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Research on Disc Cutting Unit for Cutting Energy Plants

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Summary. The paper presents the results of laboratory tests concerning the cutting process of basket willow by means of disc cutting unit. A disc for cutting wood with diameter of 600mm was used in the tests. The influence of plant's moisture and the rotary speed of the disc of cutting unit on the unitary energy were determined. The most favorable values of the operating parameters of the cutting unit were selected according to the minimum energy requirement in the cutting process of the tested plant.
Key words: cutting process, energy plants, unitary energy of cutting, moisture, rotary speed of cutting unit, basket willow.

INTRODUCTION

No matter how long the fossil fuels will suffice, the ecological aspect itself is the reason to take interest in renewable energy. The constant increase in demand for different forms of energy has caused the use of the wind, sun, biomass and geothermal energy, in other words, the sources of energy functioning in accordance with the principle of balanced development [3, 7, 8, 16]. Biomass, particularly, seems to be easy to use.

The most popular plant used for biomass production is energy willow [4, 9, 11]. Harvest and fragmentation are the most important steps in the technology of the plant's production [5, 12, 13, 14, 15]. The main idea of the research is the reduction of energy consumption in the cutting process of the plants' stems during the harvest. That is why the most favorable values of the operating parameters of cutting unit in the process of plants' cutting need to be established [6, 10, 24]. These parameters could be determined on the basis of the research carried out at the laboratory stand.

THE PURPOSE OF THE RESEARCH

The aim of the research was to determine the influence of the rotary speed of cutting unit and of plant's stem's moisture on the cutting process of basket willow. A disk for cutting wood was used as the cutting unit for the first time. In the study, an attempt was made to determine the optimum rotary speed of cutting unit at which the unitary energy of cutting process would be the lowest. The notion of unitary energy means the total energy needed for the cutting process of plants in relation to cross-section of their stems.

The research was carried out at the laboratory stand for researching the rotary cutting process of energy plants, at the Institute of Mechanical Engineering – Technical University of Warsaw in Płock. The research was a continuation of studies which had been carried out for many years [17, 18, 19, 20, 26, 27].

THE SUBJECT OF RESEARCH

The most popular species of willow used for energy purpose, i.e. basket willow, was selected for the studies. The plant is characterized by high biomass increase and high resistance to diseases and pests. It is a very popular plant in Poland, which grows in the whole country. It commonly grows on the edge of watercourses and wetlands. It comes in the form of trees and shrubs.

The basket willow grown for energy purposes is collected in one, two or three-year cycles. Depending on the position and age, its shoots reach the height of 6 m and the stems reach the diameter of 80 mm. Young shoots are flabby and very flexible. They are covered with silvery hair and sometimes change color into green or greyish. Intensely green leaves, with a visible yellow nerve, are 80–250 mm long and 6–12 mm wide. Cylindrical catkins, which bloom before the leaves appear, are its inflorescence. In the field crop, the willow is multiplied by vegetation, planting shoots cut into 250 mm long pieces and with diameter not smaller than 7 mm. The shoots cut in such a way, having been planted, take root and churn out new shoots.

The most useful areas for willow cultivation are places with class III, IV and V soils with sufficient moisture. In the process of growing willow, rainfall is very important especially in spring, because no rainfall may result in reducing the development of the root system of plants. The appropriate level of groundwater is also of vital importance. The assumed collecting system – two or three phase – should be taken into consideration while planning planting the willow. Machine harvesting requires taking into consideration the fact that heavy machinery will enter the field and it should not destroy the willow's freshly cut stumps. In case of one-phase harvesting the willow is planted in rows. Two rows were planted with the spacing of 0,75–0,8m and the rest with the spacing of 1,25–1,5 m. The space between plants in a single row is 0,45–0,5m. In case of two-phase harvesting the recommended spacing is 0,7–0,8m and the space between plants in a row 0,4–0,45m [1, 2, 21, 22, 23].

Fig. 1. Plantation of basket willow

RESEARCH STATION

In order to determine the energy consumption during the cutting process of energy plants, a special research station was built for carrying out different studies of cutting processes of various energy plants with different structure. The studies were carried out with the usage of different rotary cutting devices. Fig. 2. [25] presents the structure of the research station.

