Biomass Processing from Agricultural Residual Production and Maintenance Operations when Cutting Trees and Vines

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Abstract: *The article presents aspects related to the processing of biomass from agricultural secondary production, from maintenance operations when cutting trees and vines, and also an original solution of branch chopper with pulling knife through which branch segments with longer length are obtained compared to the classic solutions of segmentation (chopping) of the branches.*

Keywords: *Biomass, agricultural secondary production, choppers, branch segmentation*

1. Introduction

In general, all aspects of human life require the consumption of significant amounts of energy. Thus, in order to ensure normal living conditions in the cold season, significant amounts of heat are needed in order to ensure acceptable temperatures in homes. Also, living in civilized conditions involves the daily preparation, regardless of the season, for each person, of a certain amount of domestic hot water and this is also done by consuming appropriate amounts of heat. In this sense, Romania has a high biomass potential, coming mainly from agricultural (60%) and forest (20%) wastes [1].
The environmental standards of the European Union, as well as the fulfilment of the commitments assumed by Romania in the negotiation process of Chapter 22 of the Community acquis, once our country enters the EU, imposed the alignment with the ecological requirements that require the complete disposal of wastes.
A significant amount of wood wastes results from forestry areas (forestry industry) and wood processing industry (about 3% in the forestry industry sector and 11% in the woodworking industry from processed wood). Wastes resulting in the wood industrialization process, based on the technological sequences that generate them, they are the following:
- Harvesting wood by cutting it (branches, stubs, chips, sawdust)
- Primary wood processing (wood scraps, shells, chips, sawdust)
- Superior wood processing (veneer scrap, sawdust, wood chips, wood powder, solid wood scraps, etc.)
- Finishing of wood products (wood preservatives, residues of reusable substances as solvent, glues, resins, adhesives, dust retained by air filter bags, etc.)

The most representative categories of combustible wood materials are: firewood, tree bark, branches resulted from the forest logging, branches resulted from the tree orchards maintenance, vine ropes, sawdust, wood chips, small pieces of timber and other residues resulted from processing wood. Typically, trees resulted from logging are a high-quality homogeneous biofuel. From an energy point of view, combustible wood materials have an average energy content of between 14 MJ/kg and 19 MJ/kg.
The cuttings in the orchards are made in the non-vegetative period and as a result the average humidity of the cut branches is 30-35%. If we take into account a humidity of 35% of a ton of cuttings, by drying up to an average humidity of 15%, it results in 765 kg of biomass usable for the production of thermal energy. It results that a ton of cuttings has an average energy potential of 11.856 MJ or 3.3 MWhth. From a hectare of intensive orchard annually, on average, about 3000 kg of biomass is cut which has an energy potential of 35.628 GJ/ha·year.

The biomass from the cuttings is transported to the row head where it is chopped with a specialized machine at 10 ... 50 mm and stored in containers with perforated walls for a good air circulation. On average, the bulk density of the wet cut is 250 kg/m^3, which leads to a need of about 12 containers per hectare of orchard. By natural drying or forced ventilation, the biomass reaches an average humidity of 15% and a bulk density of about 200 kg / m^3.

From the published data, for Europe, results an average cost of gathering, chopping and transport for a ton of cuts of about 40 € /t. Taking into account a profit of 20% and VAT it results that a ton of biomass usable for thermal energy production can be sold for about 80 € /t. The specific price for the primary energy of biomass is in the case studied of 5.2 € /GJ or 18.6 € /MWhth, values much lower than those for diesel of 33.22 € /GJ or for LPG of 21.52 € /GJ [2].

In the combustion process, thermal power plants generally generate pollution. The size of the pollution depends on the fuel used to generate the thermal energy on the one hand, as well as on the ways of burning the fuels, on the other hand. Solid fuel in the form of pellets and briquettes that are produced from agricultural residues (straw, corn cobs, corn stalks, residues of soya, rape and tobacco, vine ropes, technological residues from orchards maintenance, etc.), is an ecological fuel and is an efficient alternative to conventional fuels for thermal boilers (natural gas, liquid fuel, coal, firewood, etc.). The major difference from the classic ones is the small size and regular shape of the pellets, which allows their use as fuel for automated heating plants.

The chemical composition of biomass differs greatly depending on the species, but it can be said that plants contain (15-30% in the dry state) lignin ($C_{40}H_{44}O_6$) and carbohydrates (sugars or glucides). The carbohydrate fraction consists of several glucides molecules bound together in long chains or polymers. The two representative categories of carbohydrates are (40-45%) cellulose ($C_6H_{10}O_5$) and (20-35%) hemi-cellulose [3].

