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MOISTURE INFLUENCE ON THE UNITARY ENERGY OF A CUTTING PROCESS OF SELECTED ENERGY PLANTS

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Summary. Research results of a cutting process of selected energy plants are presented in the following case study. The study also presents the influence of a plant's moisture on the unitary energy of cutting the stems, with various diameters, of the following energy plants: Salix viminalis, Sida Hermaphrodita, Miskanthus Giganteus, Reynoutria sachalinesis and Topinambour.

Key words: cutting process, energy plants, unitary energy of cutting, moisture.

INTRODUCTION

The rigorous requirements concerning environmental protection, as well as the search for ecological and cheap sources of energy cause the fact that the cultivation of energy plants is becoming more and more popular [Dreszer et al. 2003, Gradzik et al. 2003]. These plants, while being burnt, emit not much sulphur dioxide into the atmosphere and the carbon dioxide balance is almost zero because it is absorbed during the plants' growth [Grzybek 2002].The weight of the ash left after the burning process is twenty times lower. The expected and systematic increase of energy plants plantations causes the fact that the problem of the harvest and processing, which also means cutting process of the plants, is becoming quite significant. The knowledge about the influence of such factors as geometric dimensions, moisture and morphological constitution on the unitary energy of the cutting process is necessary for proper design and optimalization of this process [Frączek, Mudryk 2006, Górski 2001, Kowalski 1993, Kwaśniewski et al. 2006, Popko, Miszczuk 1989, Szymanek 2007]. It is of vital importance for the proper functioning of agricultural machines' cutting units.

THE PURPOSE OF THE RESEARCH

The cutting process of plants has been researched for many years at the Institute of Mechanical Engineering Warsaw University of Technology in Płock [Żuk 1979, Żuk 1986, Żuk, Rode 1992,]. The influence of selected parameters of the cutting unit and the plant's constitution and condition on the quality of the cutting process and its power-consumption has mainly been concerned in the above mentioned research [Rode 2008, Rode, Szpetulski 2010].

The aim of the latest research was to determine the influence of the moisture of the selected energy plants on the power-consumption of their cutting process. The research was carried out with the usage of a laboratory station, constructed for this purpose, at the Institute of Mechanical Engineering Warsaw University of Technology in Płock. The research of the energy plants' cutting process included determining unitary energy of the cutting process of plants' stems with different diameters, without forks and with different moisture.

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

The plants characterized by high biomass increase, high resistance to diseases and pests and with low soil requirements are cultivated for energy purposes [Baran et al. 2007, Dubas et al. 2004]. According to this, energy willow (Salix viminalis), Sida Hermaphrodita, Miskanthus Giganteus, Reynoutria sachalinesis and Topinambour were selected as representatives of such plants.

Salix viminalis is an energy willow species. It is characterized by a quick increase of timber mass (about 14 times bigger than in case of naturally grown forests) [Juliszewski et al.2006, Rudko, Stasiak 2004, Szczukowski et al.2002, Szczukowski et al.2004]. It is also characterized by very high fuel value. Its other advantages are low soil requirements, easy vegetative reproduction (shoots), resistance to frost and pests and low fertilizer and pesticides requirements (possibility of fertilization with sludge). The willow's sprouts achieve the height of even 7 metres, which is why it is the best to process them into silvers, briquettes and pellets, and then burn them in stoves. The ash weigh does not exceed 1% of the burnt weight. Moreover, it also functions as phytoremediation – soil and water natural purification of heavy metals and other chemical combinations.

