Fruit Growing Research, Vol. XXXVIII, 2022 DOI 10.33045/fgr.v38.2022.12
https://publications.icdp.ro/index.php

TEHNOLOGIE INTEGRATĂ ŞI ECHIPAMENT TEHNIC DE TOCARE A RESTURILOR VEGETALE REZULTATE DIN TĂIERILE DIN POMICULTURA / VITICULTURĂ
INTEGRATED TECHNOLOGY AND TECHNICAL EQUIPMENT FOR CHOPPING VEGETABLE RESIDUES RESULTING FROM TRIMMING IN ORCHARDS / VINYARDS

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Abstract

The recovery of wood residues from the spring or autumn pruning of branches, from orchards, in the form of briquettes or pellets, is part of the European policy on reducing non-renewable energy consumption. Also, organic agriculture brought to the fore the need to use natural fertilizers, which is why the National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry- INMA Bucharest conducted applied research for the development of an integrated technology and technical equipment for chopping plant residues resulting from cuttings in vineyards/orchards. Integrating the equipment in the technology, it is possible to obtain plant material that will be the basis for the production of mulch, which will be used in the technologies of organic fertilization of fruit/vine plantations. The advantages of this technology are the fact that the fruits obtained will no longer contain chemical compounds, contributing to the preservation of consumers' health and at the same time the branches or canes resulting from cuttings will be used efficiently. Also, the chopped wood material can be used to make pellets or briquettes, contributing to solving the global problem of harmful emissions into the atmosphere.

Cuvinte cheie: tocător, biomasă, resturi vegetale lemnoase.
Key words: chopper, biomass, wood residues.

1. Introduction

The utilization of vegetable residues from agriculture has become an important objective, considering the fact that the negative effects on the environment, due to the consumption and excessive use of natural resources, are constantly increasing. The use of coal, gas and oil as an energy source has led to an increase in atmospheric pollution, greenhouse gases, global warming and imbalances that, in the long term, can have devastating and irreversible effects.

At the European level, but also worldwide, discussions were held and strategies were established to lead to stopping these effects. Finding alternative energy sources is a global priority. Presently, biomass contributes by approximately 12% to the production of primary energy in worldwide and in the developing countries this occupies 40-50% of the necessary energy (Spirchez et al., 2017; Wisconsin K-12, 2020).

The modern waste management strategy laid the foundations for a hierarchy of actions, namely: prevention of waste; treatment of waste at the source of generation; promotion of the concept of recycling, reuse and compost production; optimization of final disposal methods (storage in waste ramps, incineration, co-incineration) for the types of waste for which there are no recovery technologies.

In the last period, many researches were carried out for the development of machines for chopping wood waste (Liashenko et al., 2019; Pratik Shubhankar & Ramesh, 2015; Cristescu et al., 2012).

The trees growing on the orchards or in the private gardens provide opportunities for sustainable biomass obtained from pruned branches every year. Profitable production of fuel material requires high-performance equipment and methods by which wood chips can be produced at low cost. The practice of chopping tree branches shows that not all chopping machines are suitable for use on homestead plots (Liashenko et al., 2022).

Agricultural and oilseed straws are a major part of crop residues and considered as important feedstocks for bioenergy applications as they have low nutritional value when used as feed for animals. Specific energy for grinding of wheat, canola, oat and barley straw grinds were investigated, to develop the technologies for obtaining biofuel from those crop residues (Tumuluru et al., 2014).

Wood waste from agricultural activities can be transformed into sawdust, or chips, which can be used for bio-fertilizers or for energy.

Part of the sawdust is burned in boilers in raw form, but it is still much better to produce briquettes and pellets from sawdust and later use them as an energy source.

The calorific power obtained by burning wood is much higher than in the case of using gas or electricity. The manufacture of briquettes from sawdust offers solutions for solving the global problem of harmful emissions in the atmosphere. The chips can also be used to obtain mulch or to obtain biomass fuel, as briquettes or pellets, made by pressing the chopped wood material.

