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A research on the cutting process of a poplar with a disk cutting unit

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Summary. The paper presents the results of laboratory tests concerning the cutting process of black poplar by means of disc cutting unit. The influence of the linear velocity and rotary speed of the disk of cutting unit on the unitary energy of cutting the black poplar's stems were determined. The most favorable values of the operating parameters of the cutting unit were selected in accordance with the minimum energy requirement in the cutting process of the tested plant.

Key words: black poplar, cutting process, energy plants, unitary energy of cutting, linear velocity of cutting unit, rotary speed of cutting unit.

INTRODUCTION

Biomass is considered to be a very good, yet still underestimated, source of renewable energy. More and better ways of controlling the process of biomass processing and combustion, the possible automation of these processes,allow to forecast that the usage of biomass in the overall energy balance will grow[4,7,8].
It is also difficult to overestimate the fact that using biomass as a source of energy, we follow the principle of balanced development, which is so important for future generations[17].

The most popular plant used for biomass production is energy willow [1,5,9,12,22,23,24].It is worth noticing, however, that other energy plants of whichcultivation under certain conditions may produce similar or better results[2,13]. A black poplar is one of such a plant [3]. A conventional disk cutting units can be used for harvesting it [11]. That is why the most favorable values of the operating parameters of cutting unit in the process of plants' cutting need to be established [6,10,16]. These parameters will be possible to be determined having analyzed the results of the research carried out at the laboratory stand for researching the cutting process of energy plants.

THE PURPOSE OF THE RESEARCH

The aim of the research is to determine the most favorable values of the operating parameters of the disc cutting unit in accordance with the minimum energy requirement in the cutting process of a black poplar. The research was carried out for:

- different travelling speeds of cutting unit,
- different rotary speeds of cutting unit.

The research was carried out at the laboratory stand for researching the cutting process of energy plants, at Department of Mechanical Systems Engineering and Automatization – Warsaw University of Technology in Płock, as a continuation of studies which have been carried out for many years [18,19,20,21,26,27,28,29].

THE SUBJECT OF RESEARCH

Energy plants should be characterized by a rapid growth and a high proportion of stems in the dry mass of the aboveground part, low soil requirements and high biomass production [2]. The black poplar chosen for the research meets these criteria.
The black poplar is an anemophilous tree. It has a dark and deeply cracked bark.Its leaves are wide and heart-shaped. Both sides of the leaves are green and shiny with a transparent narrow border. Inflorescence in the form of hanging catkins appear before or at the same time as the leaves. The fruit is a bag filled with numerous seeds, each of which is provided with a bunch of delicate white hairwhich facilitates spreadingby the wind. Poplars reproduce by means of seeds, root growth and woody margins. The root system is quite shallow (maximum 2-3 m deep) and wide (up to 30 m outside the crown).In

favorable conditions, poplars arethe fastest growing trees among the trees in our climate [14].

The black poplar is a photophilous tree growing in the river valleys and riparian areas.For cultivation of this species the best are well aerated and moist soils, with a groundwater level of 80-200 cm.

The cuttings are obtained in winter from the mother plantation. They are about 20cm long. About 5.5 to 6.6 thousand of cuttings are planted on a 1 hectare area. They are planted in rows. The space between the rows is 3–3,5 m and the space between plants in a single row is from 0.5 to 0.6m. The best is when the planted poplar is equal to the soil level or it may protrude up to 3 cm.

The poplar is harvested after vegetation. The frequency of harvesting, which depends mainly on the chosen technology of production, is generally 3 years. Harvesting is done manually or mechanically at a height of 10 - 20 cm, which allows for re-growth. An annual increase of biomass can be estimated at the level of 18-25 tons/hectare. The poplar's moisture during the harvesting should be 45 – 58%. The fuel value of poplars is 11.3 - 12.3 MJ / kg with a humidity of 30-35%.

In the dry mass the poplar contains 81.2% of volatile substancesand 1.9% of ash, and in the elementary composition it contains: carbon - 47.5%, oxygen - 44%, hydrogen - 6.2%, nitrogen - 0.4%, sulfur - 0.033%, chlorine - 0.041% [14].

