

NEW MACHINES FOR ENERGY WILLOW HARVEST IN SMALL PLANTATIONS

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The production of plant biomass in a small farms requires the application of agricultural machines adjusted for the scale of production. In the article new patented machines for small plantations of energy crops have been presented. These agricultural solutions have been worked out by authors and a part of them is still developing in cooperation with the biomass producers.

Key words: biomass, harvester, energy willow, willow mover.

Виробництво рослинної біомаси в малих господарствах вимагає застосування сільськогосподарських машин, пристосованих до масштабу її виробництва. Запропоновано нові запатентовані машини для малих плантацій енергетичних рослин. Ці технічні вирішення для сільськогосподарських машин опрацьовано авторами та частина з них є постійно поліпшувана завдяки співробітництву з виробниками біомаси.

Ключові слова: біомаса, комбайн, енергетична верба, косарка для верби.

Introduction

In the Rzeszow University of Technology the establishing technology of energetic plant plantation, harvest methods and technology of sludge processing were elaborated. Proposed solutions are based on special machines protected by patents. Characteristic feature of proposed solutions is their readjust to agricultural needs of quite small farms in Southern Poland. Proposed technical resources are also cost attractive.

Energetic willow, by its different types according to the local climatic condition allow to obtain in a short time very good amounts of wood mass per hectare. With a high productivity energetic willow can ensure the basic raw material for different applications in order to obtain compacted wooden products like solid bio-fuel or direct combustion products to produce energy. Production productivity of energetic plants depends on applied agrotechnics so workmanship and sequence of protective treatments during cultivation plants in order to get plentiful crop with high quality.

The basic knowledge about usability of soil to agricultural production are physico-chemical properties of the soils, their chemical constitution, terrain hipsography climatic conditions and hydrogeological structure. Characteristics of municipal solid waste and its utilization in agreement with decree [1] and acts [2, 3] are conditions of application of this fertilizer to the cultivation of energetic plants.

Analysis of properties of different types of renewable energy sources (RES) presented for example in papers [4, 5] lead to a conclusion that biomass in Poland is a RES type characterized by synthetic the best technical and operating parameters. The biomass energy is commonly available and simultaneously is characterized by low unit cost, high availability and exergy comparable with traditional mineral fuels which allow to commonly using of biomass in dissipated power engineering based on co-generational systems.

The deficiency of specialized machines adapted to arable area and their high cost are the following obstacle indicated by potential small producers of biomass [6, 7]. Except specialized machines destined to energetic plant crop the interesting solution is the machine developed by Lisowski et al. [8] based on the constructional assumptions of Nowakowski et al. [9]. The key constructional solution of this machine equipped with disc cuttings assembly is cutting section with feed assembly [9].

Increasing of the amount of energetic plant plantation mainly plants with ligneous shoots causes the necessity of exploration of new technologies allowing efficient harvesting and further their processing. Over the last years took place progress in submitting solutions of specialized machines for harvesting and processing of biomass logging from ligneous shoots e.g. movers, wood splitten machines, chaff cutter for wood but the problem still exists and requires further looking for correct solutions. Particularly machines assigned for small plantations and adapter for terrain hypsography are searched. Implementation of presented machines into agricultural practise allows for realisation of the most important problems of environment protection, by:

- application of environment-friendly technology concerned on system management of sewage sludge in production of both energy and industrial plants,
- meeting the requirements of closed cycle of biomass in environment,
- utilization of biomass for hating purposes or generating of electric energy non-effected on increasing of global warming,
- utilization of sewage sludge according to Waste Act [10],
- elimination from trophic cycle of a human hazardous substances included in sewage sludge in compliance with possibility of theirs environmental cycle control,

New machines for willow harvesting

The main aim of proposed by the authors constructional solutions of machines is their readjust to agricultural needs of quite small farms in Southern Poland. Simple construction of proposed machines and instruments cause that they are also cost attractive. One of the premise of taking operations connected with a construction of new machines for planting, logging and processing of the biomass of plants with ligneous shoots is high cost of high-productivity machines [11, 12]. So that their application in small farms are not profitable. Meaningful growth of amount of energetic plant plantation mainly plants with ligneous shoots causes the necessity of exploration of new technologies allowing for efficient harvesting and further their processing. Over the last years took place progress in submitting solutions of specialized machines for harvesting and processing of biomass jogging from ligneous shoots e.g. movers, wood splitten machines, chaff cutter for wood but the problem still exists and requires further searching of correct solutions. Particularly machines assigned for small plantations and adapter for terrain hypsography are searched.