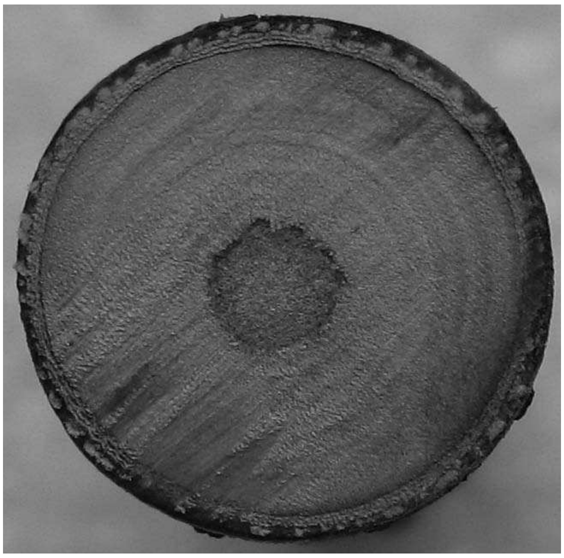


Fig. 1. View of Salix viminalis' stem in a cross-section

Sida Hermaphrodita is a perennial plant with a big increase of timber mass, especially in the first year of growth. It is cultivated mainly for energy purposes, for reclamation of chemically degraded soil or in roadsides protecting other crops from transport pollution. It is also used as a raw material in pulp and paper industry. It is characterized by high resistance to soil and climate requirements. It reproduces generatively (seeds) or by vegetation (shoots) [Rutkowski 2006].

Fig. 2. View of Sida Hermaphrodita's stem in a cross-section

Miskanthus Giganteus is a grass. It has stiff blades filled with spongy core. The blades reach the height of 250 cm (great timber mass increase). It is resistant to diseases and pests. The grass does not tolerate waterlogged and marshy ground. It reproduces by vegetation (shoots) [Rutkowski 2006].

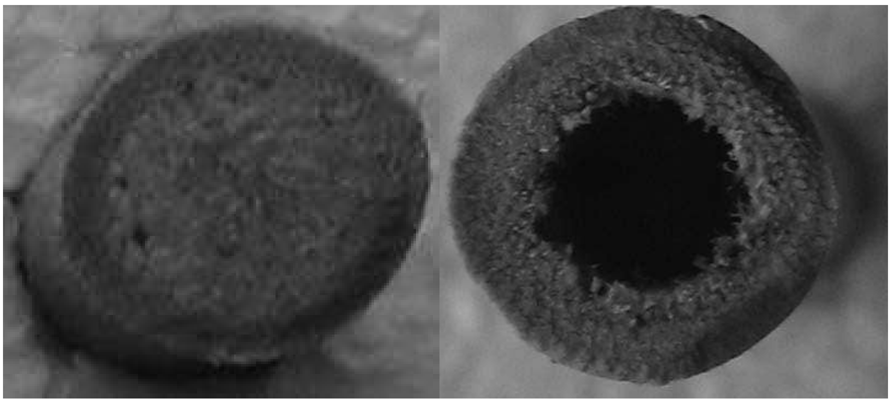


Fig. 3. View of Miskanthus Giganteus' stem in a cross-section

Reynoutria sachalinesis is a perennial plant with expansive nature. It grows to 300 cm. The empty stems look like bamboo shoots. It is characterized by great biomass increase and fuel value. Up to 580 GJ of energy can be obtained from 1 ha of crop. It accumulates heavy metals from soil. It grows in riverside bushes and flood meadows [Burnie 2005].

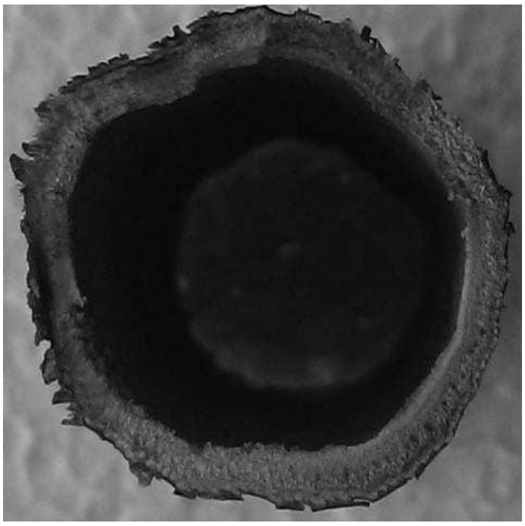


Fig. 4. View of Reynoutria sachalinesis' stem in a cross-section

Topinambour is a perennial plant growing to 350 cm. It is cultivated for its tubers, for alcohol and silage, and also for energy purposes. It grows on every soil and is resistant to temperature changes [Burnie 2005].