Fig. 1. Poplar plantation

RESEARCH STATION

The research station consisted of a frame on which the power unit from the traditional rotary mower was mounted (Fig. 2.) [26,27]. A cutting disk with diameter 600mm (200 teeth) and 3,2mm thickness with 200 teeth was used. The disk cutting unit was driven by a three-phase electric motor controlled by inverter programmed by computer. The mower's movement was simulated by a traverse motion of the truck with plant's samples placed on it. This motion forced a second electric motor, also controlled by an inverter, by means of a rope winding onto a drum.

During the research a computer registered the increase of the power consumption in the time function. On this basis, the unitary energy needed for cutting energy plants was calculated. The notion of unitary energy of cutting means the total energy needed for cutting process per unit area of the cross-section of the stems.

Fig. 2. Research station

THE METHODOLOGY AND THE COURSE OF THE RESEARCH

The research started with preparing the samples of the poplar's 200 mm long stems. Next, the stems were selected according to their diameters. The samples were placed on a truck simulating the motion of the cutting unit in the real conditions on the field (Fig.3.) Each measurement was repeated minimum three times [15]. The cutting process of the plant took place using the following parameters:

- temerature - 20 ^{o}C,
- atmospheric pressure - 766 mm Hg,
- length of the samples - 200 mm,
- diameters of the samples-7-15 mm
- moisture–45%
- thicknessof the disk - 3,2 mm,
- diameter of the disk- 600 mm,
- number of teeth on the disk - 200
- travelling speeds of the truck simulating the linear motion of the cutting unit: 0,0258 m/s, 0336 m/s, 0,413 m/s,
- rotary speeds of the disk: n= 964 rpm,1077 rpm, 1191 rpm.

Fig. 3. Truck with the poplar's samples placed on the guide rail

RESEARCH RESULTS

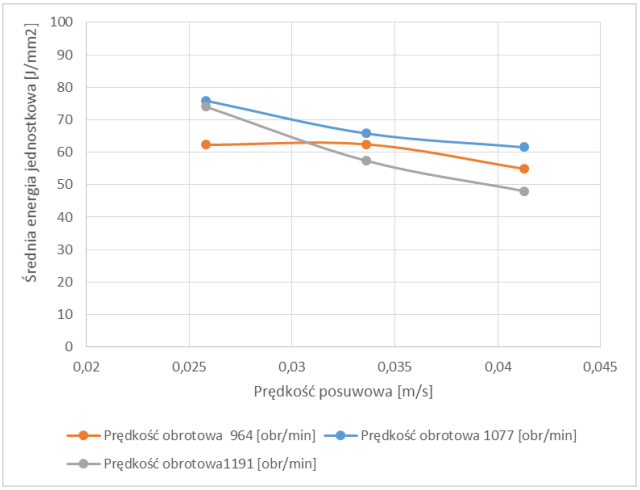

Fig. 4. The course of changes of unitary energy of cutting process of black poplar in the function oftravelling speed of the truck with plant samples for 3 different values of the rotary speed of the cutting unit
Legend: średnia energia jednostkowa – unitary energy [kJ/m^2], prędkość posuwowa –travelling speed [m/s], prędkość obrotowa – rotary speed [rpm]

The unitary energy of the cutting process of black poplar in the function of travelling speed of the truck simulating the speed of the machine working in the field decreases at each studied rotary speed of the cutting unit (Fig. 4.).

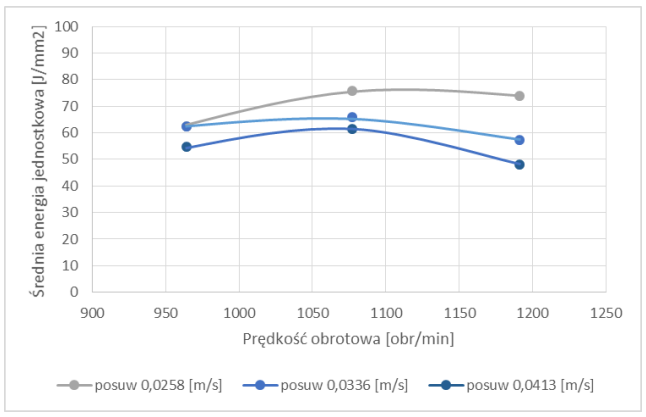

Fig. 5. The course of changes of unitary energy of cutting process of black poplar in the function of rotary speed of cutting unit for 3 different travelling speeds of the truck with plant's samples
Legend: średnia energia jednostkowa – unitary energy [kJ/m^2], prędkość obrotowa – rotary speed [rpm], posuw - travelling speed [m/s]