Till now the base prime mover for agricultural machines are farm tractors with diversified power. In case of establishing, protective treatments, logging and processing of the biomass in plantation of the energetic plants the farm tractors are basic prime mover of specialized machines. Moreover most often farm tractors transport crop from plantation terrain to further processing or to final energetic biomass management.

In the subject area of machines characterized by low productivity and destined for working in small plantations as well as verified in practice while field work there are not many commercial offers. Characteristic feature of Polish agriculture especially the area of southern country is size reduction and low degree of mechanization as well as limited buying power. In this situation lasts searching of construction solutions complying with conditions of small producers requirements in which farms is a small power farm tractor usually with primary equipment. Considering the efficiency of application of proposed machines for production, logging and processing of the biomass in small farms a few factors should be taken into account. First of all it should be considered largeness of a farm and in consequence demand on manpower and grade of accessibility of high power farm tractors. From point of view of possibility of machine utilization terrain hypsography and soil structure should be considered. The advantage of proposed solutions is their uncomplicated construction which is connected with low production cost and simple machine operation. A low mass of working tools favours carrying out the agricultural operations on fenland.

The structure of a mower for cutting down woody plants (Fig. 1) is composed of the frame (1), three-point linkage (2) for attaching to an agricultural tractor and working arm (3) coupled to the frame using articulated joint (4). To working arm near its end the ground wheel is mounted (5). At the end of the working arm circular saw (6) with a diameter of 600 mm is mounted. The drive of the circular saw is transmitted from power-take-off (PTO) by using shaft (7), intersecting the axis gear (8) and the belt

transmission (9). All movable elements of the machine are protected by safety guards. The other constructional solution of the circular saw drive is a long shaft between the saw (6) and the intersecting axis gear (8) instead of the belt transmission (9). Alternatively the mover may be equipped in the retractable working arm (Fig.2) [13].

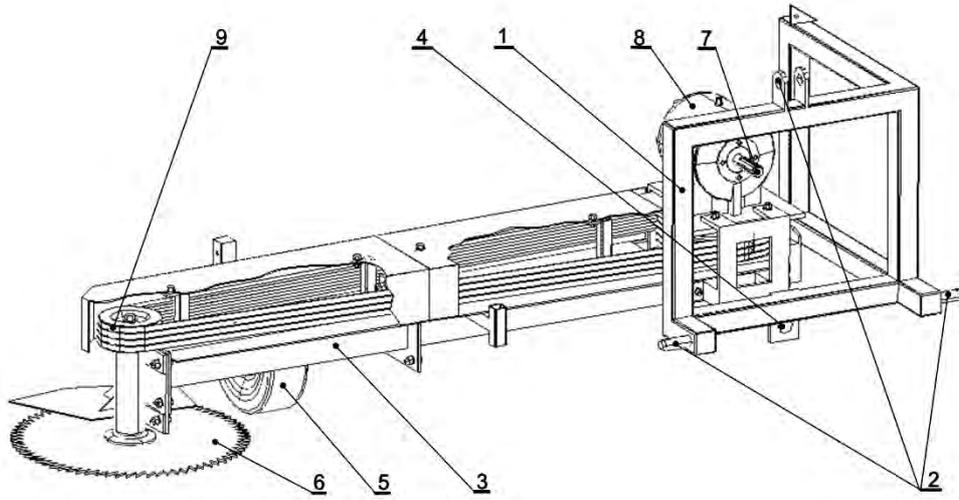


Fig. 1. Model of tractor mover for woody plants: 1 – frame, 2 – three-point linkage, 3 – working arm, 4 – articulated joint, 5 – supporting wheel, 6 – circular saw, 7 – shaft, 8 – intersecting axis gear, 9 – belt transmission

