MECHANIZATION TECHNOLOGY DEVELOPMENT FOR WOODY PLANT PRODUCTION BY LAY DOWN PLANTING: DEVELOPMENT OF HARVESTING MACHINE FOR PROPAGATION MATERIAL

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Abstract:
Many procedures exist for the propagation and plantation of woody-stemmed plant in the national and international practice of the forestry and agricultural areas. One of such methods is the planting of which multiple versions are applied. Installing the short-rotation plantations are carried out by planting seedlings or cuttings. Currently on the market available planting machines for planting of cuttings or rooted seedlings can be used only with a number of technology trade-offs. All planting machines are capable of vertically implanting the plants. Lay down propagation technology is not available currently on the market, therefore our goal is to develop such mechanization technology that’s why it is an important task to improve the energetic plant propagation. The technology to be developed will be better than traditional methods because of the higher field performance therefore the lower overhead expenses. The aim of recent study is to submits the preliminary results of a new harvesting and planting machines development, which properly serves the new lay down cutting propagation technology.

KEYWORDS: ENERGY PLANT, PLANTATION, CUTTING TECHNOLOGY, HARVESTING TECHNOLOGY

1. Introduction

The experts of the Hungarian Institute of Agricultural Engineering are participating continuously in different agricultural machine developments. In the recent years the machine developments for woody energy plant production are more and more important to increase the working quality and working speed.

A new technology development was launched by the Silvanus Group Ltd. This technology will be based on the laid down plantation of the planting material. In this case some steps of the preparations of the planting material and field, structure of the planting and the subsequent plantation management jobs are the same like in case of previous vertical planting version.

For production the required material for cutting and planting it is necessary to satisfy the special needs of the lay down planting system. To support the requirements of this alternative technology our aim is to develop the mechanized laid down plant propagation technology. For this many technical researches are required to develop new multipurpose machines. By the mechanization of the new system the field performance, operational reliability and working speed of the harvesting and planting can be significantly increased.

Based on the results of the former developments and investigations we started to develop as a first step, the harvesting machine for harvesting the propagation material for the lay down planting technology. Such a machine which is able to harvest propagation material does not exist yet. The harvesting of the propagation material had been carried out by hand work which is quite slow and expensive.

This paper submits the preliminary work of the concepts of the harvesting machine developments, which properly serves the new lay down cutting propagation technology. The technology to be developed will be better than traditional methods because of the higher field performance therefore the lower overhead expenses.

2. Alternative planting technique for planting energy plantations

In case of woody energy plant production, unlike from the conventional arable plants one of the most different specificities are the form of propagation material and the system of planting. This alternative planting technique also has some differences what are described in this section.

2.1 Production of the propagation material used in the system of ‘lay-flat’ planting

The planting rods are produced in special stoolbeds. The rods are made of one year old shoots harvested from the trees of the stoolbed. The planting rod is an intermediate stage of the cutting production. Cuttings can be produced by cut the planting rods.

During the cutting production the workers must give attention to the location of the buds on the planting rod. The incisions must be placed next to a bud on the upper part of the cutting, so after planting the sprouts can erupt from these buds immediately. During the production of planting rods it is unnecessary to deal with these problems, the workers may only watch the prescribed diameters and length of the planting rod.

To produce as much planting rods as possible, which comply with the quality and size requirements, producers need suitable stoolbeds. The spacing and the formation of the stoolbed is highly depends on the tree species and varieties. In some cases it means, that the stoolbed consists low trees, which are cut back every year. This method is mainly the characteristic of poplar stoolbeds. In other cases the trees/shoots are cut back every year on the lowest level near to the soil surface, mainly used in willow stoolbeds.

Another thing is the characteristic of the one year old shots of the tree species. They can grow straight without strong branches. It is the easier to process these rods. In case of each tree species, like white willow, the shoots grow with strong branches on them. In case of these species the proper scaling of the stoolbed has a very high importance. Willow is a fast growing tree species and the bred varieties grow faster than the original initial species. The optimal scaling of the white willow stoolbeds makes high density with low row distances. By these conditions the shoots will grow upwards and won’t grow strong branches, because the available sunlight of the shoots is limited.

2.2 Harvesting of the planting rods, preparing them for planting

Rods are taken from one-year-old material that is harvested between December and March when the plants are dormant. Each species can be harvested later, too, but only in appropriate case. The main phases of the cutting production process are: the harvesting of the rods, the removal of the branches if necessary and the cutting to size. The sizes depend on the planting technique and on the species.
During the process it is important to pay attention to the storage of the rods on low temperature. It is recommended to store the rods between -2, -4 °C where cuttings remain viable for up to 3 months. They should only be taken from cold store and delivered to the planting site on the morning of planting. If rods/cuttings are left in temperatures above 0°C a break in their dormancy will occur, adventitious roots will develop and the buds may burst. This will lead to a reduction in water and nutrient content and consequently reduced viability.

The average length of the rods is 2 m, the diameter moves between 3 cm to 0.5 cm. The thinner part of the rod has more bud on it, but it’s nutrient-poor. It is not necessary to cut the thinner part, but during the planting these parts have to overlap each other. Thus the sprouts will be strong enough and the density of the shoots will meet the requirements of a high-yield plantation.

