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PRINCIPLE AND CONSTRUCTION OF CONTINUOUS OPERATION DIGGER FOR BANANA TREE PLANTATION

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Abstract: *Banana is a tropical fruit tree grown in many countries of the world with the largest areas of cultivation. It is a very potential agricultural product for both domestic and export markets. In Vietnam, however, the productivity of banana production is still not high, compared to that of other major markets, due to high labor costs and low labor productivity. One reason for this is low level of mechanization for banana cultivation, including the mechanization of drilling holes for planting. Drilling holes for banana planting in Viet Nam is still done manually or with low-productivity machines. Existing hole-drilling machines around the world, especially in Vietnam, are the ones with intermittent operation, resulting in low productivity. Therefore, it is necessary to create a new principle of continuous operation of diggers in order to increase productivity of drilling and to facilitate the work of operators.*

Keywords: *banana; diggers; drilling holes; continuous operation*

INTRODUCTION

Banana is one of the most popular fruit trees in the world and is grown mainly in tropical climate developing countries. It grows easily and gives high yield, with an average of 20 to 30 tons per hectare. Currently, the country reaching the highest yield of bananas, which is 100 tons per hectare, is Goethemala.

According to statistics of Food and Agriculture Organization (FAO), about 98% of the world bananas are produced in developing countries and mainly exported to developed countries. The countries with the largest banana growing areas in the world are India, Brazil, Tanzania, China, Philippines, Rwanda, Burundi, Ecuador, Uganda, Vietnam, Angola, Colombia, Indonesia, Congo, and Mexico. Total area of 4 047 232 hectares for banana trees in those countries represents more than 75% of the world's total banana growing area.

The value of global banana exports is estimated annually, and from 2018 to 2019 it increased by 11.2%. In 2019, turnover of global banana exports was approximately $14.7 billion, and this was an average increase of 43.3% over the five-year period from 2015 when the total value of banana consumption was about $10.2 billion.

In Vietnam, bananas are grown in areas like orchards with the largest cultivated areas compared to those for other fruits, in many provinces from the North to the South. As stated by Information Center for Industry and Trade (VITIC), Ministry of Industry and Trade, in 2019, banana trees were planted in more than 19% of the total area of fruit trees (100 000 hectares) and

the fruit consumption volume was about 1.4 million tons annually. There are different varieties of bananas from different regions.

Tillage is an important technical and indispensable step for any crop including banana, in terms of providing favourable conditions for next technical stages and creating good conditions for the plants' growing. With banana, choosing the right method of soil treatment depends on the possibility of intensification of banana producers and characteristics of the terrain and soil (Gradysky Y. O., Litovka, S. V., 2013). As for other crops, the purposes of tillage are to keep the surface of the field loose and to destroy weeds. There are two main types of tillage as followings: (https://sites.google.com/site/tailieukn/trong-trot/ky-thuat-trong-chuoi).

i) Tillage entire surface.

ii) Minimal tillage.

For flat terrains with joint cultivation of two or some agricultural crops, entire surface tillage is mainly applied, which consists of the following stages:

- Weed cleaning;
- Plowing (depth of 30 - 35 cm);
- Loosening the soil by cultivators (2-3 times).

For sloping terrains, minimal tillage should be applied:

- Weed cleaning;
- Deepening by deep loosening chisel plow;
- Hole digging.

The size of one hole and the distances between holes are set depending on favourable conditions of the soil (good or bad for cultivation) and varieties of banana. For good soil with thick humus layer, 40-45cm width and 30-35cm depth are set, while larger sizes are applied for bad soil.

The density of planting depends on varieties of bananas, for examples for dwarf bananas it should be 2,3x2m, 2,7x2m for popular variety, and 2,7x2.7m for another banana variety.

