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The study of the rotary cutting process of energy plants

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Summary. The article presents the new research station for studying the rotary cutting process of energy plants. It is based on a power unit of a rotary mower. The article also discusses the results of the pilot studies of the cutting process of Salix Viminalis and Reynoutria Sachalinesis with the inertial method.

Key words: rotary mower, unitary energy of cutting, rotary cutting process, Salix Viminalis, Reynoutria Sachalinesis, energy plants.

INTRODUCTION

There is a tendency towards ecological behaviour nowadays. It is not only fashion but also a necessity. Using the biomass energy, instead of energy obtained from fossils, protects the environment against greenhouse effect [3, 7, 8]. In order to make this tendency last, the acquisition of energy from energy plants should be profitable. That is why the problem of the harvest, processing and breaking up these plants and preparing them for further usage is becoming quite significant [5, 16]. The features influencing the unitary energy of cutting are: plant's dimensions, shear strength, friction factor and moisture [12, 13]. The studies of the cutting process of energy plants should be useful Chile designing cutting units and choosing parameters of working units for harvest machines [10, 15, 23].

THE PURPOSE OF THE RESEARCH

The aim of the latest research series was to determine the influence of selected parameters of rotary cutting unit and the plants' constitution and stand on the quality and energy consumption of the cutting process [17, 18, 19, 24, 25, 26].

The pilot studies were carried out mainly in order to test a newly constructed laboratory station, at the Institute of Mechanical Engineering - Technical University of Warsaw in Płock [19]. The research included determining unitary energy of the cutting process of Salix Viminalis and Reynoutria Sachalinesis with different stems' diameters forming a kind of a nest.

The notion unitary energy means the total energy needed for the realisation of the cutting process falling on the unit area of the section of the cut plant.

THE SUBJECT OF STUDY

Energy plants are those, which are characterized by high biomass increase in relatively short time. The plants are also characterized by low soil requirements, high resistance to diseases and pests and high fuel value [1, 4]. Due to the growing number of energy plants plantations in our country, Salix Viminalis and Reynoutria Sachalinesis were selected for the pilot studies.

Salix viminalis is the most popular plant from energy willow species. It is characterized by a quick increase, productivity and low energy consumption during the production process. It is also characterized by quite low labour inputs as far as obtaining biomass is concerned. Moreover, it also functions as phytoremediation - soil and water natural purification. It can also be used as a protective belt from toxic emission [9, 20, 21, 22].

Reynoutria sachalinesis comes from Asia. It is a perennial plant, which grows to 300 - 400 cm. The leaves are 15 – 40 cm long, nearly heart-shaped. The flowers are small, white or beige, up to 3mmm long, produced on short panicles. Male flowers have 7-8 stamens and female flowers have one carpel. The fruit is a nut. Up to 580 GJ of energy can be obtained from 1 ha of crop. It accumulates heavy metals from soil. The root system is very deep. The plant grows in riverside bushes and flood meadows [2].

Fig. 1. View of Salix viminalis' stem in a cross-section

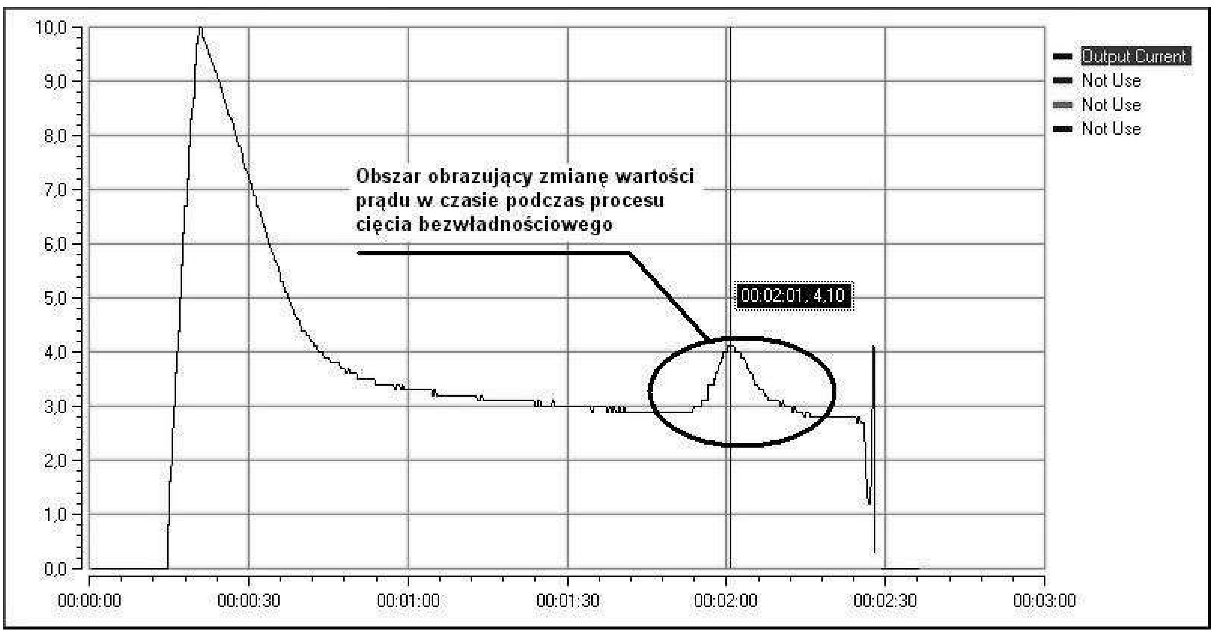
Fig. 2. View of Reynoutria sachalinesis' stem in a cross-section

RESEARCH STATION

The measurement of the unitary energy of cutting was carried out at a research station for studying energy plants rotary cutting process (Fig.3.)

