EFFICIENCY OF ENERGY CHIPS PRODUCTION FROM LOGGING RESIDUES BY THE BANDIT 2090

Tadeusz Moskalik, Magda Ostolska
Warsaw University of Life Sciences
Faculty of Forestry
Nowoursynowska 159 Str.
02-776 Warszaw, Poland
tadeusz.moskalik@wl.sggw.pl

Abstract: *The continuous civilization and economic development is inseparably connected with enormous energy consumption. In the increasingly expanding energy sector, fossil fuels are being replaced with renewable energy sources. The European Union's energy targets to be met by 2020 talk about 20% of the EU energy to come from renewable resources. In the case of Poland, the energy share, coming from renewable sources, by 2020 should increase to 15%. Promoting the use of renewable energy sources contributes to the diversification of supply sources and creates conditions for the development of distributed energy, based on locally available resources. Taking into account Polish climatic and geographic conditions, it is believed that one of the main energy sources could be biomass, including that coming from forests as well. The paper presents the efficiency of energy chips produced from logging residues by a chipper Bandit 2090. The research was carried out in different forest conditions. The achieved work productivity rate ranged from 14 to 17* m^3*/h.*

Keywords: renewable energy, logging residues, wood chipper, work productivity rate

1 Introduction

In current situation, with the increasingly limited possibilities of acquisition of fossil fuels, and at the same time, with the ascending hazards caused by the results of the greenhouse effect, forest biomass, as an elementary source of renewable energy, became significantly more important. The ecological features, proving the rightness of choosing this energy source, are carbon neutralisation and a significant reduction of the nuisances created by substances released during its combustion, in comparison to other energy carriers. Bonding of large amounts of carbon dioxide during wood production is one of the elements preventing the negative climate changes. Price attractiveness and the possibility of decreasing a sometimes inconveniently high rate of unemployment in rural areas, makes forest biomass worth promoting as an energy producing material.

Tree biomass has always been utilised by humans for heating purposes in various forms: natural, transformed into charcoal, or in the form of gas. The 1970's produced many innovative ideas for finding new energy sources. At that time, with significant shortage of wood, particular attention was paid to the so-called logging residues. After a series of observations, it was decided that the most convenient form of small-size wood acquisition would be wood chipping in the forests on site, and transportation of the obtained loose raw material in containers to the plants. Depending on the quality of material, chips became an object of interest to production plants (manufacturing chip- and fibre-boards), and to power plants. In the recent years, both throughout the world and in Poland, technologies appeared consisting in the compression of logging residues in the form of bales.

At the beginning of the 1990's, in Poland it appeared necessary to implement appropriate standards allowing for clear differentiation between chips used for industrial and heating purposes. The Standard PN-91/D-95009 „Raw wood material. Forest chips", strictly defines fire-wood as raw material that may be burdened with a 50% share of soft rot, moreover, permitted are impurities in the form of branches, pine needles, and leaves. Another Standard PN-91/D-95019 „Raw wood material. Small-size wood", explains the dependencies between the type of raw material and the possibility of obtaining a given type of processed material. The above Standard defines logging wood residues as raw material in which all kinds of wood defects are permitted.

The economic profitability of production of bio-energy from lower quality wood is only possible with the use of a high mechanisation level in both the acquisition, and transportation and processing of the obtained raw material. This will ensure significant work capacity with simultaneous decrease of costs (Stampfer, Kaznian 2006) .

This paper presents the results referring to work efficiency of the production of energy chips coming from logging residues, with the use of BANDIT 2090.

2 Purpose and scope of the study

The basic purpose of the study is to analyse the effectiveness of forest biomass acquisition for energy production purposes, in specifically selected areas, allowing to obtain the desired raw material in the form of wood-chips of low and medium quality and market value, which allows to maintain forestry management in compliance with the idea of sustainable multifunctional forestry, according to which, profitability of the treatments and condition of the environment after the completion of work are treated on an equally high level.

The survey was carried out in the Dwukoly Forest Inspectorate, located in northern Poland. An important element of this work also is the analysis of source materials, acquired from the said Forest Inspectorate, presenting the sizes of energy wood-chips obtained in this area, and the characteristics of the areas where this manner of logging residues management was chosen after the completion of respective cultivation treatments.

3 Material and methods

The research plots, where all chipper work efficiency parameters were recorded, included four sections, three of which differed in terms of logging management due to a different selection of species and the purpose of performed cultivation treatments, and one section where a caring treatment was performed, characteristic of stands in their thickness growth culmination phase, namely late thinning. The basic data referring to these plots are presented in Table 1.