3. Design of the concepts

To design the woody energy plant propagation material harvester is not an easy task because of the lack of literature and previous developments.

For the design of the concepts we could use some results and analyses from agricultural and forestry machines field tests where we investigated working quality and energetic parameters as well. We also have to determine before the start of the design the agrotechnical requirements and the propagation material parameters and standards. On the field of the Institute some planting tests we carried out this spring to investigate lay down plantations of different material and to prepare a universal test area for testing the machine prototypes. The preparation of the field and the current plantation can be seen in Fig. 1.a and b.

3.1 Requirements for the designed harvester

The basic aim of the harvester is that it should be operated by a tractor because of the seasonal usage and the sizes of the propagation material fields. Also important point of view is to design a light version that could be easily handled and operated by a smaller, around 80 hp tractor.

The harvester will cut, collect and banding the propagation material. In a single pass it will possible to remove the remaining parts of the plants after cutting by the harvester adapter. After the prototype version we will further develop the harvester to remove the side pruning from the propagation material.

From agro-technical point of view during the design we need to take care of making a difference between the types of the plantations to support the universality of the machine because of the big differences on the plantations (Fig.2).

3.2 The designed harvester concepts

With satisfying the requirements two different harvester versions had been designed for further examinations. The version 1 and 2 can be seen in Fig. 3.
In both cases the basic requirements were satisfied on different ways. Both machines have a scissors type, special designed cutter system for the clean, nondestructive cutting. The preparations of the bandings are different. In case of version 1 the structure is simpler which is always beneficial and this concept is palletizing which feature can be advantage in case of manipulating but disadvantage in case of logistic too.

The structure of the version 2 is more complex and this version is preparing round banding from the harvested propagation material. The banded material can be collected on the machine to transport them and make stacks. From logistical point of view the higher density of the compressed, banded material is also an advantage.

**4. Modeling of the concepts**

During the design we took into account potential self-propelled machines, multi-pass harvesting / stacker and forestry trailer schemes. Based on the mechanized logging technology and developments we also investigated the possibilities of these harvesting systems concepts and variants that can carry out the harvest-batch and trailer tasks in single pass. For the comparative analyses of the harvesting systems we carried out the kinetic analysis and modeling of the frame layouts. On the basis of the results of the analyses and models we will continue the optimization of the designs to support propagation material harvesting system.

Strength and vibration control of both structures was carried out using the finite element method. The finite element model of equipments is shown on the 5th figure:

The equivalent stresses can be seen on Fig. 6:

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Fig. 3 Version 1 with front cutter and palletizing

Fig. 4 Version 2 with side cutter and round banding

Fig. 5a. Finite element mesh of the two different machine variants Version 1

Fig. 5b. Finite element mesh of the two different machine variants. Version 2

Fig. 6a. Mises-Equivalent stresses [MPa] Version 1
Finite element analysis of the structure shows, that both construction versions are capable to withstand the load acting on them. The deformation of the structures also must be checked. Deformation values can be seen on Fig. 8.

The total deformation of both structures is small enough to say, that both of them can be used. Because the machines are excited by time-dependent forces, we need to look at the value of the structure’s first few natural frequencies.

**Table 1.** The first five natural frequencies are the following:

<table>
<thead>
<tr>
<th>Number</th>
<th>version 1 [Hz]</th>
<th>version 2 [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>18</td>
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<td>3</td>
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<td>26</td>
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<td>5</td>
<td>21</td>
<td>31</td>
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The mode shapes related to the first two natural frequencies can be seen on Fig. 9 and 10.

We can see on Fig 9, that a quite large deformation of version 1 can be seen there. This vibration can cause fatigue problems and some undesirable vibration of the tractor.
We can see on Fig. 10.b. a deformation of version 2, causing the "opening" of the structure which can also cause undesirable load on the structure.

5. Conclusions

Based on the results of the former developments and investigations we started to develop a harvesting machine for harvesting the propagation material for the lay down planting system as a first step to develop a whole technology. Such a machine which able to harvest propagation material does not exists yet. We carried out to investigate lay down plantations of different material and to prepare a universal test area for testing the machine prototypes on the field of the Institute some test planting had been finished this spring.

With satisfying the requirements of the propagation material harvesting two different harvester versions had been designed for further examinations. In both case the basic requirements were satisfied with different ways.

Different modeling methods and analyses, strength and vibration control, finite element analysis of the structure and had total deformation analyses had been carried out.

Strength and vibration control of both structures was carried out using the finite element method.

Finite element analysis of the structure shows, that both construction versions are capable to withstand the load arising from the static forces.

The deformation of the structures also must be checked and both of the structures can withstand against the loads during operation of the machine.

The total deformation of both structures is small enough to say, that both of them can be used.

All the results of different both modeling methods and analyses showed that structures able to withstand against the loads during operation.

Based on the preliminary results the next step of the further work will be to carry out the modeling of the material movement in the machine, start manufacturing the prototype machine and carry out some field test to measure the features of the prototype and determine the working quality and energetic parameters of the machine.

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