Fig. 5. View of Topinambour's stem in a cross-section

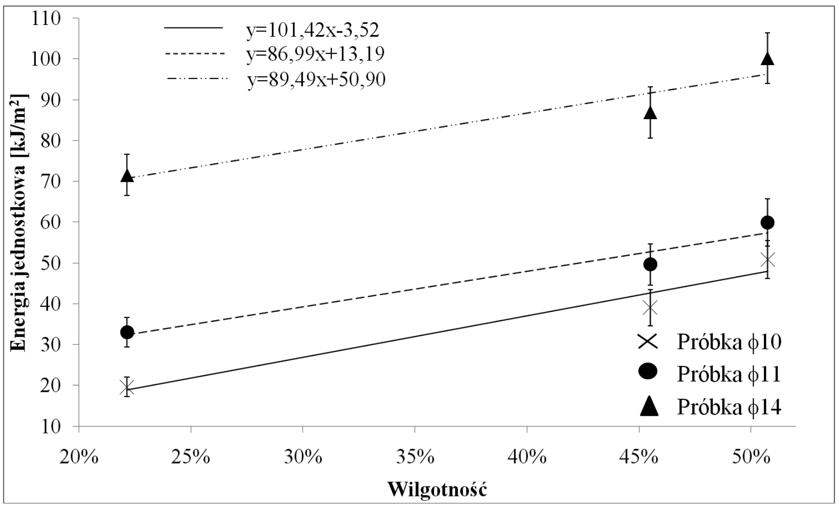
The researched plants came from the Experimental Station at the Faculty of Agriculture and Biology – University of Life Sciences in Skierniewice [Experimental Station of The Faculty of Agriculture at SGGW].

RESEARCH STATION AND THE COURSE OF RESEARCH

Research station for cutting process research is located in the laboratory at the Warsaw University of Technology in Płock [Rode, Szpetulski 2010]. It is a measuring device of pendulous type. During the cutting the plant sample is hold by the holder and is cut by a knife attached at the end of the pendulum. During the research a potential initial and final energy of the pendulum with the knife is determined. The result of a subtraction of initial and final energy determines the energy of cutting.

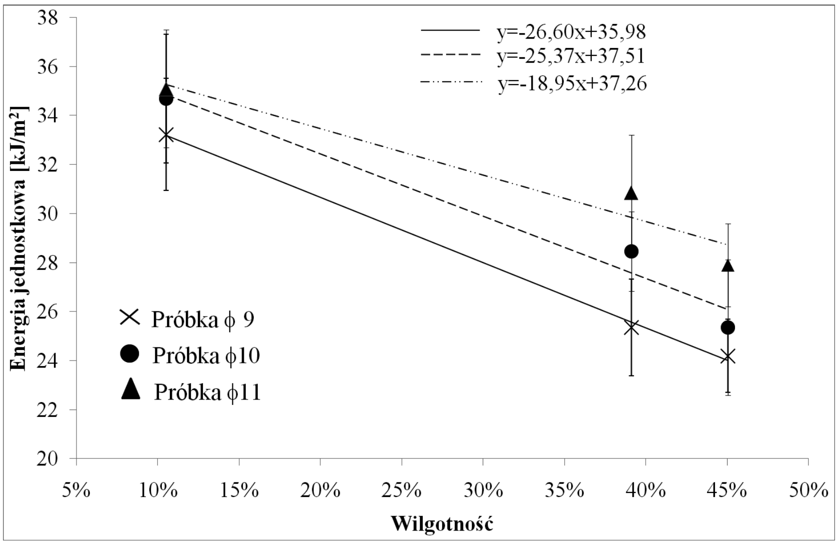
The plants from the plantation were selected at random. Then, they were selected according to their diameters, moisture and forks. The samples for cutting, 8 cm long, with different diameters and without forks, were prepared from the stems of energy plants. Each measurement was carried out at least 7 times [Mulas, Rumianowski 1997]. The cutting of the plant took place with the following parameters: knife velocity V = 4,7 m/s, knife edge thickness = 100 μm, type of knife edge: even with a cut from the top, knife edge angle $\alpha = 26°30'$.