Subject to research was a chipper BANDIT 2090. This model is a typical compact drum chipper, designed to chip strongly branched boughs and whole trees. It is a very popular machine amongst enterprises who focus their activities on chipping operations in large forest areas.

Subject to research were the following operation parameters of the machine:

- work productivity rate,
- working day structure,
- costs of wood chip production.

Work productivity rate of the chipper - determined by the amount of processed energy chips in a time unit, measured in m^3/h, was based on the time that the machine needed to process respective amounts of raw wood material in the selected tree-stand conditions. The amount of raw material was determined on the ground of data originating from the settlements of Forest Services Enterprise and the Forest Inspectorate, based on the figures matching those from the reception of small-size raw material by the foresters working in given areas, in all examined cases. Operational work productivity rate was calculated according to the dependencies generally adopted for working machines:

$$W = Vz / t \ \ (m^3p/h) \qquad (1)$$

and

$$W = Qz / t\ (m^3/h) \qquad (2)$$

where:

Vz – loose volume of wood-chips produced within the entire amount of working time in respective tree-stand conditions, m^3p

Qz – solid volume of wood-chips produced within the entire amount of working time in respective tree-stand conditions, m^3

Loose volume of wood-chips produced within one cycle equaled the capacity of the container placed in the chipper operation areas, whereas solid volume of wood-chips was calculated according to the conversion unit, taken from the Standard [PN-93 D-95000], whose value was assumed to equal 0.42.

Table 1: Description of research plots in the Dwukoly Forest District

	Cutting category			
	IB	IIA	IIIA	TPP
Number of forest compartment	243b	10m	94d	63a
Forest district	Łomia	Narzym	Mostowo	Mostowo
Age [years]	81	100	92	65
Types of forest	Fresh mixed coniferous forest	fresh mixed hardwood forest	Fresh mixed coniferous forest	fresh mixed hardwood forest
Forest cover	1	0,9	0,7	0,9
Stand quality class	I.5	II	II	I
Area [ha]	6.38	3.8	5.03	16.12

The working day structure of a chipping machine was based on the chronometerage whose record was taken by means of a timer measuring the duration of each action being a component of a working cycle of the discussed machine. Before the research commenced, the following actions were performed:

- determination of the types and number of the observed facilities,
- selection of fractions (types of actions).

The number of working cycles performed during one work-shift depends on the operation time T, because

$$T = nc \times tc \qquad (3)$$

where :

nc – number of working cycles,

tc – duration of one working cycle.

Before the commencement of the research, the number of types of areas had also been chosen, which was necessary to determine the possibility of performing the research in a field space and time, depending on the layout of activities planned in the Forest Inspectorate. The recorded results were then put in forms, which enabled calculations and interpretations of the obtained figures.

Components of the whole chipping cycle are as follows:

- Drive for the load (t1) – tractor with trailer
- Forwarding and chipping of raw material (t2)
- Drive with the load (t3)
- Unloading (t4)
- Technical intervals (t5)
- Technological intervals (t6)

Due to the nature and specificity of chipper operation, it was decided that this paper should present the effects of work/operation of only this machine. It entailed separation of all component actions from amongst the chipping stage activities. This included measuring the times of:

- Grabbing of one portion (during the forwarding of raw material to the drum)
- Forwarding in the cycle.
- Time(s) of driver in the cycle.

The cost of the analysis was calculated by means of the PlusCalc software.

4 Results

In the Dwukoły Forest Inspectorate a chipper has been employed for the past seven years, however, due to the fact that over the first three years the machine was scarcely used, the paper only includes the past four years, i.e. 2006 – 2009 (Figure 1). The last two years are a time indicating the enhancement of areas included in this way of cultivation residues utilisation, resulting from the fact of enormous growth of the need for renewable energy sources.

The performed analysis of the practically employed technologies of energy chips production in Sweden, combined with supply of the material to power stations (Jabłoński K., Różański H. 2003) authenticated the essence of chipping conditions, giving it a key position (32% share) in the overall cost of supplying power stations with energy wood-chips. The elements connected with the transportation of wood-chips to a power station amounted to a 24% share, skidding of logging residues to 20%, the price of logging residues to 8%, the remaining 16% share was defined as other costs. The obtained results of a drum type chipping machine.

4.1 Work productivity rate

The analysed work capacity of the chipping machine, in the analysed cases, oscillated from around 14 m^3/h through to slightly above 17 m^3/h, which has been presented in Table 2.