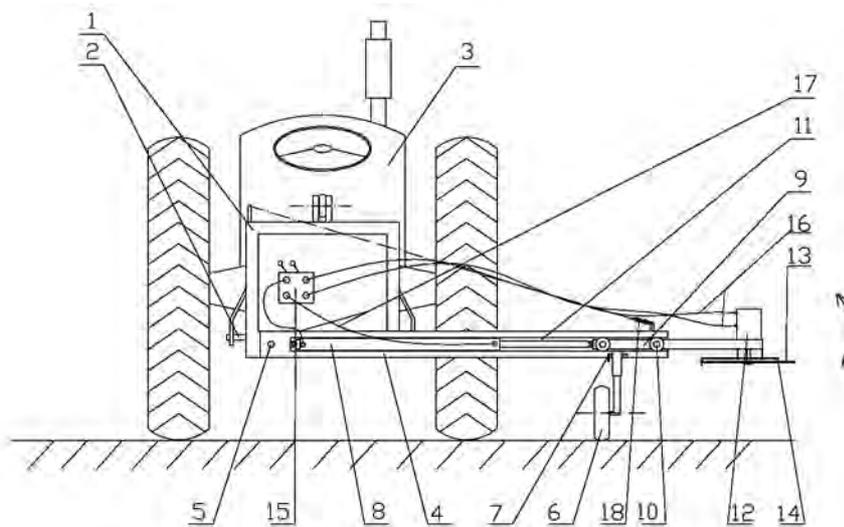
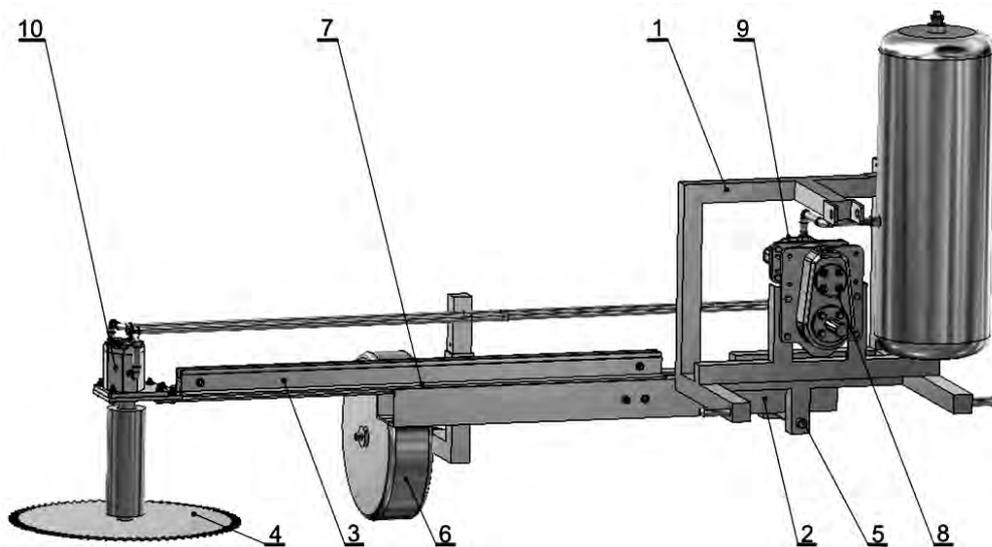


Fig. 2. Mover for woody plants: 1 – frame, 2 – three-point linkage, 3 – agricultural tractor, 4 – working arm, 5 – articulated joint, 6 – ground wheel, 7 – stopper, 8 – remote control hydraulic cylinder, 9 – tip, 10 – roller, 11 – guide, 12 – hydraulic engine, 13 – circular saw, 14 – safety guard, 15 – programmer, 16 – feeder cable, 17 – offtake, 18 – chain [13]

