologicznych

Specification Wyszczególnienie	Type of machines – Rodzaj urządzenia Area* – Powierzchnia* 1	2	3
Harvesting Pozyskanie	Husqvarna 346XP Husqvarna 350	Husqvarna 346 XP	Husqvarna 357XP
Skidding Zrywka	Fendt Favorit 612 LSA Turbo	Fendt Favorit 612 LSA Turbo	horse konna
Chipping Zrębkowanie	Bandit 1400	Bandit 1400	Vermeer BC1800A
Chip Trucking Wywóz zrębków	Kamaz 53212	Kamaz 53212	Jelcz 640

*See Table 1.
*Objaśnienia jak w tabeli 1.

The time of each operation was continuously and intermittently measured. The measurement was led with the aid of stop watch, and the accuracy was 1 second. The calculations based on formulas given below were used to define the operative labour consumption (P_{02}).

$$P_{02} = \frac{T_{02}}{Q} \; [\mathrm{h \cdot m^{-3}}]$$

Q – the quantity of cutting,
T_{02} – the operative active time.

$$T_{02} = T_1 + T_2$$

T_1 – effective active time (the time, within which accordingly to its application machine works, and an object of work and working groups are under load; this time includes the time of turning back or unloading the material, if these executed actions do not cause interruption in the process, In which the machine participates),

T_2 – subsidiary time (the time of turning back, when process is interrupted, the time of empty drive in working place, time of unloading of the gathered material and the time, in which the trailers were exchanged).

The operative labour consumption was counted for one employee.

RESULTS OF INVESTIGATIONS

The technology concerning horse skidding and chipping with Vermeer BC1800A chipper (with manual feeding) (4) was the most labour consuming. The operative labour consumption in this technology totalled 3.893 h·m^{-3} (Fig. 3).

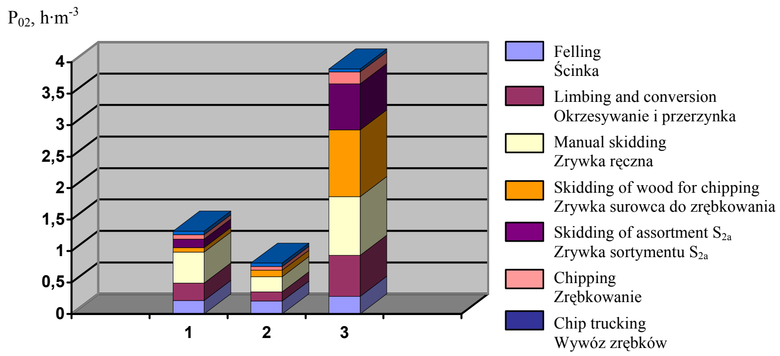

Fig. 3. The operative labour consumptiont of technologies of wood chips harvesting with specified operations
Rys. 3. Pracochłonność operacyjna procesów technologicznych pozyskiwania zrębków z wyszczególnieniem operacji

The technology in which the wood was extracted with an agricultural tractor with a trailer (Fendt Favorit LSA 612 Turbo) and the operation of chipping was carried out by a chipper with a mechanical feeding system (Bandit 1400) was the least labour consuming (P_{02} = 0.807 h·m^{-3}).

Basic data characterizing individual operations of technologies, which were analysed, are presented in Tables 3 and 4.

Table 3. The basic data characterizing the operations of felling, limbing, conversion and manual skidding
Tabela 3. Podstawowe wielkości charakteryzujące operacje ścinki, okrzesywania i przerzynki oraz zrywki ręcznej

Specification Wyszczególnienie	Area* – Powierzchnia*		
	1	2	3
Volume of harvested wood, m^3 Ilość pozyskanego surowca, m^3			
Total Ogółem	37.26	44.26	35.37
M_1, S_{3a}	31.06	44.26	26.44
S_{2a}	6.20	–	8.93
Number of removed trees, pcs Liczba ściętych drzew, szt.	1 258	1 976	1 554
Average volume of one tree, m^3 Średnia miąższość 1 sztuki, m^3	0.030	0.022	0.023
Average operative time of felling of one tree T_{02}, s Średni operacyjny czas ścinki 1 sztuki T_{02}, s	23	16	27
Average operative time of limbing and conversion of one tree T_{02}, s Średni operacyjny czas okrzesywanie i przerzynki 1 sztuki T_{02}, s	30	12	49
Average operative time of manual skidding of one tree T_{02}, s Średni operacyjny czas zrywki ręcznej 1 sztuki T_{02}, s	52	19	76
Operative time of felling T_{02}, h Operacyjny czas ścinki T_{02}, h	7.94	9.01	9.97
Operative time of limbing and conversion T_{02}, h Operacyjny czas okrzesywania i przerzynki T_{02}, h	10.37	6.59	23.03
Operative time of manual skidding T_{02}, h Operacyjny czas zrywki ręcznej T_{02}, h	18.31	10.65	33.00
Operative labour consumption of felling P_{02}, h·m^{-3} Pracochłonność operacyjna ścinki P_{02}, h·m^{-3}	**0.213**	**0.204**	**0.282**
Operative labour consumption of limbing and conversion P_{02}, h·m^{-3} Pracochłonność operacyjna okrzesywania i przerzynki P_{02}, h·m^{-3}	**0.278**	**0.149**	**0.649**
Operative labour consumption of manual skidding P_{02}, h·m^{-3} Pracochłonność operacyjna zrywki ręcznej P_{02}, h·m^{-3}	**0.491**	**0.241**	**0.933**

*See Table 1.
*Objaśnienia jak w tabeli 1.