Fig. 1. Pits for planting banana trees

EXPOSITION

Famous principles and construction of hole drilling machines for planting

According to construction and operation principle of working tools of digger, it can be classified by some types as followings (Le Tan Quynh, 2006):

- Diggers with passive working tools: Most of these types are excavators suitable for drilling holes for big trees. These machines work discontinuously and this leads to low productivity. These machines are suitable for big trees those require large holes, but for banana trees.

- Diggers with active working tools: This type of diggers is the most common for the creation of planting pits in agriculture. Most of them are of the screw type.

Fig. 2. Screw digger

The biggest disadvantage of these machines is the intermittent operation. To dig a hole requires many operation steps to be done by operator, such as moving the aggregate (knocking, moving and stopping the aggregate), starting to drill holes, and removing the tool from the ground. This leads to low productivity of the machine.

There is a type of machine with a close target of diggers, which forms suitable sites for planting different crops (Gradysky Y. O., Litovka, S. V., 2013), called site-forming machine. This machine is used to prepare sites on spring and mountain slopes for planting forest crops. A site-forming machine can be operated continuously preparing stepped platforms during continuous movement of its conjunct tractor. The working part of a site-forming machine can be tiller's drums on which soil cutting knives are mounted.

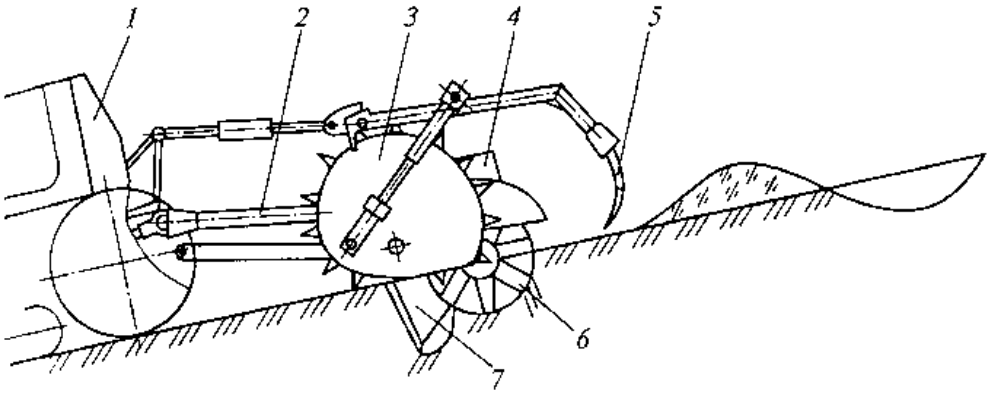

Fig. 3. Site Forming machine PDI-1
1) Tractor; 2) cardan shaft; 3) cam wheel; 4) reducer; 6) knives; 6) cutter; 7) knife

With the above principle, one machine can form many pits, and the depth of any pit can be adjusted by changing eccentric camshaft wheel. The depth of pit by the principle can be very large, and that gives good response to agronomic demand for rambling of banana trees (with PDI-1, its width and depth are 1 and 1.2 meters accordingly).

Determination of principle and construction of continuous operation machine to drill holes for banana tree plantation

a) Principle

From the above analysis, it can be seen that the greatest disadvantage of this type of machine is zero relative speed in horizontal direction between its working tool and tractor. In order to ignore the disadvantage, it is necessary to add to the scheme of the unit a degree of freedom, which ensures longitudinal movement of the digger's working tool. When the implement is immersed in the ground, its speed in longitudinal direction must be approximately equal to speed of the tractor in the opposite direction. In addition, it must return when emerged from the ground afterward.

Figure 4. shows the schematic diagram of drilling hole machines with continuous movement.