The modification of the presented mower for woody plants is the mover with the retractable arm and hydraulic drive of the circular saw (Fig. 3). The mover structure is consisted with the frame (1) adapted to three-point linkage of agricultural tractor and working arm (2) with extension arm (3). At the end of extension arm is mounted the circular saw (4) and the ground wheel (6). The working arm (2) is connected with the frame using articulated joint (5). The remote control hydraulic cylinder is coupled with the extension arm (3). The end of the working arm (2) has rollers mating with the guide (7). The circular saw is driven by the hydraulic engine (10). The drive of the circular saw is transmitted by the reduction gear (8) and the hydraulic pump (9).



*Fig. 3. Model of tractor mover made in Autodesk INVENTOR program:
 1– frame; 2– working arm; 3 – outrigger; 4 – circular saw; 5 – articulated joint;
 6 – supporting wheel; 7 – guide; 8 – reduction gear; 9 – hydraulic pump; 10 – hydraulic engine*

Biomass may be processed directly on chips by using harvester (Fig. 4) [14] or by using wood cutter (Fig. 5) [15], especially for cutting on specified pieces bevelled energetic plants or branches constituting discard from e.g. cross-cutting of the fruit tree in orchard. In agreement with registered design wood cutter [14] characterizes by that cutting gang has replaceable heads with three, four or six cutters allowing for change of length of cutting elements.

One of the many conceptual agricultural harvesters is presented in Fig. 4. The harvester [14] is destined for harvest and shredding plants with ligneous sprouts and branches. The harvester is mounted on the agricultural tractor using three-point linkage (1) and it has a drum cut system. The drive of harvester is transmitted from power-take-off of the agricultural tractor by system of belt and gear transmissions. The cut assembly (2) of harvester has two drums (3) to which circular saws (4) is mounted. The drums (3) have strips (5) that make biomass easy to retract into the throat of cutting assembly (6).

The construction of the cutting assembly of the harvester was granted legal protection under utility no. W-116926 and includes the units developed and patented by Rzeszow University of Technology. The cutting assembly is composed of feed assembly (7) and cutting strips (8) mounted on two rotational drums (9). Both cutting and shredding systems are protected by overload coupling. The applied kinematic system of shredding assembly and possibility of change the cutting strip amount allows to shred ligneous biomass on the length of 10-300 mm. Cutting assembly is equipped with the outrigger (10) which bend high sprouts. The longer chips are transported on the trailer by using the belt conveyor (Fig. 4a). The short chips are transported alternatively by using centrifugal mechanisms (Fig. 4b).

The shredding assembly is a constructional solution adapted from a wood cutter (Fig. 5) [15] and is composed of the head (1) in which the cutting knives (2) are located. Depending on required length of chips the shredding assembly has three, four or eventually six knives located uniformly on the head circumference.

Characteristic feature of the presented harvester are:

- possibility of application of each typical agricultural tractor with a power above 60 kW,
- multifunctionality: moving, shredding, transport to the trailer,
- by the operating parameters the harvester is adapted for especially small farms of energetic plants.