RESEARCH RESULTS



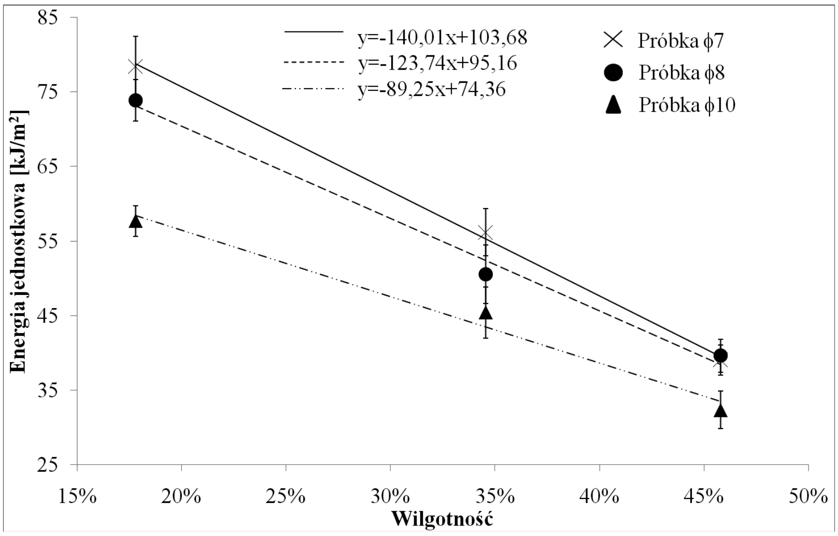
Legend: energia jednostkowa [kJ/m^2] – unitary energy, wilgotność – moisture, x- sample Ø10, ● sample Ø 11, ▲ sample Ø 14

Fig. 6. Comparison of the course of changes of unitary energy (in moisture function) of cutting the Salix viminalis's stem for 3 different diameters



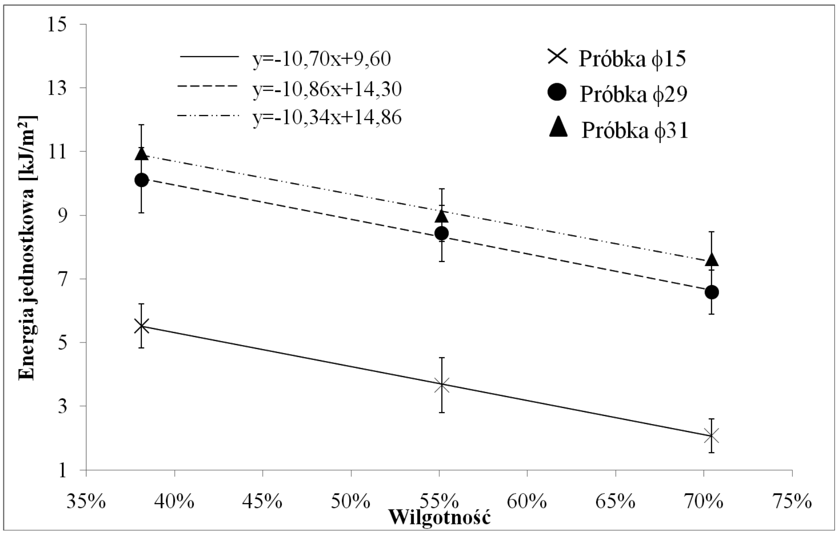
Legend: energia jednostkowa [kJ/m^2] – unitary energy, wilgotność – moisture, x- sample Ø9, ● sample Ø 10, ▲ sample Ø 11

Fig. 7. Comparison of the course of changes of unitary energy (in moisture function) of cutting the Sida Hermaphrodita's stem for 3 different diameters