Some authors carried out research applicable to the analysis of influence of grinding process on the form of flakes that result from the process, energy consumption (Wargula et al., 2018). Their study also allowed to make conclusions leading to the improvement of the processes that use grinded mass. The construction specifity of the kind of machines and their working principles results from the fact, that the cutting process they perform concerns orthotropic plant material that has inhomogenic structure and physical-chemical properties requires further analysis.

The purpose of our applied research was to create a medium-capacity equipment to chop woody plant residues, equipment to complete the range of machines intended for the execution of this activity.

Chopper offers the possibility of a rapid reintegration into nature of wood material through composting and reduces storage space for branches.

2. Material and methods

INMA Bucharest has carried out applied research for the design, construction and testing of a machine for chopping wood waste, which is collected from agricultural works, including branches resulting from the shaping of tree crowns. The purpose of conducted researches is to increase the efficiency of the process of biomass chopping to the given size by justifying the rational design and technological parameters of a medium-sized chopper. Computerized design can be extremely useful in the application of the constructive solutions defined by the team of researchers, allowing the simulation of movement and the identification of interactions with a destructive effect, between the component parts of the machine. In this way, the construction of the equipment can be optimized and the time required for the design can be reduced.

Description of software used. The software used was 3D Solidworks, which allowed the three-dimensional creation of the model, which has been the basis for the construction of the parts and component assemblies. This software can reduce the time for development, reduce the investments and improve the quality of the final product. Test projects can be tested under real-world conditions, by simulation of the working process. 3D Solidworks ensure product quality while reducing prototyping and physical testing costs. In the figure 1 are presented the main assemblies of the machine.

Wood waste chopper requirements deriving of branches characteristics, with direct reference to physical characteristics: size, weight, shape, firmness.

The cutting process is influenced by several factors, namely: the species of wood, the humidity of the wood, the degree of sharpening of the knife, the cutting speed given by the peripheral speed at the tip of the knife, the friction between the knife and the chip.

For the realization of this machine, the constructive solutions existing on the market at the present time were analysed, the research team developing new solutions for the chopping device.

Wood chopping machine must be provided with the ability to set limits of the kinematic parameters and functional corresponding speeds (conveyor speed, chopping rotor rotational speed, flows and so on), to avoid mechanical damage and obtain chips at the desired size.

The wood chopping equipment made at INMA Bucharest has a special construction, characterized by a rotor equipped with knives, arranged in a spiral, which makes the cutting process to be carried out through a process of progressive shearing of the wood branches.

The equipment consists of welded assemblies and elements in series production (gear motor, transmission chains, bearings, wheels, hydraulic cylinders, hydraulic components, removable fasteners: screws, nuts, washers, flat washers Grower and so on). The main part is the chopping rotor, which it is different from the constructive solutions currently in production.

The knives, by a thick of 15 mm, have been made by special steel, HARDOX 500, characterized by very good resistance to shocks and deformations (https://www.uconstruct.ro/hardox500-tuf-otel-dur-de-inalta-rezistenta-pentru-piese-de-uzura/).

The chopper is also equipped with a counter-knife, realized by the same special steel. Together they work like a scissors, under the acting force and inertia force.

The cutting of the branches is done transversely, the size of the chips depending on the speed of the scraper conveyor, of the type with scrapers arranged on chains with special sprockets.

The main position of the knife in relation to the direction of the wood fibres is longitudinal-transverse. Transversal cutting is considered as position 0, the sectioning angle will continuously increase in the plane of the direction of the fibres until it reaches θ=90 degrees.

The acting of the drive rotor and the scraper conveyor, which bring the material to the chopping area, is hydrostatic, the command being given by a hydraulic distributor. The peripheral speed of the two subassemblies can be correlated so that the amount of material brought to the chopping area can be varied, depending on the quality and quantity of the material to be chopped.

3. Results

Preliminary results were obtained at the stationary tests of the wood chopper.

Measurements were made of the main constructive dimensions of the experimental model and of the subassemblies, the overall dimensions, functional dimensions; the tires of the undercarriage were identified. Measurements of the masses were made, at the stationary, and will be also done during the field experiments, in the next stage of the research.

The measured values are presented in Table 1.

Own chopper masses were determined by weighing on a scale, provided by INMA Bucharest, the values being presented in table 2.