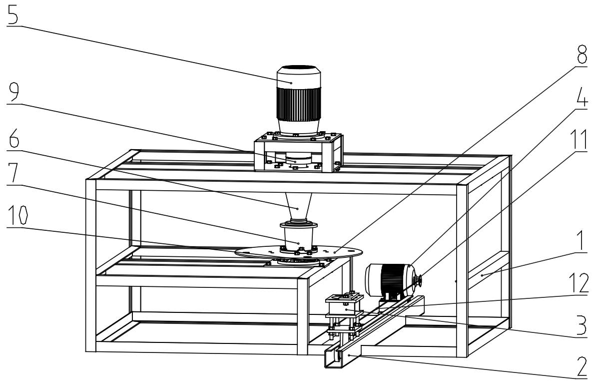
The station consists of two, independently working, units (cutting unit and transporting unit). The units are set in a construction frame (1). The cutting unit consists of inertial knives placed on the circumference of the working plate – diameter 50cm (8). The knives are set with knife holders (10). The working plate (8) is set with screws to the working hub (7), which is placed on the working roller with the usage of bearings. The torque transmission from the electric motor (5) to the cutting unit proceeds through the working roller, which is connected with the motor by means of the overload coupling (9). The transporting unit consists of the electric motor (4), which pulls the truck (3) along the slideway (2) by a line (12). The truck's construction allows to set the research material of different dimensions and constitutions. The inverter controls rational speed of the motor (5) which drives the cutting unit. The inverter keeps a constant voltage ratio to the frequency – from initial frequency to the basic frequency. The inverter, which controls rational speed of the motor driving the transporting unit, adjusts voltage characteristics to the frequency not linearly but according to the respective load at a given moment. The value of the rational speed of the motor which drives transporting unit (4) as well as the motor's of the cutting unit (5), is achieved through putting the adequate frequency. A required frequency value is put into a computer programme (Drive View), which is designed for LG inverters.

The load increase on the motor, which drives the cutting unit, resulting from the research material cutting, causes the increase of the current strength needed for running this process. It is then registered in the computer programme (Drive View) as a graph illustrating the power consumption in time function (Fig. 4). The results analysis allows to determine unitary energy necessary for the proper course of the plants cutting process.



Legend: the area illustrating the voltage value change during the rotary cutting process.

Fig. 4. An exemplary graph illustrating power consumption in time function



1. construction frame,
2. truck slideway,
3. truck,
4. electric motor for truck shift,
5. electric motor of the cutting unit,
6. working roller's housing
7. working hub,
8. working roller,
9. overload coupling,
10. knife holder,
11. spool,
12. line.

Fig. 3. Research station for studying energy plants rotary cutting process

METHODOLOGY AND THE COURSE OF RESEARCH

For the study of the rotary cutting process the samples of Salix Viminalis and Reynoutria Sachalinesis were prepared. The researched plants came from the Experimental Station at the Faculty of Agriculture and Biology – University of Life Sciences in Skierniewice [Stacja Doświadczalna Wydziału Rolnictwa SGGW]. A 25 cm long sample was cut from the stem and set in such a way so that the cutting could take place at the height of 10cm from the ground. The cutting process in the field takes place at such a height. The samples of the researched plants were set on the truck in two rows (Fig. 5). The photos of the plants cross section were taken each time after the cut. On the day of carrying out the study the moisture of the researched plants was determined. Salix Viminalis samples with moisture of 15% and Reynoutria Sachalinesis of 12% were chosen. Each measurement was carried out at least 7 times [Mulas, Rumianowski 1997].

The cutting process at the research station was carried out with the following parameters:

– Rational speed of the cutting unit n=1710 r.p.m.
– Linear velocity of the truck shift V= 0,03m/s.
– Linear velocity of inertial knives V= 44,75 m/s.
– Inertial knife's weight m= 6505g.
– Knife edge angle α = 29°20'.
– Type of knife edge: even with a cut from the top.