The discrepancies come from the tree-stand differences and differences in the type and manner of the execution of cultivation treatments preceding the work of the chipper. The greatest work capacity was noted in the area 94d, where group-clear cutting was applied, where three openings in the stand of a total floor-area of approx. 1ha were performed, not exceeding 20% of the maneuvering zone. The treatment was performed with the use of chainsaws, and low-quality wood was then put in stacks, which significantly facilitated work of the skidding tractor and the chipper, amongst other factors, by reducing the average work cycle time to about 38 minutes and 9 seconds. Slightly lower productivity was noted in section 10m, in which shelterwood large-area by means of a Ponsse Ergo harvester and chainsaws in single cases. This combined treatment entailed felling of over 110-years-old pine trees, and lower quality oak trees, Hus preparing the stand to the natural large-seeded species restoration, the so called seed cutting. Due to a large concentration of raw material in the individual locations, connected with work of the harvester, (boughs and branches in rather large stacks once every few meters in the area); machines included in the observations obtained the shortest required time of a single working cycle (on average: 36 minutes and 47 seconds).

Another analysed area treated with clear cutting, performed with the use of a multi-operational machine (the same as in shelterwood IIA) within a total floor-area not exceeding 3 ha. Average work productivity rate of the tractor with trailer and chipper amounted to 15.82 m^3/h. The lowest productivity of the chipper was noted in the thinning area (section 63a) executed with a 20% intensification with the use of a harvester. The obtained work capacity of the chipping machine was into a large degree connected with the dispersion of raw material (16.12 ha section 63 a), smaller energy-chip wood sizes, resulting from factors like stand age (65 years), and into a lower degree from the type of forest community.

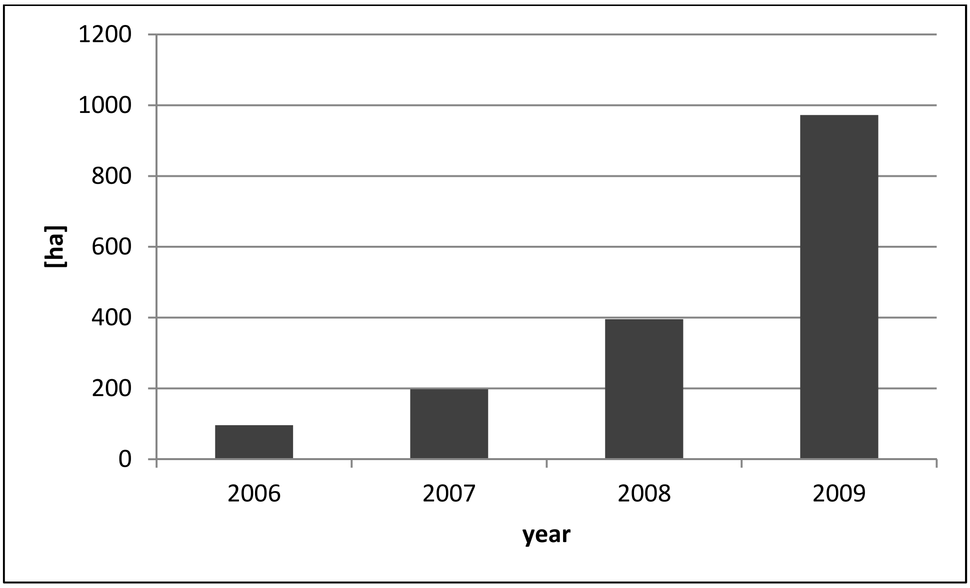

Figure 1: Total work area of BANDIT 2090 in years 2006 – 2009 in the Dwukoły Forest Inspectorate

The numbers obtained during the research carried out in the Dwukoły Forest Inspectorate were insignificantly greater than the results of the observation research on a self-running chipper Bruks 805 CT, whose work capacity amounted to an average of 27.2 mp/h, which converted/translated into the volume of the obtained material provided approx. 11.7 m^3/h (Zychowicz, Gendek 2009; Moskalik, Sadowski 2006).

An average hourly work capacity of the chipping machine, within an 8-hour working day, clearly shows a productivity drop after the first 1.5-hour work time in all logging areas (Figure 2). Another productivity drop, this time in all examined cases, falls onto approx. 11:30am and 1.00pm hours, which results from tiredness of the workers, increase of ambience temperature, lunch break, and machine maintenance.