The physical characteristics of solid fuels obtained from biomass are the following [4]:

▪ dimensions and shape - influences the handling and combustion technology;

▪ moisture content - influences the storage time, the design of the installation and the power calorific;

▪ calorific value - is the most important property of a fuel that influences the method of obtaining thermal energy and the design of the combustion plant;

▪ bulk density - influences the transport, handling and storage of fuel;

▪ ash content - also an important feature that influences technology combustion, emission of solid particles, handling and use of ash;

▪ granulation - influences the drying and formation of dust;

▪ abrasion resistance - influences segregation and quality change;

▪ ash melting temperature - influences the combustion technology, the safety in operation and the control system of the combustion installation.

The chemical characteristics of solid fuels obtained from biomass are as follows [4]:

▪ C content - important characteristic that influences the calorific value, which must be as high as possible;

▪ O content - important characteristic that influences the calorific value, which must be as high as possible;

▪ H content - important characteristic that influences the calorific value, which must be as high as possible;

▪ N content - influences NOx emissions (toxic);

▪ S content - influences SOx emissions (toxic) and corrosion;

▪ Cl content - influences HCl (toxic) emissions and corrosion;

▪ K content - influences the use of ash, the formation of aerosols, the corrosion of the combustion plant and reduces the melting temperature of the ash;

▪ Na content - influences the formation of aerosols, corrosion of the combustion plant and reduces the melting temperature of the ash;

▪ Mg content - influences the use of ash and the melting temperature of ash;

▪ Ca content - influences the use of ash, the formation of aerosols and increases the melting temperature of ash;

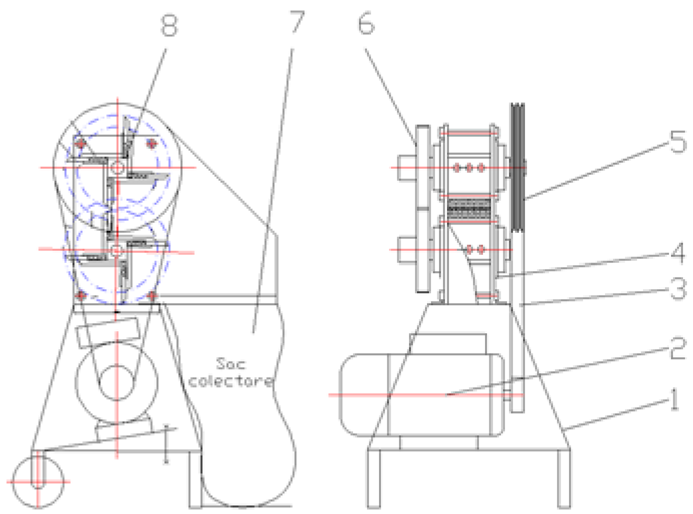
▪ volatile substances content - influences the design of the combustion plant in order to increase its efficiency;

▪ heavy metal content - increases pollutant emissions and reduces the possibilities of using ash

The use of biomass from agricultural secondary production and from periodic pruning of vines and orchards or from the technological process of wood processing has several advantages such as:
• Solves the problem of environmental pollution with sawdust and wood wastes or by burning stubble and plant debris;
• Dry agricultural biomass and energy plants are an inexhaustible resource of raw material;
• The production of pellets and briquettes (ecological, non-polluting products) is undertaken with the application of a technology with a high degree of mechanization, low manufacturing costs and allows obtaining thermal energy with advantageous costs.
• The natural chopping and drying of the branches are a resource of combustible material for heating.
The main potential beneficiaries are small and medium farmers, associations of agricultural landowners, economic agents who carry out activities in the agricultural field and who want to provide part or all of their thermal energy by using their own renewable energy sources, marketing pellets and briquettes in order to ensuring energy independence [5].

2. Branch chopper with pulling knife

Wood is the most widely used solid biofuel. The raw material can have the following shapes: logs, stumps, stems, leaves and needles from the forest, bark, sawdust, firewood and wood chips from the wood industry and wood recovered from construction. They can be used chopped when is possible directly as a fuel, or they can be processed into forms that are easier to transport, store and burn, such as: pellets, briquettes and wood dust.
In most cases of energy conversion of biomass, the potential chemical energy from biomass is converted - directly or after some preparatory biological and / or chemical processes - into heat obtained by combustion. We can say that the main form of energy conversion of biomass is its "generic combustion" and the main primary form of usable energy obtained in this way is heat.
The first operation for the use as an energy source of branches resulting from periodic cuttings in orchards and vineyards is their segmentation (chopping).



