The study of the rotary cutting process of chosen energy plants

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Summary. The article presents a comparison of study results concerning the cutting process of three energy plants: Salix Viminalis, Side Hermaphrodite and Miskanthus Giganteus. The study also presents the influence of the surface area of a stem's cross-section and the speed of rotary disk with knives speed on the unitary energy of the cutting process of stems.

Key words: rotary mower, unitary energy of cutting, rotary cutting process, Salix Viminalis, Side Hermaphrodite, Miskanthus Giganteus, energy plants

INTRODUCTION

The biomass energy can partly replace energy used from fossils. The use of biomass energy protects the environment against greenhouse effect [2,3,6,7]. New technologies for energy plants production need to be effective and cheap. That is why it is important to optimize the harvest, processing and breaking up of these plants [5]. The features influencing the unitary energy of cutting are: plant's dimensions, shear strength, friction factor and moisture [9,11,12]. The studies of the cutting process of energy plants should be useful while designing cutting units and choosing parameters of working units for harvest machines [10,13,21].

The studies of the cutting process of energy plants have been carried out at the Institute of Mechanical Engineering – Warsaw University of Technology in Płock for many years. The research mainly refers to the influence of the cutting process parameters and the plants' constitution on the quality and energy consumption of the cutting process. The previous research had been carried out on a laboratory stand of pendulous type and referred to axe cutting. The new laboratory stand enabled rotary cutting of energy plants' stems.

THE PURPOSE OF RESEARCH

The aim of the research was to determine the influence of selected constructional and functional parameters of the cutting unit on the rotary cutting process of energy plants: Salix Viminalis, Side Hermaphrodite and Miskanthus Giganteus [14,15,23,24,25].

The study was carried out at the research stand for studying energy plants rotary cutting process at the Department of Mechanical Systems Engineering and Automation – Warsaw University of Technology in Płock [16,22].

The research of the energy plants' cutting process included:

– determining unitary energy of the cutting process in the function of surface area of the section of the plant's stem with different diameters
– determining unitary energy of the cutting process in the function of rotary speed of the disk with knives.

The notion of 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 – in accordance with the UE law – are those which grow on plantations and are processed into biofluel, biocomponents, heat energy or electric energy.

The plants are characterised by quick and high biomass increase, high fuel value, high resistance to frost and pests and low soil requirements – due to which wasteland can be used. Moreover, due to the energy plants features, there is a high vulnerability to mechanized agro-technical activities connected with starting a plantation, running it and harvesting biomass [1,4].

Salix viminalis, Sida hermaphrodita and Miscantus gigantheus were selected for the study. The plants were selected according to their popularity and constitution distinctness. Salix viminalis is an arborescent plant, Sida hermaphrodita is a perennial plant and Miscantus gigantheus is a grass [8,17,18,19,20].

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

RESEARCH STAND

The measurement of the unitary energy of cutting was carried out at the research stand for studying energy plants rotary cutting process (Fig.2.). The stand consists of two independently working units (cutting unit and transporting unit) set in a construction frame. The cutting unit consists of inertial knives placed on the circumference of the working plate – diameter 50cm.The working plate is set to the working hub, which is driven by electric motor of the cutting unit. Transporting unit is driven by another electric motor, which pulls a truck along the slide by a line. The truck's construction allows to set the research material of different dimensions and constitutions.

The inverter controls the rational speed of motors. The value of the rational speed of motors is achieved through adequate frequency setting. A required frequency value is put into a computer programme (Drive View), which is designed for LG inverters.

METHODOLOGY AND RESEARCH

For the study of the rotary cutting process, 150mm long samples were prepared. Due to the plants' different constitutions, the samples with the following diameters of stems were prepared: Salix Viminalis (9 – 13,5) mm , Side Hermaphrodite (7,5 – 12) mm, Miskanthus Giganteus (6,5 – 11) mm. The measurement of the diameters was done with the use of a slide calliper in 3 different surfaces. The samples of the researched plants were set on a truck. Its motion imitated the transmission of the cutting unit when used in real condition on plantation farm. The truck's speed was constant, 0,314 m/s, during all the tests. The samples of the plants were set vertically in rows. The measurement was done 3 times for each diameter of the stems. The rotary speed of the working plate, the moisture of the samples and the voltage were constant during the tests. The atmospheric pressure, where the research took place, was equal to 762 mm Hg and the temperature was 20^{o}C. The cutting process for 3 different rational speeds of the disk with knives was studied: at 1424 r.p.m, 1824 r.p.m and 2108 r.p.m.