For the station's drives three-phase motors Celma Indukta codenamed SKH 90S-2 and 2SIE100L6 with rated power of 1.5 kW each were used. The first motor was used to drive the cutting unit. Its max rotary speed was n = 2835 rpm. The other motor was driving the truck with plant's

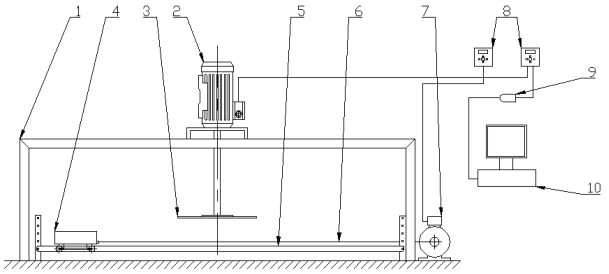

Fig. 2. Research station for studying the cutting process of energy plants: *1* – frame, *2* – electric motor for cutting unit, *3* – cutting disc, *4* – truck for holding the samples, *5* – truck slideway, *6* – truck's drive cord, *7* – electric motor for truck, *8* –LG series iG5A frequency converter, *9* – signal converter ADA – I9140, *10* – controlling computer with DriveView7software

samples by means of a line being rolled on cable wheel, which simulated the mower's movements on the field. Its max rotary speed was n = 950 rpm.

The key element in the carried out experiment was the cutting disk. Two disks were selected – one with diameter of 710 mm (100 teeth and 4mm thickness), the other with diameter 600mm (200 teeth and 3,2mm thickness) (Fig. 3.).

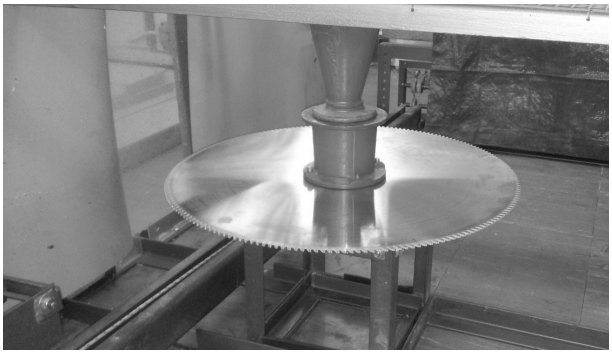

Fig. 3. Disc of cutting unit PI – 505 600 x 100 x 3,2

Rotary speed of the cutting unit and travelling speed of the truck with plant's samples were controlled due to the fact that power frequency was converted by means of inverters. The signal converter ADA – I9140 and a computer with DriveView7 controlling software were used to register the power consumption at the time. By means of measuring – controlling card a signal was sent from inverter to the computer. The changes in power consumption by motor driving the cutting unit were registered by the computer. With Autodesk AutoCAD software it was possible to determine the surface area under the graph which corresponded with the energy consumed during the cutting process of the willow. The total gained energy was referred to the cross – section area of plant's samples which gave the unitary energy of the cutting process in J/mm².

THE METHODOLOGY AND THE COURSE OF THE RESEARCH

Two cutting disks were tested in the research. The one with bigger diameter and teeth (710x100x4) put too much

resistance and the cutting process did not go smoothly. That is why a smaller disk (600x100x3,2) made especially for the research purpose was used. The samples of energy willow were collected at different times which gave samples with different levels of moisture. The samples placed on the truck were 150mm long with diameter of 8-27mm. The smaller plants were divided into 4 groups in order to easily count the cross section of the stems. The samples on the truck were cut at the height of about 65mm, that is at about 20-30mm measuring from the upper edge of truck. Each measurement was repeated minimum three times.

The cutting process of the plants took place using the following parameters:

– temperature 20 ºC,
– atmospheric pressure of 770 mmHg,
– disk's diameter φ = 600 mm,
– number of teeth on the disk z = 200 ,
– speed of the truck simulating linear motion of the cutting unit: V=0,0315 m/s,
– rotary speeds of cutting unit: n= 964, 1077, 1191 rpm,
– cross-sectional area of stems: 968 – 1386 mm²

Fig. 4. 150mm long samples prepared for the research

RESEARCH RESULTS

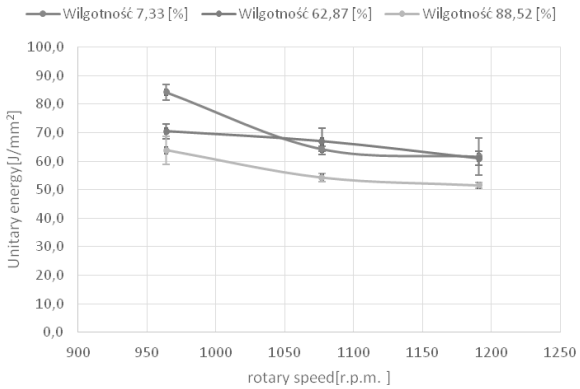

Fig. 5. The course of changes of the unitary energy of basket willow cutting process in the function of rotary speed of disk for 3 different values of moisture of the stems and at the constant speed of the truck V=0,0315 m/s Legend: wilgotność – moisture [%]

The unitary energy of the cutting process of basket willow decreases with the increase of the rotary speed of the disk of the cutting unit for all the moisture values of the stems tested (Fig. 5).

