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ENERGY CONSUMPTION IN THE PRODUCTION OF CHIPS AND BUNDLES FROM LOGGING RESIDUES

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Abstract. The paper presents an analysis of energy consumption values for two machine energy wood harvesting technologies. Both technologies were used to produce woody fuels from logging residues, one focused on chipping and the other on bundling logging residues. The energy analysis comprised the built-in energy in the machines used, the energy contents of the fuels used and physical loads of machine operators. The energy contained in the fuels used by the machines dominated and its share in the total consumption reached 75%. The analysis of energy consumed in different technological operations showed, that the hauling of chips and bundles (50 km) were most energy consuming, and the energy consumption value reached 100 MJ/m^3. Both energy wood harvesting technologies, in which wood chips as well as bundles were produced, showed similar energy consumption values, which amounted to about 196 MJ per 1 m^3 of woody fuels.

Key words: logging residues, woody fuels, wood chips, energy consumption

INTRODUCTION

The need to mitigate the climate change and to save fossil fuels contributes to using renewable energy sources. In the Polish conditions the main renewable energy potential is in biomass, not least in forest biomass. The problems of using forest biomass for energy purposes is widely presented in literature [Energi... 1999, Lundborg 1998, Wikström 2007, Różański and Jabłoński 2003, 2006].

The purpose of the investigation was to determine the energy consumptions of the technologies in which woody fuels in form of chips and bundles were produced from logging residues.

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METHODS

The investigations into the production of energy wood from logging residues were conducted in 100 year old pine tree-stands, in Dąbrowa, Stare Jabłonki and Orneta Forest Districts.

Two machine technologies were used for the harvesting of wood with operations covering the conversion of logging residues to woody fuels. One of the technologies comprised the chipping of logging residues on the clear-cut area and the hauling of the chips, while the other technology comprised the bundling of logging residues on the clear-cut area and the hauling of the bundles.

The technology used for the production of woody fuel in the form of chips comprised the following technological operations:
– felling, delimbing and bucking stems into wood assortments with a Timberjack 1270D one-grip harvester
– forwarding wood assortments with a Timberjack 1010D forwarder
– gathering the logging residues with a Timberjack 1010D forwarder
– chipping the logging residues with a Bruks 804 mobile chipper
– hauling the chips in containers for 50 km.

The technology used for the production of bundles from logging residues comprised the following technological operations:
– felling, delimbing and bucking stems into wood assortments with a Timberjack 1270D one-grip harvester
– forwarding wood assortments with a Timberjack 1010D forwarder
– bundling the logging residues with a Timberjack 1490D bundler
– forwarding the bundles with a Timberjack 1010D forwarder
– hauling the bundles for 50 km.

The operational productivities W_{02} of the technological operations were calculated based on time studies, according to rules specified in the Polish Forest Machine System [Botwin 1993].

The energy consumed in the course of the technologies used consisted of the following energies:
– energy built-in in the machines
– energy contents of the fuels used for operating the engines of the machines
– physical loads used by machine operators.

The built-in energy values in the machines were taken from a paper by Forbrig [2000], and the adopted value was 98 MJ per kg of the machine, assuming a 10000 mh economic use of a machine [Forstmaschinen 300... 2000]. The energy stored in the engine fuel used during machine operations was calculated by multiplicating the fuel consumption (dm^3/mh) by its energy content (38.22 MJ/dm^3), after Forbrig [2000]. The physical loads carried by machine operators were based on the unit energy load which was 3.1 kJ/min and was determined by Grzywiński [2005]. The energy load expressed in MJ per 1 mh was calculated into MJ per 1 m^3 of wood by dividing the MJ/mh value by operational productivity. Based on the publication by Kärhä and Vartiamäki [2006] it was assumed that one bundle made of logging residues contained 0.5 m^3 wood.

In the case of the technological operations referring to round wood assortments (felling, delimbing, bucking and forwarding the round wood), the energy values consumed by those operations were reduced to a fraction equal the share of logging residues in the total above-ground tree-stand biomass. This share was determined by detailed measurements of wood and logging residues on the clear-cut areas, where the investigations were conducted.