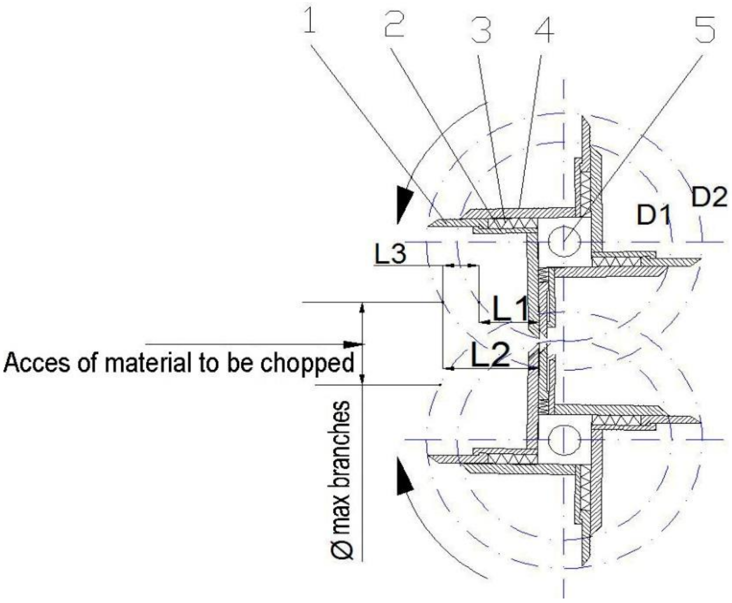
1. Mobile frame
2. Electric engine
3. Transmission belt
4. Frame with bearings
5. Belt wheel
6. Gears
7. Beg collection system
8. Chopping assembly

Fig. 1. Branch chopper with pulling knife

The forest wastes chopper has the role of crushing the forest residues from the field (branches, twigs, etc.), obtaining a roughly segmented wood mass, which will be used either for direct burning in stoves or for crushing to specific granulation for briquetting or pelletizing.
Below is an original solution of chopper with pulling knife [6] used in the industrial or domestic field for branch chopping, vine ropes or other wood materials from agricultural secondary production in order to use them for burning in stoves.

The chopper with pulling knife, fig. 1, consists of a mobile frame with two wheels (1), an electric engine (2) a transmission belt (3) a frame with bearings (4) a belt wheel (5) two gears (6) a bag collection system (7) and two axes (8) with four cutting knives on which are mounted pulling arms that ensure the advance of the chopping material between the cutting sequences resulting in a longer length of the cut segments.

The chopping assembly according to fig. 2 consists of two axles, one drive axle, actuated by the belt wheel and one drive axle led by a gearing with gears with transmission ratio 1. The shaft (5) is bearing at the ends and the central part is square in shape. The cutting knives (4) are screwed to each side of the square. On each cutting knife is mounted with screws a housing (2) in which the pulling arm (1) is seized which slides in the housing against a spring (3). When the chopping material is touched, the pulling arm (1) takes it and pushes it forward until the two cutting knives (4) positioned in the mirror cut the chopping material, with length L2, larger by L3 compared to the version without pulling arm L1 [6].



1. Pulling arm
2. Pulling arm housing
3. Spring
4. Knife
5. Rotatory shaft

Fig. 2. Chopping assembly

The cutting force varies in very large limits depending on the wood structure, its length and diameter, knots, species, fiber distribution, etc.
To calculate the sizing of the chopping equipment, start from the force required for the cutting process.

$$F = K \cdot p \cdot L \cdot d \qquad (1)$$

where:
k - a coefficient that takes into account the angle of the knife and the state of sharpening, the species and the humidity of the wood; indicative values between 0.003 and 0.009;
p - specific resistance to cutting;
The resistance to compression parallel to the fibers has values between 30 - 90 N/mm^2, depending on the essence of the wood.
L, d - length and diameter of the wood to be cut.
For the calculation, values will be chosen slightly above average.

$$F = 0.009 \cdot 70 \cdot 40 \cdot 40$$

$$F = 1008\text{N} = 100.8\ \text{kgf}$$

It is taken into account $F_{max} = 100$ kgf. [7]

3. Conclusions

The need to provide heat in the cold season but also for food preparation has been and remains a very important factor in people's lives. Also, the accessibility of the population to the fuels necessary to ensure the current energy, is becoming more and more important both from a logistical and financial point of view. That is why a first conclusion is that wood biomass in its various forms, which is a cheap source of heating and is found in abundance, can provide the energy needed for a part of the population.
The chopping operation contributes both to the easier handling of biomass and to the creation of a compact finished product for final consumers. In order for the chopping of the branches to be carried out with optimal energy consumption in the specialized literature, there are studies and researches aimed at improving the chopping and shredding equipment, both in terms of design and in terms of fulfilment the requirements of processing of the shredded material after this stage.
The advantages of chopped biomass obtained with the chopper with pulling knife are the following;

• Larger firewood segments are obtained that behave better when burning in stoves;

• Can be handled more easily;

• They can be stored easier and with smaller volumes;

• Wood materials from agricultural secondary production are used;

• It creates a source of ecological energy from renewable sources;

The presented solution of chopper with pulling knife can contribute to the modernization of the equipment in the biomass processing technology chain resulting from periodic cuttings of vines and orchards.

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