Fig. 1. View of the researched plants' stems in a cross-section: (starting from left) Salix Viminalis, Side Hermaphrodite and Miskanthus Giganteus

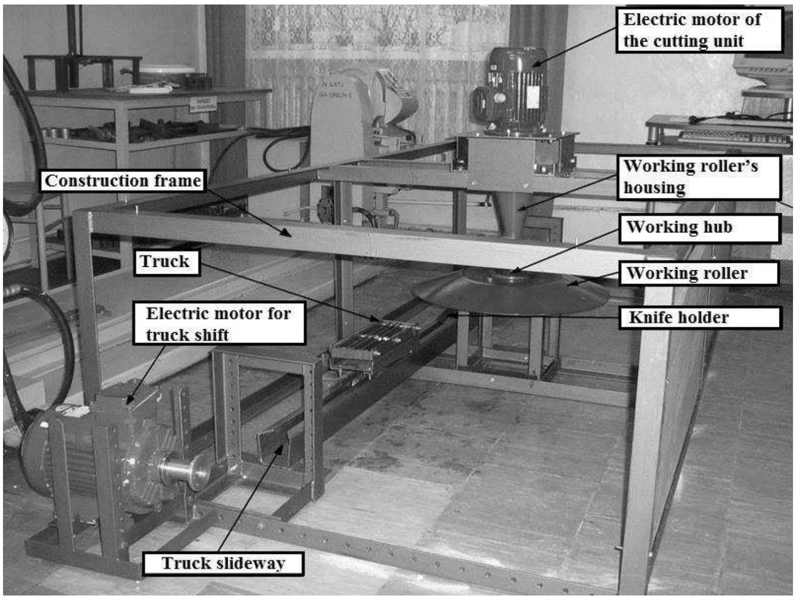

Fig. 2. Station for studying energy plants rotary cutting process

RESEARCH RESULTS AND ANALYSIS

It can be stated, on the basis of the research results, that the unitary energy of Salix Viminalis stems cutting increases together with the cutting surface increase (Fig.3.) and it decreases together with the increase of the rotary speed of the disk with knives from the cutting unit (Fig.4). This tendency is the same for all the tested speeds and diameters. It is connected with the cutting resistance of the plants epidermis. The resistance decreases together with the knife's speed increase.

The unitary energy of cutting Side Hermaphrodite stems decreases together with the cutting surface increase (Fig.5.). This tendency is true for the 2 speeds of the 3 studied. The unitary energy of cutting reaches a significant minimum at the rotary speed of the disk with knives being 1800 r.p.m. (Fig.6.). The tendency is true for all the cut plants' surface areas studied.

The unitary energy of cutting Misknthus Giganteus stems decreases significantly together with the cutting surface increase (Fig.7.). This tendency is true for the speeds studied. The unitary energy of cutting reaches a significant maximum at the rotary speed of the disk with knives being about 1800 r.p.m. (Fig.8.). The tendency is true for all the cut plants' surface areas studied.

CONCLUSIONS

The study of the rotary cutting process of energy plants is the continuation of studies carried out on the research station of pendulous type. The next step is to carry out a research for chosen energy plants that would determine the influence of some other parameters, e.g.: moisture or the truck's linear velocity on the unitary energy of the cutting process. The research should involve some other energy plants, e.g.:

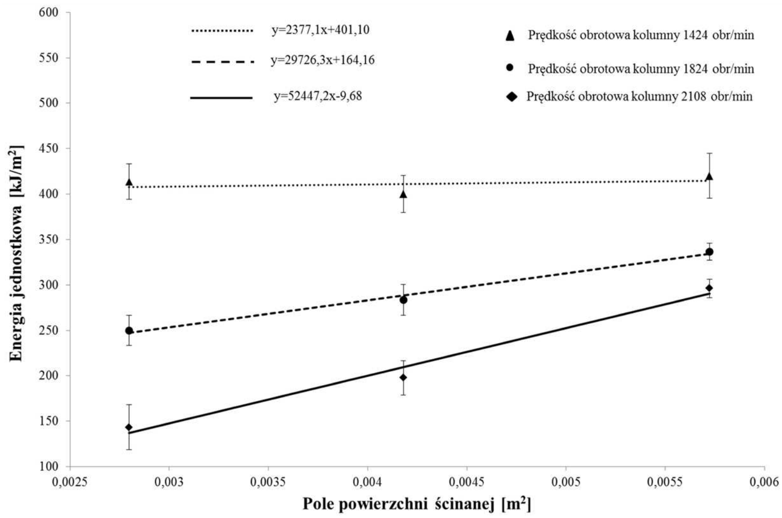

Fig. 3. The course of changes of unitary energy of Salix Viminalis in the cut surface area function
Legend: energia jednostkowa – unitary energy [kJ/m²]; pole ścinanej powierzchni – cut surface area [m²]; ●▲♦ rotary speeds