RESULTS

The results of the weight measurements of particular parts of trees on the test areas allowed to determine the participation of the logging residues in the above-ground tree weight. One adult tree contains on average 72 kg branch wood and 67 kg of twigs with needles. Assuming an average 300-400 tree per ha, one can expect 21.6-28.8 t of branch wood and 20.1-26.8 t of twigs on an area of one hectare. The share of logging residues in the above-ground biomass of trees is estimated at 15%.

The analysis results of the energy consumed by various machines for the harvesting, forwarding and hauling of logging residues are presented in Table 1. Out of the three

Table 1. Energy consumption values in the production of chips and bundles from logging residues
Tabela 1. Nakłady energetyczne poniesione podczas pozyskiwania zrębków i pakietów z pozostałości zrębowych

Operation Operacja	Energy wood harvesting technology Technologia pozyskiwania surowca energetycznego			
	energy wood chips zrębki energetyczne		bundles from logging residues pakiety z pozostałości zrębowych	
	time consumption pracochłonność mth/m^3	energy consumption nakład energii MJ/m^3	time consumption pracochłonność mth/m^3	energy consumption nakład energii MJ/m^3
Felling, delimbing and bucking* Ścinka, okrzesywanie i wyrzynka*	0.018	1.89	0.018	1.89
Forwarding of round wood* Zrywka drewna okrągłego *	0.030	2.53	0.030	2.53
Forwarding of logging residues Zrywka pozostałości zrębowych	0.091	50.67	–	–
Chipping Zrębkowanie	0.027	48.74	–	–
Bundling Pakietowanie	–	–	0.077	46.75
Forwarding of bundles Zrywka pakietów	–	–	0.067	37.15
Hauling of chips Wywóz zrębków	0.077	91.98	–	–
Hauling of bundles Wywóz pakietów	–	–	0.091	108.71
Total Razem	0.243	195.81	0.283	197.03

*Energy consumption reduced to the 15% share of logging residues in the total harvested tree biomass.
*Nakład energii odniesiony wyłącznie do pozostałości zrębowych, stanowiących 15% całej pozyskiwanej masy drewna.

analysed sources of energy consumed in the course of the harvesting, forwarding and hauling operations, the energy contained in the fuels consumed by the machines performing the operations dominated with a share of 75%. The rest was the energy consumed in the course of the manufacturing processes of the machines (the so called built-in energy). Interestingly enough, the share of energy consumed in the form of the physical loads by workers was insignificant.

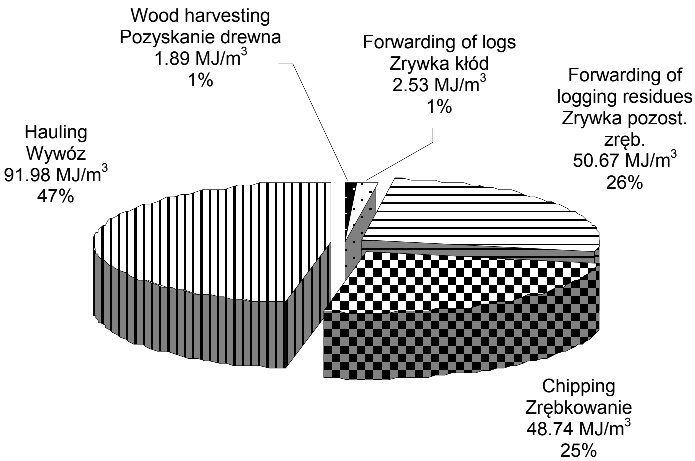

Fig. 1. Energy consumed by operations in the production of energy wood chips

Rys. 1. Nakłady energii na operacje technologiczne pozyskiwania zrębków energetycznych