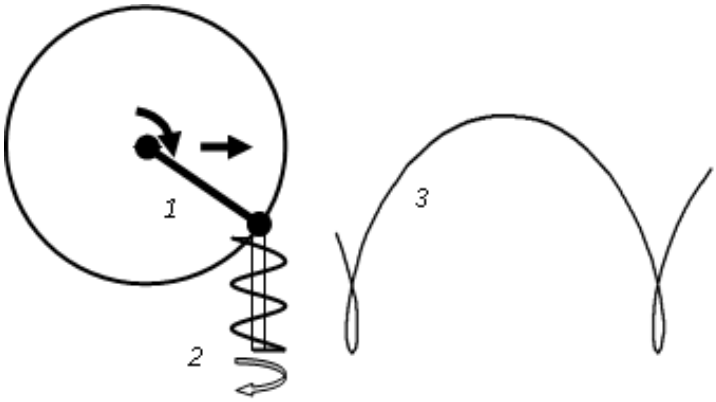

Fig. 4 The basic scheme of digger with continuous movement
1) Swivel unit (rotary housing); 2) Working tool of digger; 3) Cycloid trajectory of working tool

One end of rotating unit is hinged to the frame of digger, to ensure constant speed moving. When rotating, the other end of the rotating unit is described as a cycloid trajectory. The longitudinal velocity of the points at the bottom of the cycloid line is very small, nearly zero. Therefore, when the working tool enters the ground, it is almost motionless in the longitudinal direction relative to the ground, which ensures required minimum length of pits.

b) Construction of working tools

The working tools of one digger can be:

i) A drill

One of the technical requirements for a drill-type working tool is that its axis moves following vertical direction. However, the drill is mounted on the rotating unit on which directions are continuously changed. Therefore, if a drill is used as a working tool, its structure should be able to maintain its direction such as parallelepiped structure. This will complicate the construction of the machine.

Another disadvantage of this type is that the drill's rotating axis is perpendicular to the rotating body unit, thus the addition of a bevel gearbox to change the rotating direction is needed.

ii) A rotary tiller

The first advantage of using a tiller-type working tool for a digger is that it can cut soil along its entire periphery, thus the tiller can be directly mounted to the digger, without a supporting structure to maintain the direction.

Another advantage of tiller-type working tool is that its cutter's rotating axis is parallel with the axis of rotating body unit. In this case, simple gears can be used to drive the cutter such as chain gear or sylinric gear.

With the above analyses on advantages and disadvantages of digger's principles and construction, the following schemes (Fig. 5) for digger are chosen:

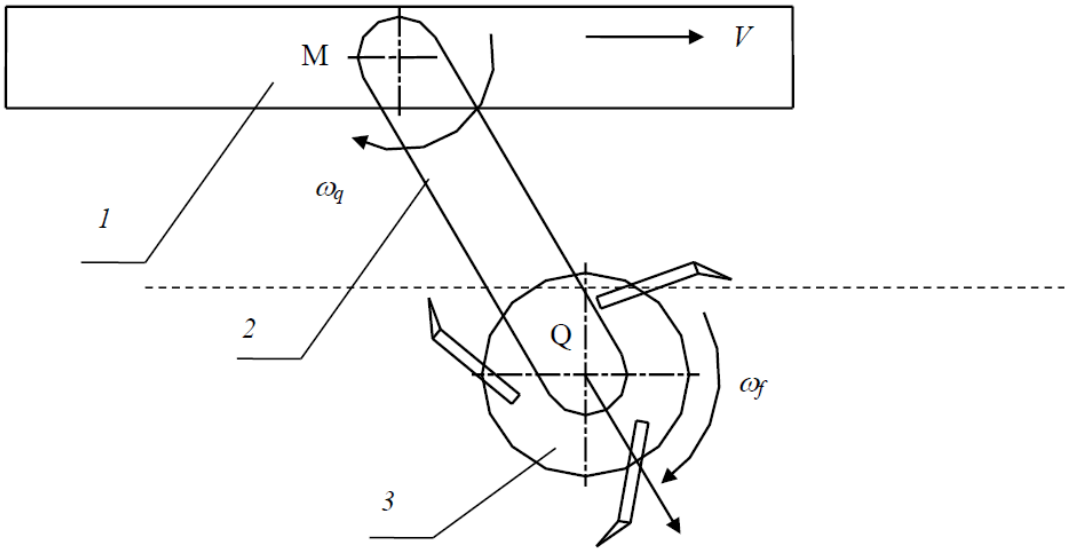

Fig. 5. Principle of digger continuous operation
1. Frame; 2. Rotary body of digger; 3. Cutter-drum

The principle of digger construction is shown at Fig. 6.