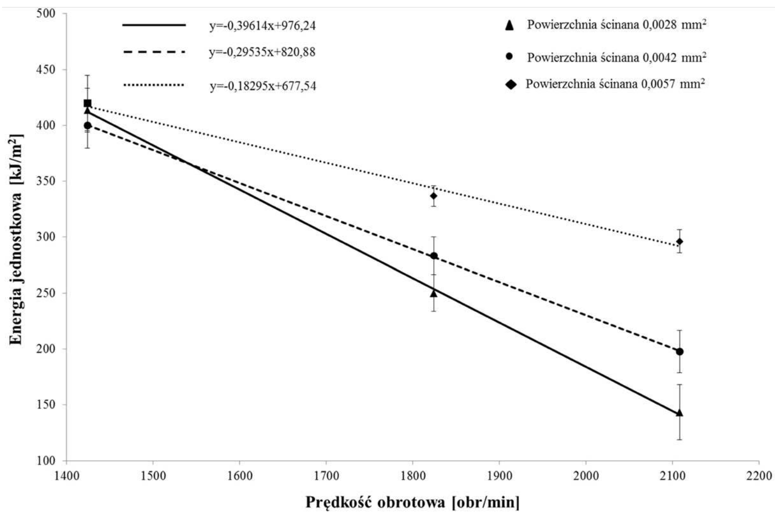

Fig. 4. The course of changes of unitary energy of Salix Viminalis in the function of rotary speed of disk with knives
Legend: energia jednostkowa – unitary energy [kJ/m²]; prędkość obrotowa – rotary speed [r.p.m.]; ●▲♦ the cutting surface

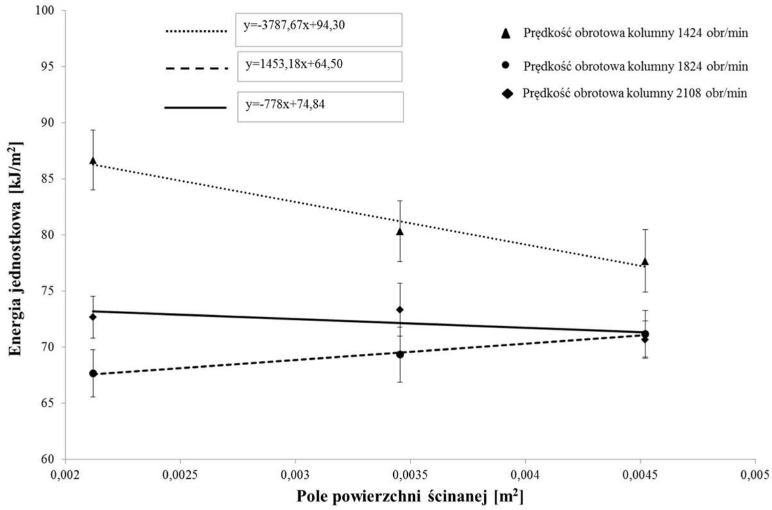

Fig. 5. The course of changes of unitary energy of Side Hermaphrodite in the cut surface area function

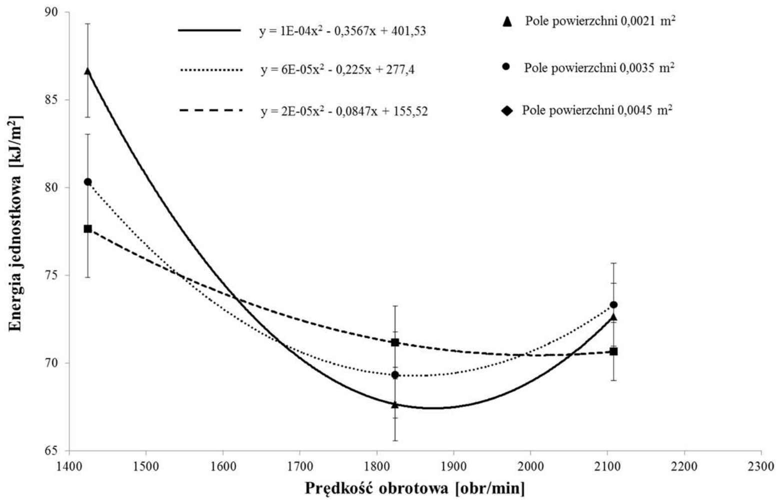

Fig. 6. The course of changes of unitary energy of Side Hermaphrodite in the function of rotary speed of disk with knives.