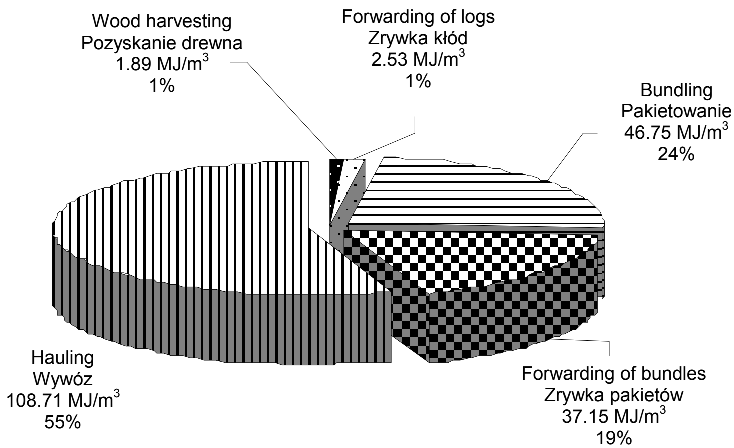

Fig. 2. Energy consumed by operations in the production of bundles from logging residues

Rys. 2. Nakłady energii na operacje technologiczne pozyskiwania pakietów wykonanych z pozostałości zrębowych

The analysis of energy consumed in different technological operations showed, that the hauling of chips and bundles were most energy consuming, and the energy consumption value reached 100 MJ/m^3. Relatively low energy consumption values shown by the first two round wood harvesting and forwarding operations resulted from the fact that only a fraction of the energy consumed by these two operations was taken into account. The fraction corresponded with the share of logging residues in the total biomass harvested, which amounted to 15%.

Figures 1 and 2 show the energy consumption values broken down into the operations of the two technologies analysed. In both cases the hauling of the woody fuels in the form of chips and bundles consumed as much as 80% of the total energy. It should be noted however, that the energy consumption in the hauling operation strongly depends on the hauling distance. In the experiment, this distance reached 50 km, which was a modest value considering the vast spaces covered by forests. Longer hauling distances would definitely lead to still higher energy amounts consumed by this operation.

CONCLUSIONS

In the case of the technology which included the chipping of logging residues, the operations of forwarding the logging residues and their chipping showed similar energy consumption values, 50.67 MJ/m^3 and 48.74 MJ/m^3, respectively. Each of them constituted a quarter of the total energy consumed by the technology. In the case of the bundling technology, the operation of bundling (46.75 MJ/m^3) performed with a bundler consumed 5% more energy than the operation of forwarding the bundles (37.15 MJ/m^3). In both technologies the operations of felling, delimbing, bucking and forwarding round wood assortments made up 2.3% of the total energy consumed by the whole technology. This low share of energy consumed by these operations resulted from the fact that the logging residues, from which the chips and bundles were made, participated with 15% in the total above-ground biomass.

Among various energy wood harvesting technologies, the fully mechanized ones, characterised by high productivity values are really worth considering. They can be successfully used for the harvesting of energy wood from logging residues which are left behind on the clear cut areas after the round wood in form of logs and boles has been extracted. Both energy wood harvesting technologies, in which wood chips, as well as bundles were produced, showed similar energy consumption values, which amounted to about 196 MJ/m^3.

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ENERGOCHŁONNOŚĆ POZYSKIWANIA ZRĘBKÓW I PAKIETÓW Z POZOSTAŁOŚCI ZRĘBOWYCH

Streszczenie. W pracy przedstawiono analizę energochłonności dwóch maszynowych technologii pozyskiwania drewna energetycznego. Obie technologie zostały wykorzystane do wyprodukowania paliwa drzewnego z pozostałości zrębowych. W jednej z nich skoncentrowano się na zrębkowaniu, w drugiej – na pakietowaniu pozostałości zrębowych. Analiza energochłonności obejmowała energię maszyn, wartość energetyczną zużytych paliw oraz wydatek energetyczny operatorów maszyn. Dominowała energia zawarta w paliwach zużytych przez maszyny, a jej udział w całkowitym zużyciu energii wynosił 75%. W analizie energii wykorzystanej w czasie wykonywania różnych operacji technologicznych wykazano, że operacja wywozu zrębków i pakietów na odległość 50 km była energochłonna najbardziej, a wartość energochłonności osiągnęła 100 MJ/m^3. Obie technologie pozyskiwania drewna energetycznego, w postaci zarówno zrębków, jak i pakietów, charakteryzowały się podobnymi wartościami energochłonności, które wynosiły około 196 MJ na 1 m^3 paliwa drzewnego.

Słowa kluczowe: pozostałości zrębowe, paliwa drzewne, zrębki drzewne, energochłonność

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