The bigger moisture of a plant, the lower unitary energy needed for the cutting process of plants.

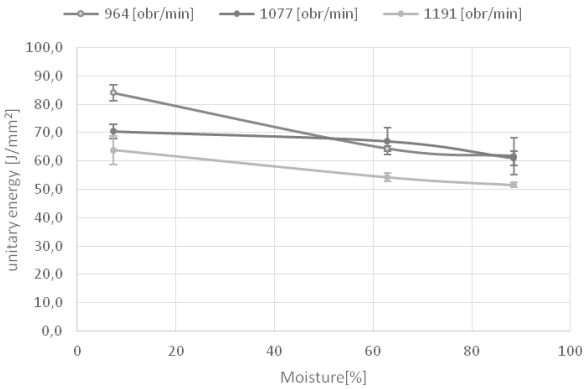

Fig. 6. The course of changes of the unitary energy of willow cutting process in the moisture function for 3 different rotary speeds of disk and at the constant speed of the truck V=0,0315 m/s

The unitary energy of the willow cutting process of using a disk decreases with the increase of the plants' moisture. It is true for each rotary speed of the cutting unit tested (Fig. 6.)

The higher rotary speed of the cutting unit, the lower unitary energy needed for the plants cutting process.

CONCLUSIONS

1. The unitary energy of the cutting process of basket willow decreases with the increase of moisture. That is why plants with high moisture level should be harvested. However, it causes the necessity to dry the harvested stems. It is worth while carrying out a full energetic analysis concerning the whole process of using basket willow as energy carrier.
2. The unitary energy of the cutting process of basket willow decreases with the increase of rotary speed of the cutting unit. That is why the stems should be cut at the maximum possible speed. However, this causes the increase of energy needed for driving the cutting unit. It is worth while finding the most optimal solution in this case.
3. The amount of samples placed on the truck influences the energy consumption of the cutting process of basket willow. The unitary energy increases with the amount of stems (while maintaining the cross-sectional area at a constant level). This results from the botanical characteristics of the plant because the outer layer (bark) is more resistant to the saw's blade than its core.
4. Using samples with the diameter bigger than 15mm at intervals of approximately 10mm stabilizes the cutting unit.
5. The motor with the power of 1,5 kW driving the cutting unit at low rotary speed (600–700 rpm) showed lack of power and torque. This narrowed the scope of research. For safety reasons the rotary speed did not exceed 1200 rpm.
6. In order to extend the scope of research it is recommended to exchange the electric motor with such one that

would enable carrying out the research with the installed disk with the diameter bigger than 600mm.
7. Modifying the research station so that it would be possible to install a disk with the diameter lower than 600mm is another issue.
8. In order to avoid unnecessary friction of samples against the disk it is recommended to use openings regulating the inclination angle of the slideway. Thanks to this the rotation axis of the disk would not be perpendicular to the upper edge of the truck with samples.
9. In order to simulate real conditions prevailing in the plantations of willow it would be reasonable to change the construction of the truck for placing samples. In the research, the stems were placed in one row. The optimal solution would be to place them in a pocket – as it is in natural conditions.
10. It would be worth while determining the influence of linear velocity of the cutting unit on the unitary energy of the cutting process in subsequent studies.

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BADANIA TARCZOWEGO ZESPOŁU TNĄCEGO DO CIĘCIA ROŚLIN ENERGETYCZNYCH

Streszczenie. W pracy zaprezentowano wyniki badań laboratoryjnych procesu cięcia wierzby wiciowej tarczowym zespołem tnącym. W badaniach użyto tarczę do cięcia drewna o średnicy 600 mm. Określono wpływ wilgotności rośliny oraz prędkości obrotowej tarczy zespołu tnącego na energię jednostkową cięcia łodyg wierzby. Dokonano doboru najkorzystniejszych wartości parametrów roboczych zespołu tnącego ze względu na minimalne zapotrzebowanie na energię w procesie cięcia badanej rośliny.
Słowa kluczowe: proces cięcia, rośliny energetyczne, energia jednostkowa cięcia, wilgotność, prędkość obrotowa zespołu tnącego, wierzba wiciowa.