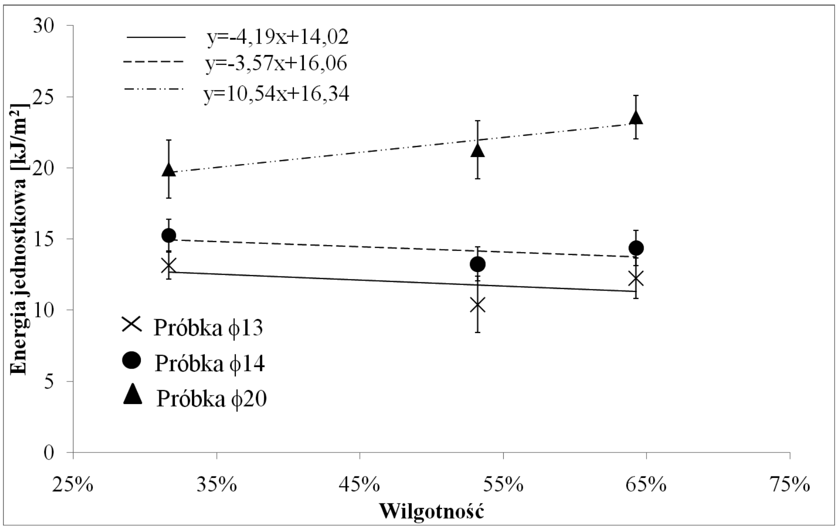
Legend: energia jednostkowa [kJ/m^2] – unitary energy, wilgotność – moisture, x- sample Ø7, ● sample Ø 8, ▲ sample Ø 10

Fig. 8. Comparison of the course of changes of unitary energy (in moisture function) of cutting the Miskanthus' stem for 3 different diameters



Legend: energia jednostkowa [kJ/m^2] – unitary energy, wilgotność – moisture, x- sample Ø15, ● sample Ø 29, ▲ sample Ø 31

Fig. 9. Comparison of the course of changes of unitary energy (in moisture function) of cutting the Reynoutria sachalinesis' stem for 3 different diameters



Legend: energia jednostkowa [kJ/m^2] – unitary energy, wilgotność – moisture, x- sample Ø13, ● sample Ø 14, ▲ sample Ø 20

Fig. 10. Comparison of the course of changes of unitary energy (in moisture function) of cutting the Topinambour's stem for 3 different diameters

CONCLUSIONS

1. For stems of Salix viminalis the unitary energy increases together with moisture increase. It is independent from the stems' diameter. It may be connected with the plant's constitution. In the Salix viminalis' stem's cross-section the fibrous tissue is the greatest in terms of percentage.
2. Topinamour moisture increase does not change the unitary energy of cutting process regardless of the stem's diameter. Topinambour's stem has a full cross-section.
3. The increase of moisture in the remaining plants researched has an impact on the unitary energy decrease. It may result from the fact that there is less energy needed for crushing the plants and also from the epidermis and fibrous tissues cutting resistance. Those plants' stems' cross-sections are as those of a pipe.
4. The energy of cutting of the plant decreases rapidly when the plant breaks.
5. The measurement results show, that the moisture has a significant impact on the unitary energy of cutting the plant. The less fulfilled the plant's stem is, the greater influence of moisture there is.