Manoeuvrability

The inner and outer turning diameters were measured and the turning radius of the tractor-chopping equipment aggregate was calculated.

From the measurements of the inner and outer manoeuvring lane, it was calculated that the turning radius of the aggregate, consisting of the New Holland T 80 tractor and the technical equipment for chopping plant residues, symbol TRL-0, was approx. 4.5 m.

Determination of the rotational speed of the chopping rotor

The chopping rotor is driven by a mechanical transmission, consisting of cardan, conical group, belt transmission. The movement taken from the tractor's power take-off shaft (PTO) is transmitted to the conical group, which changes the direction of rotation to 90 degrees and transmits the speed to a multiple belt wheel, with a diameter of D_p=400 mm, and from this, by means of multiple trapezoidal belts, the movement is transmitted to the chopping rotor axis, through a belt wheel with a diameter of D_p=125 mm, the transmission ratio being i=3.2.

At the synchronous PTO of the tractor, when working unloaded, at the nominal speed of the tractor engine n_{tr}=1800 rpm, the rotational speed at PTO was n_{PTO}=515 rpm, and the rotational speed measured at the chopping rotor had the average value $n_{chopper}$ =1430 rpm, result as an average of 3 successive measurements, carried out with the tachometer provided by INMA.

Determination of the drive rotor feed speed and the working speed of the scraper conveyor

The working speed of the scraper conveyor determines the machine's feed rate, constituting, together with the peripheral speed of the feed rotor and the peripheral speed of the chopping rotor, the basic elements that determine the work capacity of the aggregate.

The advance speed of the conveyor can be changed by changing the flow of oil entering the OMP50 hydraulic motor, modified by one of section of the distributor, which can be adjusted to certain values, by the appropriate positioning of the hydraulic distributor lever. The rotational speed of the drive rotor can be in a range of 0...20 min^{-1}.

From the successive measurements for 3 repetitions, it was found that the forward speed, $v_{forward}$, of the scraper conveyor can vary, depending on the position of the lever operating the distributor, being in a range t_{rans} = 0... 0.425 m/s.

Images during the measurement of the revolutions of the working bodies are presented in Fig. 7.

To achieve the project's objectives, the following INMA own infrastructures were used - according to the http://erris.gov.ro/ platform:

- System design, execution and optimization of technical equipment and technologies (https://www.erris.gov.ro/SYSTEM-OF-DESIGNING-EXECUTION-AND-OPTIMISING-THE-TECHNICAL-EQUIPMENT-AND-TECHNOLOGIES);
- Research infrastructure for technical systems in agriculture, forestry and the food industry (https://www.erris.gov.ro/RESEARCH-INFRASTRUCTURE-FOR-AGRICULTURE-FORESTRY-AND-FOOD-INDUSTRY)

4. Conclusions

After the experiments realized at the stationary conditions, with the physical model of the chopper unloaded, regarding its functioning and usability as well as the safety in using the machine, the following conclusions were established:

- the equipment for chopping wood residues, symbol TRL-0, corresponds to the requirements imposed by the design theme;

- the equipment for chopping branches obtained from orchards/vineyards farms by pruning the crown trees or trimming the vines, can contribute at the needs of Romanian horticulture for valuing its organic wastes as a biocompost or biofuel.

Researches will be conducted for experimental tests in real conditions and the results will be presented in a new article.

Acknowledgements

This work was supported by a grant of the Romanian Ministry of Research, Innovation and Digitization, on the national NUCLEU Program / CORE Program, contract no. 5N / 07.02.2019, AAd.8/2022, research project named “Managementul integrat al lucrarilor din fermele agricole, viticole si pomicole / Integrated management of works in agricultural, vineyard and fruit farms”

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https://www.erris.gov.ro/RESEARCH-INFRASTRUCTURE-FOR-AGRICULTURE-FORESTRY-AND-FOOD-INDUSTRY