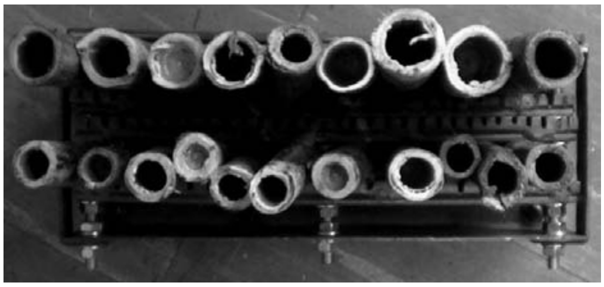
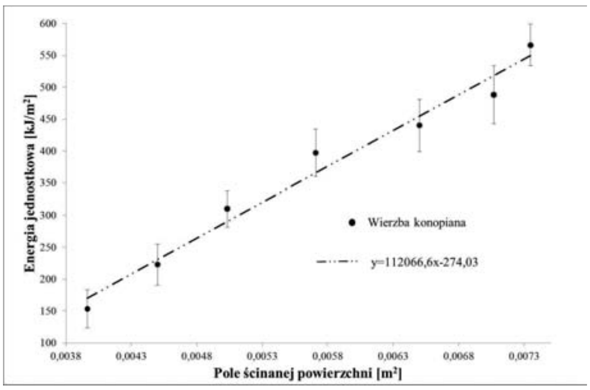


Fig. 5. The energy plants samples set on the truck

RESEARCH RESULTS AND ANALYSIS

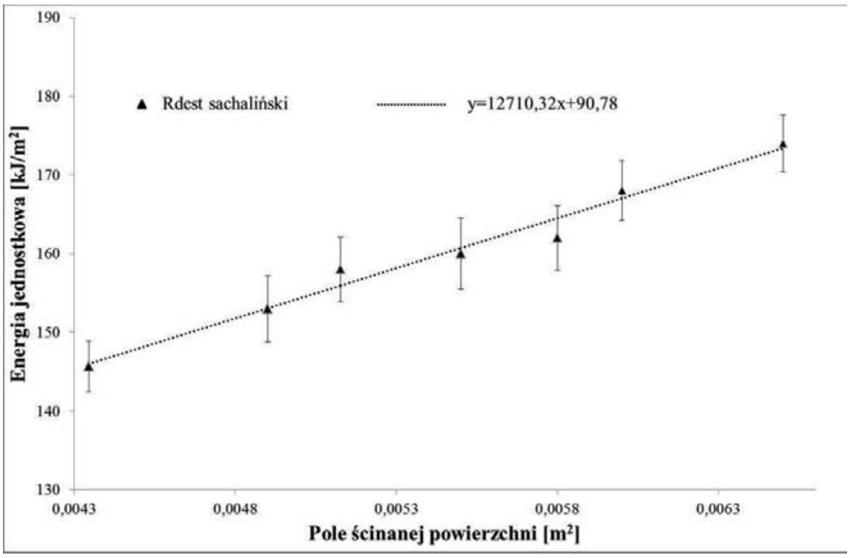
It can be stated, by analysing the results, that very low increase of surface area of the cut Salix Viminalis stems, forming a kind of a nest, causes a high increase of the unitary energy of the cutting process. With the 90% increase of the cut surface area the energy increases by 250% (Fig.6.). Such a rapid increase may be caused by the ligneous constitution of the stems section, which with relatively low moisture (15%) were fibrous and required a total cut in order to split the tissues.

In comparison with Salix Viminalis the demand for unitary energy is relatively low in the case the Reynoutria Sachalinesis cutting. It may be connected with the inner section of the studied plant. Reynoutria Sachalinesis is empty inside (section of a pipe) and its morphological constitution is similar to bamboos. Changing the size of the cut surface area does not cause a rapid increase of the unitary energy. With a 50% increase of cross – section the unitary energy increases only by 20% (Fig.7.). Relatively low moisture (12%) caused the fact that the plant's stems were fragile, they broke during the cutting



Legend: energia jednostkowa – unitary energy [kJ/m^2]; pole ścinanej powierzchni – cut surfie are [m^2]; ♦ wierzba konopiana – Salix Viminalis

Fig. 6. The course of changes of unitary energy of Salix Viminalis in the cut surface area function



Legend: energia jednostkowa – unitary energy [kJ/m2]; pole ścinanej powierzchni – cut surfie are [m2]; s rdest sachaliński – Reynoutria Sachalinesis

Fig. 7. The course of changes of unitary energy of Reynoutria Sachalinesis in the cut surface area function.

process and did not weight down the knife in the final cutting phase.

CONCLUSIONS

The study of the rotary cutting process of energy plants are the continuation of studies carried out on the research station of pendulous type. The new research station allows for the study of the cutting process in the natural-like conditions. It also allows for using chipper disk as well as circular saw [Górski 2001, Kwaśniewski et al. 2006].

The presented pilot studies only slightly show the possibilities of the new research station and the results should be treated as initial ones.

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BADANIE PROCESU CIĘCIA ROTACYJNEGO ROŚLIN ENERGETYCZNYCH

Streszczenie. W artykule przedstawiono nowe stanowisku do badań procesu cięcia rotacyjnego roślin energetycznych bazujące na zespole napędowym kosiarki rotacyjnej. Omówiono także wyniki badań wstępnych procesu cięcia wierzby konopianej i rdestu sachalińskiego.

Słowa kluczowe: kosiarka rotacyjna, energia jednostkowa cięcia, cięcie rotacyjne, wierzba konopiana, rdest sachaliński, rośliny energetyczne.