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EFFICIENCY AND TECHNICAL PARAMETERS OF THE CRUSHING OF LOGGING RESIDUES WITH A MERI CRUSHER MJS-2.0 DT MACHINE

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Abstract. The crushing of the logging residues was carried out on a forest area, on a mixed fresh coniferous site (BMśw). The weight of the logging residues which were left behind on the clear cut area, after taking away the round wood assortments was 47 t. The object of the analysis was a Meri Crusher MJS-2.0 DT crushing machine powered by a Valtra T-190 tractor. The crusher was 2000 mm wide and the power of the tractor was 190 HP. During the analysis the quantity of the biomass to be milled and the productivity of the milling operation itself were determined. Based on given technical parameters of the crusher (the rpm of the PTO, number of cutters, diameter of the drum and the driving speed of the tractor), the rpm of the working drum, the linear velocity of the cutters, the power and torque of the working drum and the productivity of milling were determined. Based on the analysis of working movements of the machine, the total force on all the cutters as well as the average force per one cutter were calculated. It was found that the average force on one cutter was 770 N.

Key words: logging residues, crusher, labour consumption

INTRODUCTION

Wood harvesting in final fellings in pine stands touches the problem of the utilization of logging residues which are left behind on the clear cut area after the round wood assortments have been taken away. One of the utilization methods is to crush the residues and leave them in the site. The operation of crushing is usually carried out with crushers powered by relatively strong agricultural tractors. The efficiency of the operation depends on the quantity of the biomass contained in the logging residues as well as on the technical parameters of the crushing machine (working drum width, rotational speed of the drum, the number of cutters).

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The crushing machines that are used today consist of three main components: a working drum, a rear drum and a felling frame with fittings. The working drum is the most important part of a crusher, on which the cutters for milling the soil, stones and wood are fitted. The rear drum prevents pieces of wood and stones from flying behind the crusher, while the felling frame presents a special outfit of crushers used mainly for working in young tree-stands. The details of the construction and the kinematic scheme of the crusher which was used in the field work were presented in the paper by Różański and Jabłoński [2006].

METHODS

The logging residue crushing efficiency field tests were carried out on a forest site in the Dąbrowa Forest District (Regional Directorate of State Forests in Toruń), in forest compartment 207b. The area of 3.36 ha was covered with a mature 96 year old pine stand, the average dbh was 33 cm, the average height was 26 m and the yield was 332 $m^3 \cdot ha^{-1}$ (merchantable and small dimensional wood). The site was a mixed fresh coniferous one, and the site quality class was I,5. In the forest stand a 0.5 ha experimental plot was marked, on which detailed stand measurements were carried out (dbh, height, number of trees) and then 15 sample trees were selected according to the Urich II method, in order to determine the volume of stemwood branches and tops. The biomass of the sample trees was divided into wood assortments and logging residues (branches and tops with needles) with the help of a harvester. In the process of machine harvesting the trees were only partly delimbed by the harvester head, as some of the branches were thick and their cutting with the delimbing knives of the harvesting head might lead to some damage of the head.

The round wood assortments and the logging residues were weighed in fresh condition, with the accuracy of 1 kg. The crushing of the logging residues was carried out with a Meri Crusher MJS-2.0 DT machine powered by a Valtra T-190 agricultural tractor.

Based on the technical parameters of the tractor and crusher (PTO rotational velocity, number of cutters, milling drum diameter, driving speed, rear drum diameter; Table 1) the following characteristics were calculated:

– the rotational velocity of the milling rum,
– the linear velocity of the cutters,
– the power and torque of the milling drum and
– the milling efficiency of the machine.

The analysis of the movements of the cutters enabled the authors to determine the sum of circumferencial forces on the cutter tips and the average force exerted by one cutter. The formulas used for calculating the above mentioned traits are provided in the paper by Różański et al. [2006].

Table 1. Technical characteristics of the crusher MJS-2.0 DT and tractor Valtra T-190
Tabela 1. Dane techniczne rozdrabniarki MJS-2,0 DT i ciągnika Valtra T-190

Parameter Parametr	Symbol	Unit Jednostka	Value Wartość
Maximum tractor engine power Maksymalna moc na wale silnika ciągnika	P_1	kW	139.65
Power used for driving Moc zużyta na opory jazdy	P_j	kW	30
Tractor engine rotational speed Prędkość obrotowa wału silnika	n_1	min^{-1}	1 000
T-transmission ratio Przełożenie przekładni kątowej	i_1		17/23
Chain transmission ratio Przełożenie przekładni łańcuchowej	i_2		17/23
Diameter of working drum Średnica walca roboczego	D_r	mm	460
Length of working drum Długość walca roboczego	L_r	mm	2 000
Number of cutters Liczba zębów roboczych	z	pcs szt	74
Radius of the circle drawn by cutter tips Promień okręgu wierzchołków zębów	R_r	mm	330
Driving speed Prędkość jazdy	V_j	$km \cdot h^{-1}$	1.4

RESULTS

The results of the biomass measurements comprising the round wood and logging residues are presented in Table 2. The largest share in the total aboveground tree biomass was presented by wood logs (77.6%) while short pieces of round wood (up to 2.5 m long) represented only 7% of the total biomass. The share of logging residues in the total aboveground biomass reached over 15%, which is consistent with the results obtained by other authors [Kubiak et al. 1985, Pilarek et al. 2007].

Based on the relevant formulas [Różański et al. 2006], the basic figures characterizing the process of milling were calculated and they are presented in Table 3.