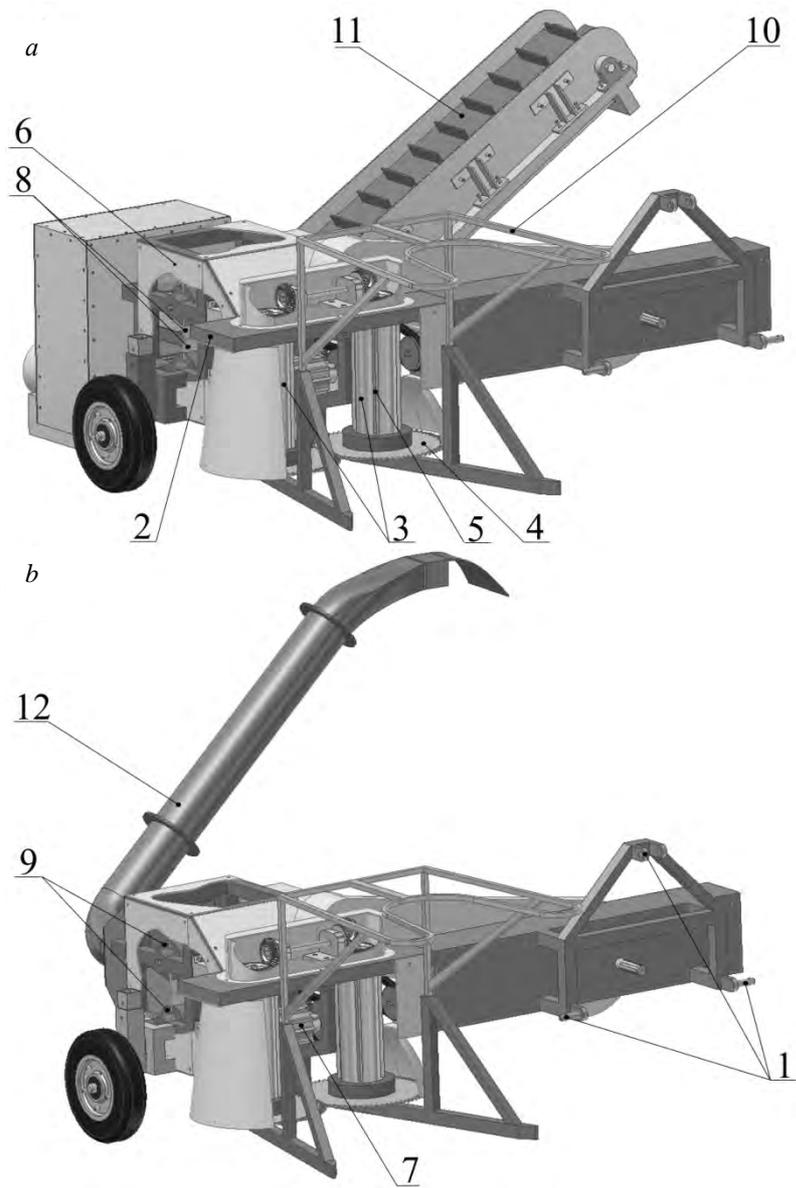


Fig. 4. Model of harvester with belt conveyor (a) and centrifugal ejector (b):
 1 – levers of toolbar assembly, 2 – cut assembly, 3 – drums, 4 – cut disc, 5 – firm strip, 6 – shredder,
 7 – feed assembly, 8 – cut tool, 9 – drum, 10 – outrigger, 11 – belt conveyor, 12 – centrifugal mechanism [14]

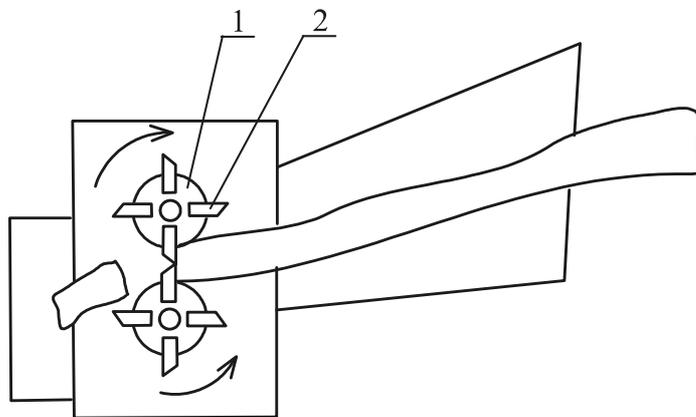


Fig. 5. Cut assembly of wood cutter: 1 – cut head, 2 – cutter [15]

In search of machine productivity intensification and simultaneously the increase of savings during exploitation the authors have constructed the multifunctional machine – harvester (Fig. 6) [16]. In the crop season the harvester will allow to make the harvest of ligneous biomass possible and in the residual period it may be used as a stationary chipper of branches and logs. The harvester for harvest and shredding of crop is composed of the agricultural tractor with a power of 60 kW and equipped in front power-take-off. At the front of the tractor is a machine for cutting and shredding of the biomass depending on necessity on chips or chaff. Furthermore, the operating module of the harvester may be used as a stationary chipper at orchard cultivation and support services in forests. The harvester is especially destined for small biomass producers, for which purchase of professional machines is financially inaccessible.