REFERENCES

1. Baran D., Kwaśniewski D., Mudryk K. 2007: Wybrane właściwości fizyczne trzyletniej wierzby energetycznej. Inżynieria Rolnicza, nr 8(96), s. 7-12.
2. Burnie G. i inni, 2005: Botanica. Rośliny ogrodowe. Kónemann.
3. Dreszer K., Michałek R., Roszkowski A. 2003: Energia odnawialna – możliwości jej pozyskiwania i wykorzystania w rolnictwie. Wydawnictwo PTIR, Kraków – Lublin –Warszawa.
4. Dubas J., Grzybek A., Kotowski W., Tomczyk A. 2004: Wierzba energetyczna – uprawa i technologie przetwarzania. Wyższa Szkoła Ekonomii i Administracji. Bytom.
5. Frączek J., Mudryk K. 2006: Metoda określenia oporów cięcia pędów wierzby energetycznej. Inżynieria Rolnicza, nr 8(83), s. 91-98.
6. Górski J. 2001: Proces ciecia drewna elektryczną pilarką. Rozprawy Naukowe i Monografie. Wydawnictwo SGGW, Warszawa.
7. Gradzik P., Grzybek A., Kowalczyk K., Kościk B. 2003: Biopaliwa. Warszawa.
8. Grzybek A. 2002: Biomasa jako alternatywne źródło energii. Warszawa.
9. Juliszewski T., Kwaśniewski D., Baran D. 2006: Wpływ wybranych czynników na przyrosty wierzby energetycznej. Inżynieria Rolnicza, nr 12(87), Kraków, s. 225-232.
10. Kowalski S. 1993: Badania oporów cięcia wybranych roślin. Zeszyt Prob. Post. Nauk Rol. 408, s. 297- 303.
11. Kwaśniewski D., Mudryk K., Wróbel M., 2006: Zbiór wierzby energetycznej z użyciem piły łańcuchowej. Inżynieria Rolnicza, nr 13(88), s. 271-276.
12. Mulas E., Rumianowski R. 1997: Rachunek niepewności pomiaru. WPW, Warszawa.
13. Popko H., Miszczuk M. 2004: Badania oporów krajania niektórych produktów spożywczych.. Zeszyt Prob. Post. Nauk Rol. 354.
14. Rode H. 2008: Badania procesu cięcia wybranych roślin energetycznych, Rozdział w monografii Wybrane zagadnienia mechaniki w budowie urządzeń technicznych. s. 286-297. Politechnika Warszawska, Płock.
15. Rode H., Szpetulski J. 2010: The study of the willow viminalis cutting process. Bioagrotechnikal Systems Engineering. vol.6(22), Płock, s. 63-75.

16. Rudko T., Stasiak M. 2004: Właściwości mechaniczne pędów wierzby energetycznej. III Zjazd Naukowy. Referaty i doniesienia. Dąbrowice 27-29. 09.2004.
17. Rutkowski L.2006:Klucz do oznaczania roślin naczyniowych Polski niżowej. Wyd. Naukowe PWN, Warszawa.
18. Szczukowski S., Tworkowski J., Stolarski M.J. 2004. Wierzba energetyczna. Wydawnictwo Plantpress Sp. z o.o., Kraków.
19. Szczukowski S., Tworkowski J., Wiwart M., Przyborowski J. 2002: Wiklina (Salix Sp.) Uprawa i możliwości wykorzystania. Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego, Olsztyn.
20. Szymanek M. 2007: Analysis of cutting process of plant material. Teka Komisji Motoryzacji i Energetyki Rolnictwa – OL PAN, VIIA, s.107-113.
21. Żuk D. 1979: Określenie koniecznej prędkości elementów tnących w maszynach do ścinania źdźbeł i łodyg. Maszyny i Ciągniki Rolnicze nr 3/1979. Warszawa.
22. Żuk D. 1986: Proces cięcia źdźbeł zbóż. Prace Naukowe Politechniki Warszawskiej - Mechanika z. 95. Warszawa.
23. Żuk D., Rode H. 1992: Propozycje oceny energetycznej zespołów tnących. Prace Naukowe Politechniki Warszawskiej - Mechanika z. 152. Warszawa.

WPŁYW WILGOTNOŚCI NA ENERGIĘ JEDNOSTKOWĄ CIĘCIA WYBRANYCH ROŚLIN ENERGETYCZNYCH

Streszczenie. W pracy omówiono wyniki badań procesu cięcia wybranych roślin energetycznych. Omówiono wpływ wilgotności rośliny na energię jednostkową cięcia łodyg wierzby konopianej, ślazowca pensylwańskiego, miskantusa olbrzymiego, rdestu sachalińskiego oraz topinamburu o różnych średnicach.

Słowa kluczowe: proces cięcia, rośliny energetyczne, energia jednostkowa cięcia, wilgotnośc.