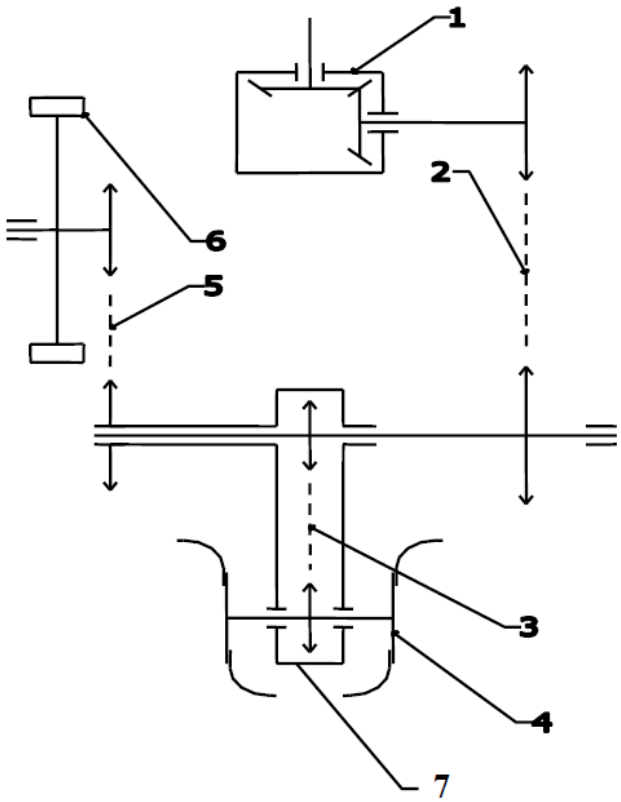

Fig. 6. Principle of digger construction
1. Conical gearbox ;2. Chain gear 1; 3. Chain gear 2; 4. Cutter;
5. Chain gear for rotary body; 6. Fifth wheel; 7. Rotary body

From PTO through cardan coupling, the movement of milling blade is transmitted through conical gearbox (1) and two chain drives (2 and 3). Rotation of rotary body (7) is transmitted from the fifth wheel with grippers (6) through the chain drive (5).

CONCLUSION

The initial research and analyzes in this paper can be summarised into the following conclusions:

1) Existing hole-drilling machines in Vietnam and around the world are those ones with intermittent operation, therefore they are working at low productivity. It is necessary to create a new principle of continuous operation of digger in order to increase the productivity of hoeing and facilitate the work of operators.
2) The principle and construction of digger shown in Fig.5 and Fig.6 can perform continuous operation. It is needed to justify both structural and operating parameters of the machine.

RECOMMENDATIONS

Recommendations are made as followings:

1) Previous research has been applied to ordinary tillage machines for field tillage at a constant forward speed. However, a continuous operation digger moves at variable speeds to change its direction. For the purpose of designing and manufacturing that type of digger, study on the basic kinematic parameters of the machine, such as the speed of cutting, the thickness of the cut soil chips, the angle of cutting, especially the size of the drilled holes, should be carried out.

2) Due to the non-stationary nature of the digger's operation, it is necessary to study the dynamics of the machine unit of the digger with the conjunct tractor, in order to find an optimal operation mode of the whole unit.

3) It is not less important to experimentally determine energy and quality indicators of the unit, in order to justify design and operating parameters for a machine working with saving energy and reaching agro-technical indicators.

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