The influence of the rotary speed of the cutting unit on the unitary energy of the cutting process is not unique. The reason for it, most probably, is frictional resistance between the cutting disk and the cut stem (Fig.5.).

The nature of the course is similar for all tested travelling speeds of the truck with the plant's samples.

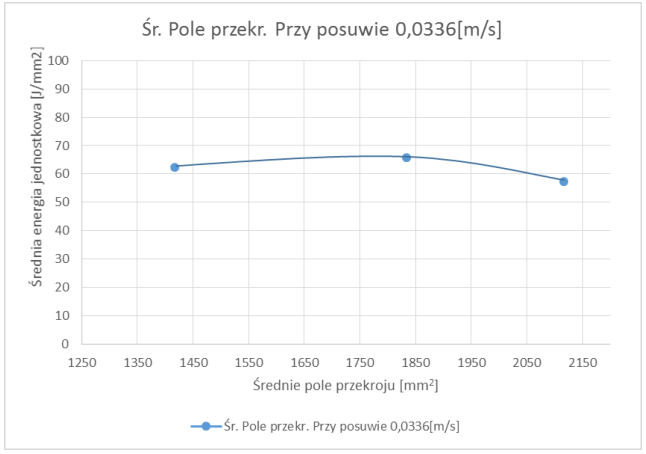

Fig. 6. The course of changes of unitary energy of cutting process of black poplar in the function of average cross-section of the cut stems for the travelling speed of 0,0336 m/s
Legend: energia jednostkowa – unitary energy [kJ/m^2], średnie pole przekroju –average cross-section [mm^2]

The unitary energy of the cutting process of black poplar in the function of cross-section of the cut plants does not change significantly (Fig.6.).

CONCLUSIONS

1. For the stem of the black poplar the unitary energy of the cutting process decreases with the increase of the travelling speed of the truck with samples. It is true for all the tested rotary speeds of the cutting unit. This may be associated with the observed cracking process of the plant while cutting at higher travelling speeds. It can be assumed, with great probability, that increasing the travelling speed beyond the range tested during the research will affect the further reduction of unitary energy. However, it was difficult to carry out such a research for safety reasons.
2. The unitary energy of the cutting process of the black poplar does not show unique changes with changes in rotary speeds of the cutting unit irrespective of the travelling speed of the truck with the plant's samples. It can therefore be assumed that the lowest possible rotary speed of the cutting unit should be used during harvesting.
3. The unitary energy of the cutting process of the black poplar in the function of the cross-section does not change significantly. It has a cleardecreasing tendency when the stems of cut plants are moved apart.
4. A study of the influence of the moisture on the cutting processof the black poplar should be the next necessary step in the research of the cutting process of this plant.
5. The most favorable values of the operating parameters of the cutting unit for the black poplar, in terms of energy, at the plant's moisture of 45% are: the rotary speed of the cutting unit equal to 969 rpm and the travelling speed higher than 0,0413m/s.

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BADANIA PROCESU CIĘCIA TOPOLI TARCZOWYM ZESPOŁEM TNĄCYM

Streszczenie. W pracy zaprezentowano wyniki badań laboratoryjnych procesu topoli czarnej tarczowym zespołem tnącym. Określono wpływ prędkości liniowej i prędkości obrotowej tarczy zespołu tnącego na energię jednostkową cięcia łodyg topoli. Dokonano doboru najkorzystniejszych wartości parametrów roboczych zespołu tnącego ze względu na minimalne zapotrzebowanie na energię w procesie cięcia badanych roślin.

Słowa kluczowe: topola czarna, proces cięcia, rośliny energetyczne, energia jednostkowa cięcia, prędkość liniowa zespołu tnącego, prędkość obrotowa zespołu tnącego.