Table 4. The basic values characterizing the operations of skidding, chipping and chip trucking
Tabela 4. Podstawowe wielkości charakteryzujące operacje zrywki, zrębkowania i wywozu zrębków

Specification Wyszczególnienie	Area* – Powierzchnia*		
	1	2	3
Average volume of load in one cycle of skidding of wood for chipping, m^3 Średnia miąższość ładunku w 1 cyklu zrywki surowca do zrębkowania, m^3	4.50	5.50	0.15
Average volume of load in one cycle of skidding of assortment S_{2a}, m^3 Średnia miąższość ładunku w 1 cyklu zrywki sortymentu S_{2a}, m^3	3.00	–	0.45
Volume of load in one full cycle of chip trucking, m^3 Miąższość ładunku w 1 pełnym cyklu wywozu zrębków, m^3	14.52	14.52	13.22
Average distance of skidding of wood for chipping, m Średnia odległość zrywki surowca do zrębkowania, m	300	400	80
Average distance of skidding of assortment S_{2a}, m Średnia odległość zrywki sortymentu S_{2a}, m	500	–	80
Distance of chip trucking, km Odległość wywozu zrębków, km	7	7	5
Operative time of skidding of wood for chipping T_{02}, h Operacyjny czas zrywki surowca do zrębkowania T_{02}, h	2.23	4.43	28.02
Operative time of skidding of assortment S_{2a} T_{02}, h Operacyjny czas zrywki sortymentu S_{2a} T_{02}, h	0.83	–	6.55
Operative time of chipping T_{02}, h Operacyjny czas zrębkowania T_{02}, h	2.16	2.64	4.95
Operative time of chip trucking T_{02}, h Operacyjny czas wywozu zrębków T_{02}, h	1.75	2.40	1.30
Average time of one cycle of chip trucking T_{02}, h Średni czas trwania 1 cyklu wywozu zrębkówT_{02}, h	0.58	0.60	0.65
Operative labour consumption of skidding of wood for chipping P_{02}, $h \cdot m^{-3}$ Pracochłonność operacyjna zrywki surowca do zrębkowania P_{02}, $h \cdot m^{-3}$	**0.072**	**0.100**	**1.060**
Operative labour consumption of skidding of assortment S_{2a} P_{02}, $h \cdot m^{-3}$ Pracochłonność operacyjna zrywki sortymentu S_{2a} P_{02}, $h \cdot m^{-3}$	**0.134**	**–**	**0.733**
Operative labour consumption of chipping P_{02}, $h \cdot m^{-3}$ Pracochłonność operacyjna zrębkowania P_{02}, $h \cdot m^{-3}$	**0.070**	**0.060**	**0.187**
Operative labour consumption of chip trucking P_{02}, $h \cdot m^{-3}$ Pracochłonność operacyjna wywozu zrębków P_{02}, $h \cdot m^{-3}$	**0.056**	**0.054**	**0.049**
Operative labour consumption of one full cycle of chip trucking P_{02}, $h \cdot m^{-3}$ Pracochłonność operacyjna 1 pełnego cyklu wywozu zrębków P_{02}, $h \cdot m^{-3}$	**0.040**	**0.041**	**0.049**

*See Table 1.
*Objaśnienia jak w tabeli 1.

In total, circa 117 m^3 wood (circa 102 m^3 of which comprises chips), was harvested from the investigative surfaces (1-3). The assortment S_{2a} constituted remaining 15 m^3. In total were cut down 4788 trees. An average volume of one harvested tree was from 0.02 m^3 to 0.03 m^3. An average operative time of felling of one tree was the lowest on surface 2 and it totalled 16 s.

On remaining surfaces, the average time of the felling of one tree took 23 s (1) and 27 s (3) respectively. The operative labour consumption of felling was amounted from 0.204 h·m^{-3} (2) to 0.282 h·m^{-3} (3).

A strongly branched stand on surface 3 and severe weather conditions (trees were harvested in temperature of almost 30°C made the operation more difficult.

The average operative time of the limbing and conversion of one tree totalled 12 s (2) (there were tree crowns and thicker branches cut), 30 s (1) and 49 s (3) (the strongly branched stand). The operative labour consumption of the limbing and conversion was totalled from 0.149 h·m^{-3} (2) to 0.649 h·m^{-3} (3).

The average operative time of the manual skidding of one tree was took from 19 s (2) to 76 s (3), and labour consumption of this operation was from 0.241 h·m^{-3} (2) to 0.993 h·m^{-3} (3). On surfaces, where two people worked (1, 3), the manual skidding was executed more slowly than on surfaces, where only 1 person worked. It was related with the fact that an assistant had to wait for preparation of raw material for manual skidding. The dead time was particularly high on surface 3 (70%).