4.2 Structure of machine work in one cycle

In the plots where the measurements of respective components of a full machine work cycle were taken, amongst other factors, time that the machine needed to approach the raw material assigned for chipping. In the first two examined cases, in cutting IB and IIA covered plots, a drive for the load makes some 4% of the entire chip production cycle time. In a cutting IIIA plot, this time amounted to 6.68%, which was probably the result of the need to driver between the openings in the stand. The greatest share of that time however was observed in the clear-cutting area, which certainly results from the dispersion of raw material and its smaller sizes.

Undoubtedly the most important element in the entire chipper operation cycle process is the chipping itself (t2), which is proven by its predominant share over the other components. In the plots included in clear cut manner of forest management it oscillates around 80%, which is a result of a large concentration of raw material and the manner of wood preparation for the chipping process, whereas in the plot covered by caring treatment it took almost 60%.

Due to such a great amount of time required for chipping, a decision was made to carry out a more accurate field survey of this very element of the machine operation. The results are presented in Table 3.

Table 2: Work productivity rate of Bandit 2090 for each plot

	Chips volume				Average mean value
Type of treatment	IB	IIA	IIIA	TPP	
Operational productivity	36.79	38.93	39.67	32.79	37.05
Effective productivity	38.44	40.6	40.19	35.65	38.72
	Wood volume				Average mean value
Cutting category	IB	IIA	IIIA	TPP	
Operational productivity	15.82	16.74	17.06	14.1	15.93
Effective productivity	16.53	17.46	17.23	15.33	16.64

Table 3: Times of biomass feeding and drives between consequential positions

	Cutting category				Average mean value
	IB	IIA	IIIAU	TPP	
Time of grip in whole cycle	00:12:38	00:11:44	00:12:25	00:10:23	00:11:47
Number of crane grip movements	53	55	54	56	54,5
Average time of one portion grasping [s]	14.3	12.8	13.8	11.2	13.03
Time of feeding in cycle	00:05:16	00:09:06	00:14:14	00:05:37	00:08:33
Number of supplied portions	54	57	74	39	56
Average time of feeding [s]	5.85	9.58	11.55	8.64	8.91
Time of driver in cycle	00:12:49	00:07:38	00:05:41	00:09:07	00:08:49
Number of drives	19	13	12	17	15,25
Average time of one drive [s]	40.5	35.2	28.5	3.2	34.1
Mean time value - t2	00:30:43	00:28:28	00:32:20	00:25:07	00:29:09

The above table clearly shows what a great effect productivity has on the frequency and types of time elements being components of work cycles.

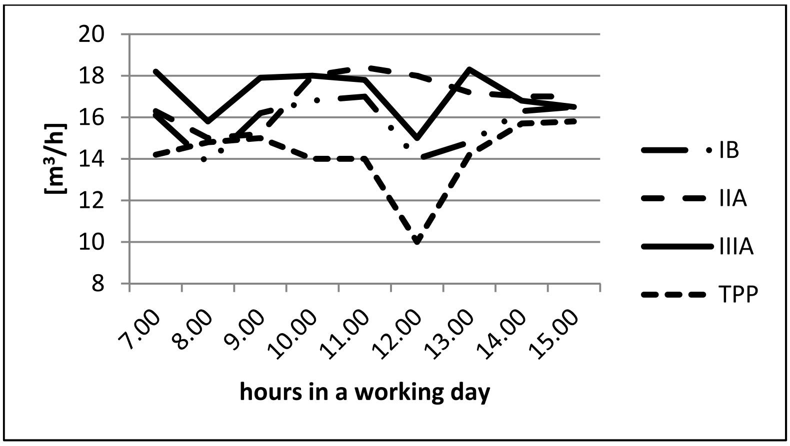

Figure 2: Work productivity rate of BANDIT 2090 in particular working hours

4.3 Costs

In the chipping process, an important role plays the economic side of the analysed process. During the research the following costs were calculated:

1. Hourly cost of use of a tractor-towed chipper – 52.30 Euro
2. Hourly cost of use of a tractor with trailer – 30.91 Euro
3. Total cost of the machine kit cooperation – 83.21 Euro
4. Cost of chipping of 1 m^3 of wood material – 3.30 Euro
5. Cost of extraction of 1m^3 of wood material – 1.55 Euro
6. Cost of production of 1m^3 wood-chips (excluding transport) – 4.85 Euro

It was calculated by the 1PLN = 0,25Euro

The total hourly cost in this work is close to the utilisation costs of a chipper Bruks 805 CT. This cost amounted to 83.5 Euro/h (Zychowicz, Gendek 2009). However, the obtained unit cost of production of 1m^3 of energy chips by Bandit 2090 were significantly lower comparing to the said machine, where it amounted to approx. 10.3 Euro/ m^3. This probably results from the terrain specificity or from the manner of the work structure preparation. Results presented by Eker (2011) show that unit cost amounted from 2 Euro/t (in case of small chipper) to 5,6 Euro/t (by middle sized chipper).