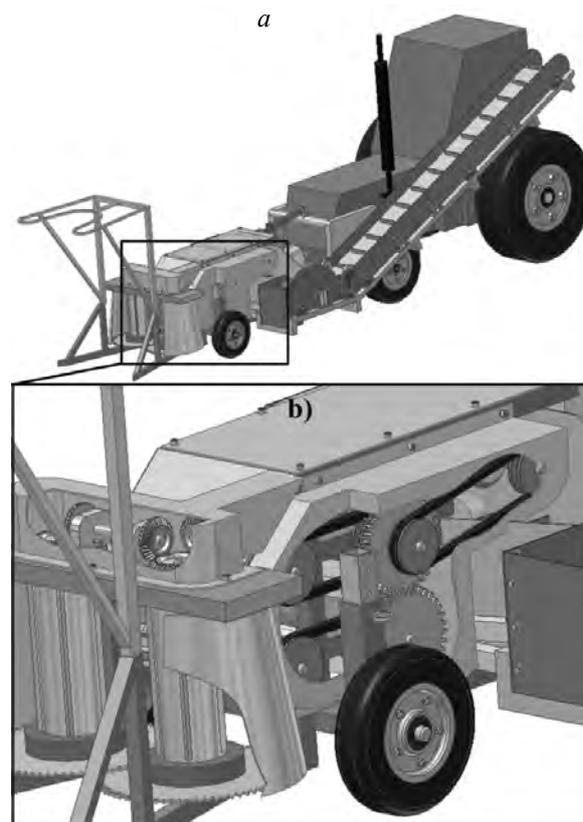


Fig. 6. Harvester for harvest and shredding of energetic plants with ligneous sprouts (a), view of base driving mechanisms of machine (b)

The biomass crop is transported by using a belt conveyor mounted from the side of the agricultural tractor on the trailer (Fig. 7a) or container (Fig. 7b) mounted in three-point linkage of the tractor. This harvest and transport system is recommended during biomass harvest in small plantations. The belt conveyor does not limit visibility of the driver and does not make manoeuvrability of the tractor difficult during working and crop transport. Inclination angle of the belt conveyor is controlled by using the hydraulic cylinder.

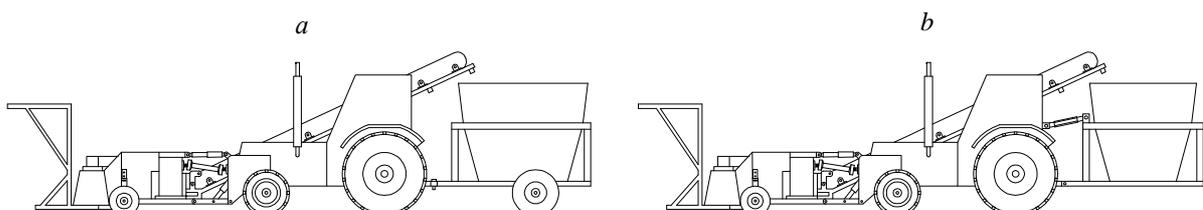


Fig. 7. Transport systems of the biomass into trailer (a) and container (b)

The mobile harvester for harvest and crop shredding (Fig. 8) [17] is composed of a caterpillar tractor, a machine cutting down the ligneous plants and shredding the crop on chips or chaff. The both cutting and shredding assemblies are driven by own prime mover. Locating of above mentioned assemblies at the front of the agricultural tractor facilitates the driver efficient machine handling and continuous control of their functioning. The cutting and shredding assemblies were granted legal protection under utility [14]. The application of the hydraulic drive of the cutting assembly allows for stepless regulation of the tangential velocity of circular saws mounted on two drums. Adjustment of tangential velocity of circular saws and driving speed of harvester is necessary in order to not shred of the trunks which make difficult further plant growth.