When considering skidding, the operation, in which a horse was used (3), was the most labour-consuming. In case of wood for chipping, the value of operative labour consumption for skidding totalled circa 1.0 h·m^{-3} and in assortment S_{2a} case – circa 0.7 h·m^{-3}.

The lowest operative labour consumption was observed in the operation, where the mechanical skidding with an agricultural tractor with a trailer was used.

The skidding of wood for chipping with the agricultural tractor Fendt Favorit LSA Turbo with a trailer took from 0.07 h·m^{-3} to 0.10 h·m^{-3}. In assortment S_{2a} case, operative labour consumption for skidding totalled 0.134 h·m^{-3}.

The operative labour consumption of the chipping with a chipper with a mechanical feeding system was took 0.065 h·m^{-3}, for a chipper with a manual feeding totalled 0.187 h m^{-3}.

The chip trucking was the lowest labour consuming operation in all of the technologies, which were analysed. The value of operative labour consumption amounted circa 0.05 h·m^{-3}.

DISCUSSION

Wood harvesting in a forest farm is the most labour-consuming and oppressive technology [Laurow 1999]. Excluding geographical, natural, stand and weather conditions, the important issues are planning, organizing the work as well as a proper education of employees.

The results of the analysis concerning chip harvesting technologies raised doubts to the arguments that support the idea of harvesting of assortment S_{2a} (which comprise usually about 20% of the general amount of harvested material).

It was suggested, that if all the wood was harvested for chipping, the labour consumption of chip harvesting technologies would decrease.

Resignation from assortment S_{2a} facilitate the operation of limbing, in which only trees' crowns and thicker branches are cut. It enables to reducing labour consumption of this operation for about 50%.

Single harvesting can affect decrease of labour consumption of technology, too. It is advisable, while considering ergonomics. The performance of different actions enables employee to avoid work monotony. Furthermore, the application of mechanical skidding and conduction of chipping with a chipper with a mechanical feeding will have an influence on reducing labour consumption of technology.

In chip trucking case, the number and types of applied export vehicles should be adjusted to the effectiveness of chipping.

Finally, it is doubtless, that the least labour-consuming operation is the technology with application of multi-operative machines, which are able to perform felling and chipping of whole trees.

According to European Union's resolutions, which indicate the requirements concerning increments of the input of renewable resources in the general energy balance, it is proper to think about spreading the idea of taking advantage from heating with chips.

Except using rods for that aim, it should be considered, as it is in other countries, to increase the amount of branches and logging residues in general balance of biomass destined to energetic.

CONCLUSIONS

1. The technology in which horse skidding was used and the wood was chipped with a chipper with a manual feeding was the most labour-consuming.
2. The technology with mechanical skidding and chipping by a chipper with a mechanical feeding system was the least labour-consuming.
3. Manual skidding was the most labour-consuming (on average 34%), and chip trucking the least (4%). Exception – the technology with horse skidding, which was the most labour-consuming (46%).
4. Limbing including only the cutting of trees' crowns and thicker branches in comparison to limbing with cutting trees' crowns and all the branches allow reduction of labour consumption of this operation to about 50%.
5. Manual skidding in single harvesting in comparison to two-person groups facilitated reduction of labour consumption of this operation to over 50%.
6. In comparison to the usage of a chipper with a mechanical feeding system, the operative labour consumption was two times more effective when a chipper with manual feeding was used.

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PRACOCHŁONNOŚĆ OPERACYJNA PROCESÓW TECHNOLOGICZNYCH POZYSKIWANIA ZRĘBKÓW ENERGETYCZNYCH Z CIĘĆ PIELĘGNACYJNYCH DRZEWOSTANÓW SOSNOWYCH

Streszczenie. Wyczerpywanie się zasobów paliw kopalnych oraz dążenie do ograniczenia emisji szkodliwych gazów do atmosfery przyczyniło się do wzrostu zainteresowania energetycznym wykorzystaniem surowca drzewnego, a w szczególności zrębków. Celem badań było określenie pracochłonności operacyjnej stosowanych aktualnie w praktyce PGL LP procesów technologicznych pozyskiwania zrębków energetycznych. Charakteryzujące się różnym stopniem mechanizacji, procesy poddano analizie na podstawie wskaźnika pracochłonności. Najmniej pracochłonny okazał się proces z zastosowaniem zrywki nasiębiernej i zrębkowania z mechanicznym podawaniem surowca. Z kolei najbardziej pracochłonny był proces z zastosowaniem zrywki konnej oraz zrębkowania z podawaniem ręcznym. Przeprowadzona szczegółowa analiza pracochłonności poszczególnych operacji badanych procesów pozwoliła stwierdzić, iż najbardziej pracochłonna była operacja zrywki ręcznej, zaś najmniej operacja wywozu zrębków. Wyjątek stanowił proces z zastosowaniem zrywki konnej, w którym najbardziej pracochłonna okazała się zrywka konna.

Słowa kluczowe: zrębki energetyczne, zrębkowanie, pozyskiwanie zrębków, pracochłonność operacyjna

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