Percentage structure of respective machine work costs is presented in Figure 3.

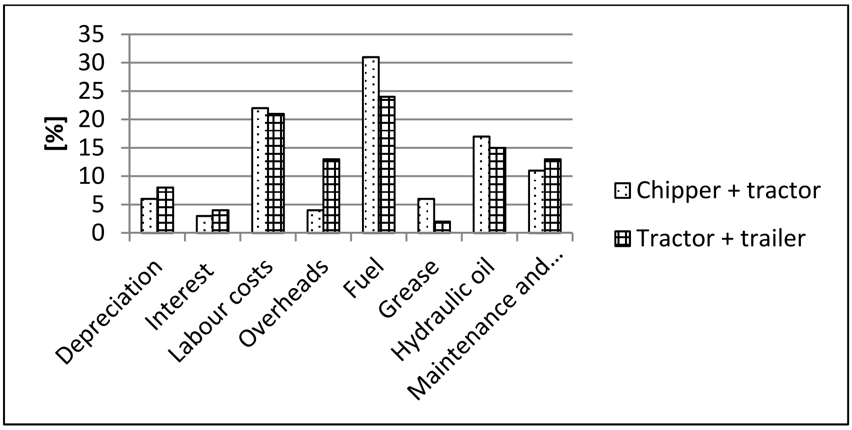

Figure 3. Percentage structure of the hourly cost elements

5 Conclusions

On the ground of the performed research the following conclusions may be drawn:

In the recent years, energy wood-chips have become a subject of increased interest as a source of renewable energy. The performed analysis of a scale of energy wood-chips acquisition for power production purposes over the past four years on the example of the Dwukoły Forest Inspectorate allows us to say that desire for this type of raw material is continually increasing.

Average work capacity of a chipping machine amounts to 15.93 m^3/h. This number varies depending on the type of a tree-stand where the work carried out, and it oscillated within 14.1 to 17.06 m^3/h. The decisive factor in this situation, determining the changes in productivity, are tree-stand conditions and concentration and the manner of raw material placement.

Hourly costs of chipping amount to approx. 52 Euro The unit cost of chipping of 1m^3 of wood-chips in the plots amounted to around 3.3 Euro on average. The obtained price values were possible thanks to cooperation of machine operators in the research areas and good training of the persons preparing work infrastructure.

Basic parameters determining profitability of wood-chip production are high prices of the machinery, fuel, hydraulic oil and maintenance/repairs (in particular of hydraulic tubes and replacement of chipper knives/scissors). On the ground of the obtained price values we can firmly say that an element necessary for effective wood-chip production are appropriate work organisation and preparation of raw material.

The greatest percentage share, from amongst the components of the whole work cycle, appeared to be the chipping process, taking on average approx. 75%. This figure also includes material collection. The time of feeding takes on average some 29.33%, and strictly depends on the number of portions of collected material and the manner of placement/stacking, which directly affects the smoothness of the entire operation.

6 References

1. Jabłoński K., Różański H. (2003) Prospects for fuel wood harvesting in Poland. Acta Scientiarum Polonorum, Seria Silvarum Colendarum Ratio et Industria Lignaria. Poznań. Nr 2(1), 19-26.

2. Eker M. (2011) Assessment of procurement systems for unutilized logging residues for Brutian pine forest of Turkey. African Journal of Biotechnology Vol. 10(13), pp. 2455-2468.

3. Moskalik T., Sadowski J. (2006) Utilisation of logging residues by Bruks CT chipper. 39th International Symposium on Forestry Mechanisation – Formec. Sofia. Bulgaria.

4. Stampfer K, Kanzian C (2006). Current state and development possibilities of wood chip supply chains in Austria. Croatian J. For. Eng. 27(2): 135-145.

5. Zychowicz W., Gendek A. (2009) Efektywność stosowania samobieżnej rębarki z zasobnikiem do pozyskiwania zrębków na cele energetyczne. KMRiL SGGW. Warszawa.

The research was carried out within the framework of the grant: “Projekt międzynarodowy niewspółfinansowany - Efektywność procesów pozyskiwania, przetwarzania i dostaw biomasy leśnej do celów energetycznych” realised within COST ACTION FP0902.