The theoretical productivity of the crushing of the logging residues was 0.18 $ha \cdot h^{-1}$. Taking into account that there were 47 t of logging residues on 1 ha area, the specific efficiency of crushing was 8.5 tonnes of residues per 1 h. The theoretical sum of the circumferencial forces on cutter tips was 5133 N, and average force per 1 cutter was 770 N. The linear speed of cutter tips v_r was 18.86 $m \cdot s^{-1}$.

Table 2. Weights of wood assortments produced in a final felling in a pine stand, per 1 ha
Tabela 2. Masy sortymentów uzyskanych w cięciach rębnych w drzewostanie sosnowym, na 1 ha

Wood assortment Sortyment	Weight – Masa	
	$kg \cdot ha^{-1}$	%
Logs – Kłody	238 602	77.6
Round wood pieces up to 2.5 m long Wyrzynki	21 827	7.1
Logging residues – Pozostałości zrębowe	47 242	15.3
Total – Razem	307 671	100.0

Table 3. Technical parameters calculated for the crusher
Tabela 3. Zbiorcze zestawienie określonych parametrów technicznych rozdrabniarki

Parameter Parametr	Symbol	Unit Jednostka	Value Wartość
Theoretical productivity Teoretyczna wydajność	W	$m^2 \cdot h^{-1}$	1 764
Rotational speed of the working drum Prędkość obrotowa wału roboczego	n_r	min^{-1}	546
Linear speed of cutter tips Prędkość obwodowa wierzchołków zębów roboczych	v_r	$m \cdot s^{-1}$	18.86
Power on the working drum Moc na wale roboczym	P_r	kW	96.86
Torque on the working drum Moment obrotowy na wale roboczym	M_r	N·m	1 694
Angular speed of the working drum Prędkość kątowa wału	ω_r	s^{-1}	57.18
Sum of circumferencial forces on cutter tips Suma sił obwodowych na wierzchołkach zębów	ΣF_r	N	5 133
Average circumferencial force on one cutter tip* Średnia siła obwodowa przypadająca na jeden ząb*	F_r	N	770

*The average force per one cutter was calculated, based on the assumption that of the 30% of all the cutters placed around the drum and were facing the ground, those which covered 30% of the drum length were hitting the residues at the same time.

*Średnią siłę obwodową przypadającą na jeden ząb roboczy obliczono, zakładając, że chwilowo pracuje 30% zębów rozmieszczonych na obwodzie bębna roboczego, na średniej szerokości 30% bębna.

In a prolonged usage of the crushing machine, the cutter tips wear down, which diminishes the diameter of the circle drawn by the cutter tips. That reduction, which can reach up to 10 mm of the radius of the circle drawn by the cutter tips leads to a 3% increase in the total force on the cutters. These small changes do not have any effect on the crushing process, but they can considerably reduce the life of cutter holders [Różański and Jabłoński 2001, Fig. 1 and 2].

The tractor Valtra T-190 that was used in the tests was able to provide slightly more power (and torque) on the PTO than was needed. Assuming that the power on the PTO shaft were 160 HP (117.7 kW; which would be enough to do the work and well within the power range suggested by the manufacturer of the crusher: 110-180 HP) the values of the torque and forces would be lower than those in Table 3.

CONCLUSIONS

1. Wood biomass measurements in a mature pine stand showed that about 15% of the aboveground tree biomass is left behind on the clear cut area in the form logging residues. On the area of 1 ha, with 300 trees on average, the total weight of the logging residues (branches with needles and tree tops) was 47 tonnes.

2. The theoretical productivity of milling was 0.18 $ha \cdot h^{-1}$, at the working drum rotational velocity of 540 rpm ($\omega_r = 57.18\ s^{-1}$), and assuming that 16% of the tractor's power was used for driving. The average force on one cutter was about 770 N. The instantaneous forces may however reach values which are even several times higher, when the cutters hit unyielding objects like stones or hard stumps.

3. The linear velocity of the cutter tips on the Meri Crusher MJS-2.0 DT was about 19 $m \cdot s^{-1}$, compared to very limited driving speed of the tractor (0.39 $m \cdot s^{-1}$).

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EFEKTYWNOŚĆ I PARAMETRY TECHNICZNE ROZDRABNIANIA POZOSTAŁOŚCI ZRĘBOWYCH MASZYNĄ MERI CRUSHER MJS-2,0 DT

Streszczenie. Rozdrabnianie pozostałości zrębowych prowadzono na powierzchni leśnej, na siedlisku BMśw. Masa pozostałości zrębowych, które znajdowały się na powierzchni po zabraniu z niej sortymentów drewna okrągłego wynosiła ok. 47 ton. Obiektem analizy była rozdrabniarka Meri Crusher MJS-2,0 DT, którą agregatowano z ciągnikiem Valtra T-190. Rozdrabniarka o szerokości roboczej 2000 mm była agregatowana z ciągnikiem o mocy 190 KM. Przy parametrach technicznych rozdrabniarki (prędkość obrotowa bębna, liczba elementów roboczych, średnica bębna roboczego, prędkość jazdy) określono prędkość obrotową wału roboczego, prędkość obwodową elementów roboczych, moc i moment obrotowy na wale roboczym oraz wydajność. Na podstawie analizy zjawisk występujących podczas pracy rozdrabniarki (analiza ruchu elementów roboczych) określono sumę sił i średnią siłę obwodową przypadającą na jeden element roboczy. Wykazano, że średnia siła obwodowa przypadająca na jeden element roboczy wyniosła około 770 N.

Słowa kluczowe: pozostałości zrębowe, rozdrabniarka, pracochłonność

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