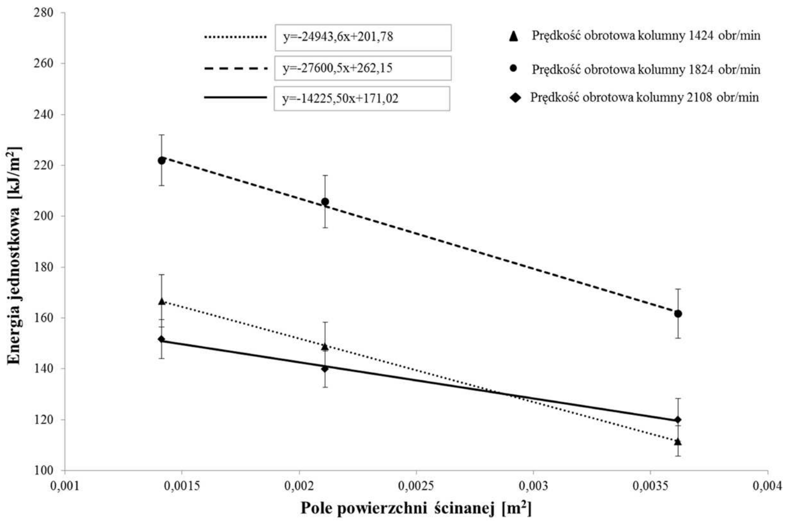

Fig. 7. The course of changes of unitary energy of Miskanthus Giganteus in the cut surface area function

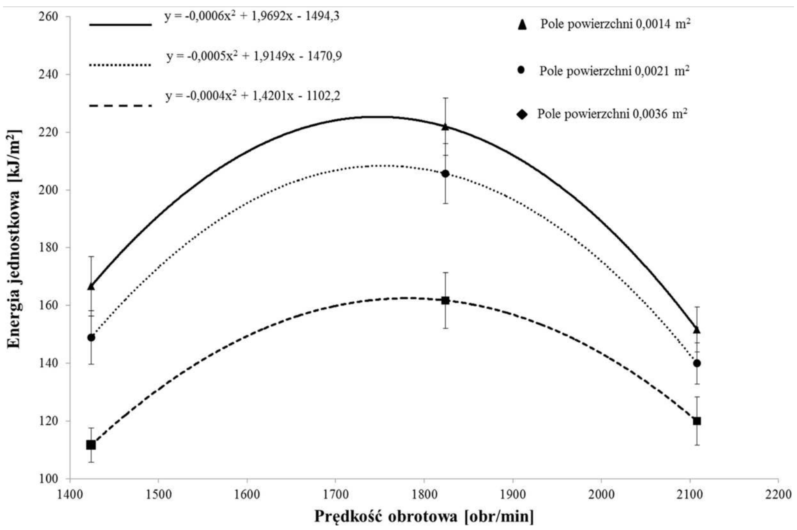

Fig. 8. . The course of changes of unitary energy of Miskanthus Giganteus in the function of rotary speed of disk with knives

a multiflower rose. The cutting process should be studied with the use of flat disk of the cutting unit.

Determining the influence of the cutting unit type on the cutting process energy is another issue. It is necessary to replace the disk with knives with the disk of circular saw.

There is a need to build a new research station equipped with a unit of two cutting disks with adjustable angle of inclination. This should be as close with the construction of a cutting unit of an agricultural machine as possible. An initial design of such a station is being prepared.

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BADANIE PROCESU CIĘCIA ROTACYJNEGO WYBRANYCH ROŚLIN ENERGETYCZNYCH

Streszczenie. W artykule porównano wyniki badań procesu cięcia trzech roślin energetycznych: wierzby konopianej, ślazowca pensylwańskiego, miskantusa olbrzymiego. Przedstawiono wpływ pola powierzchni przekroju przecinanej łodygi rosliny oraz prędkości obrotowej tarczy z nożami na energię jednostkową procesu ich cięcia.
Słowa kluczowe: kosiarka rotacyjna, energia jednostkowa cięcia, cięcie rotacyjne, wierzba konopiana, ślazowiec pensylwański, miskantus olbrzymi, rośliny energetyczne.