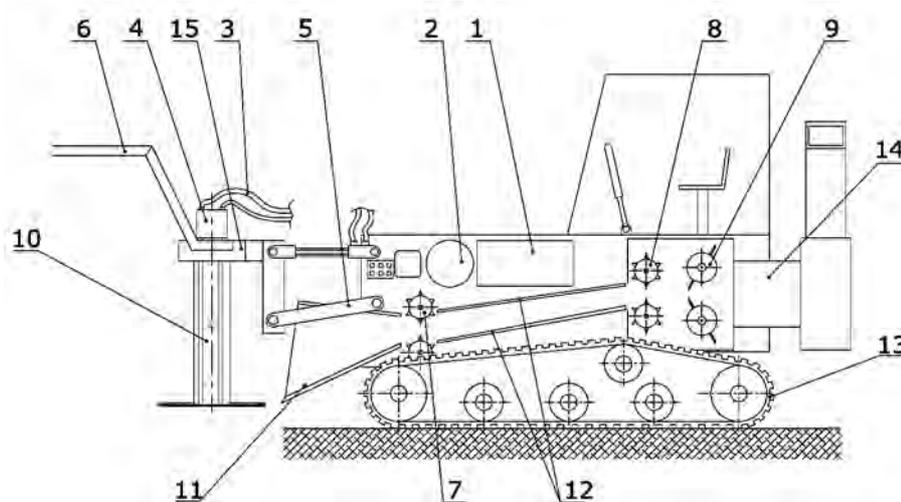


Fig. 8. Scheme of the mobile harvester: 1 – combustion engine, 2 – tank, 3 – hydraulic wires, 4 – hydraulic engine, 5 – arms, 6 – outrigger, 7 – draw in rollers, 8 – feed rollers, 9 – rotational drums with cutters, 10 – strips, 11 – throat, 12 – strips, 13 – caterpillar, 14 – ejector, 15 – body of cutting assembly [17]

The advantages of caterpillar harvester are:

- application of rubber caterpillars for harvester drive allow for its operating in waterlogged areas,
- rubber caterpillars as the alternative of traditional metallic caterpillars have smaller mass and adhere better to the irregularity of the terrain,
- universality of use; harvester allow for chips production or cutting of ligneous plants on pieces with specified length,
- using of the hydraulic engine for the drive of circular saw simplifies the kinematic chain of the harvester and influences on mass reduction of the machine,
- possibility of stepless regulation of rotational speed of the hydraulic engine,
- after disassemble of the cutting assemble the harvester may be used as a stationary chipper of branches and logs,
- multifunctionality of the machine: cutting down, shredding and transport of the biomass on the trailer.

Summary

In the subject area of machines characterized by low productivity and destined for working in small plantations as well as verified in practice while field work there are not many commercial offers. In this situation lasts searching of construction solutions complying with conditions of small producers requirements in which farms is small power farm tractor usually with primary equipment. Proposed agrotechnical machines have original constructions and take into account the needs of small producers of the ligneous biomass. Machines destined for operation in small and medium-sized plantations of energetic plants are characterized by simple construction and do not require highly skilled workers. In case of

establishing, protective treatments, logging and processing of the biomass in plantation of the energetic plants the farm tractors are basic prime movers of specialized machines. The majority of developed machines are mounted on farm tractor using levers of toolbar assembly.

Considering the efficiency of application of proposed machines for production, logging and processing of the biomass in small farms a few factors should be taken into account. First of all it should be considered largeness of a farm and in consequence demand on manpower and grade of accessibility of high power farm tractors. From point of view of possibility of machine utilization should be considered terrain hypsography and soil structure. The advantage of proposed solutions is their uncomplicated construction which is connected with low production cost and simple machine operation.

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