 DOI 10.33045/fgr.v38.2022.12

Tables and Figures

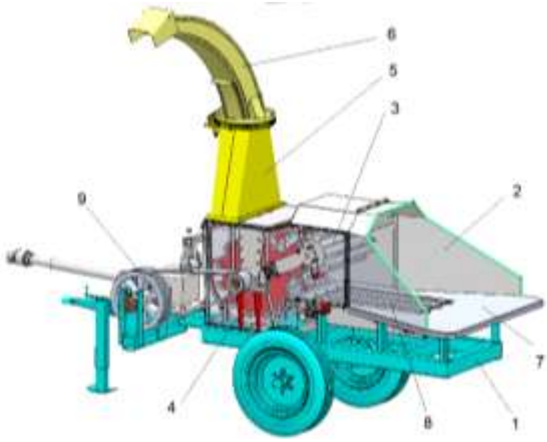

Fig. 1. Technical equipment for wood waste chopping
1 – infrastructure; 2 – assembled housing; 3 – wood drive rotor; 4 – chopping rotor; 5 – intermediate section; 6 – material discharge basket; 7 – loading platform; 8 – conveyor chain; 9 – mechanical transmission; 10 – hydraulic transmission

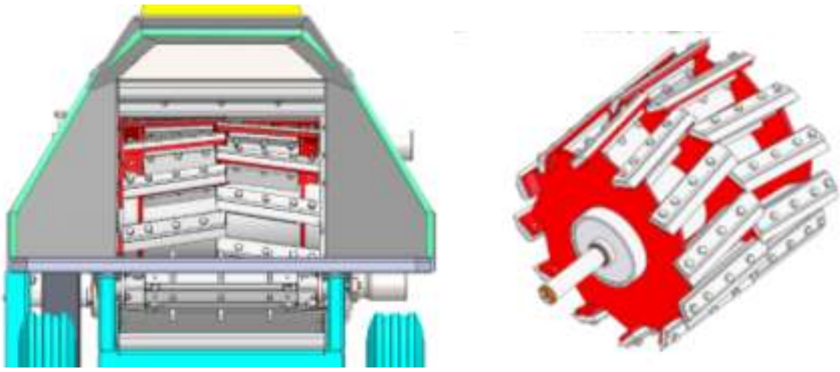

Fig. 2. Chopping rotor with staggered knives

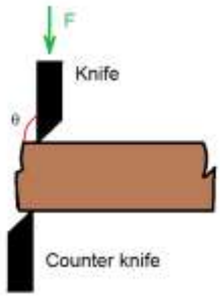

Fig.3 Chopping process

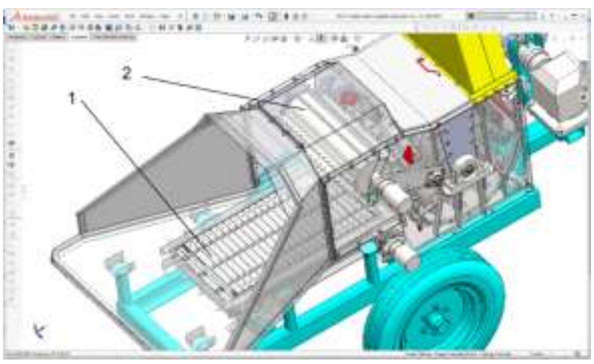

Fig. 4. Scraper conveyor (1) and feed rotor (2)

Fig. 5. Experimental model of the wood chopper, symbol TRL-0

Fig. 6. Images during dimensional measurements

Table 1. Dimensional measurements

Characteristics	Value
Overall dimensions, mm - length - width - the height without the exhaust pipe - the height with the exhaust pipe	 3440 1210 1555 2930
Dimensions of the feeding area, mm - width - height	 592 428
Diameter of chopping rotor, mm	610
Drive rotor diameter, mm	308
Distance from the ground to the feeding plant, mm	855
Gauge, mm	1025
Wheelbase, mm	2020
Height to the coupling eye, mm	545
Tires 6.00/65-16. Static radius	340
The rotation angle of the exhaust pipe, deg.	0...270

Table 2. Masses measurements

Characteristics	Value
Own weight of the chopper (kg)	
Own mass on the coupling eye (kg)	
Own mass on the axle (kg)	

Fig. 7. Images during rotational speed measurements of the chopping rotor and feed rotor