Design and simulation analysis of chain type sweet potato seedling recycling machine

Wei Lele[1], Lv Zhaoqin[1,2*], Zheng Wenxiu[1], Lu Yao[1], Liu Zhengduo[1], Zhu Binbin[1], Cai Yuhu[1]

(1. *College of Mechanical and Electronic Engineering, Shandong Agricultural University, Tai'an 271018, China*;
2. *Shandong Provincial Key Laboratory of Horticultural Machinery and Equipment, Tai'an 271018, China*)

Abstract: In this paper, a kind of chain type sweet potato seedling recycling machine is proposed. And the 3D design and virtual assembly of the recycling machine are completed with Solidworks software. The machine size is 2300 mm× 1500 mm×1200 mm. The parametric design of eccentricity and eccentric shaft speed which influence the cutter speed were completed by ADAMS. The simulation results showed that the eccentric shaft speed had greater influence on the cutting speed than eccentricity. If the potato seedlings were cut off in one time, the rotational speed range of the eccentric shaft need to stay in 450-550 r/min. Through the cutting chart calculated by MATLAB, the speed of the machine in line with the cutting speed was 4.2-6.3 km/h which meets the machine operating speed requirements. This design has the following characteristics: the copying shovel of machine is in the bottom of ditch when the machine is in work; the longer potato seedlings can be cut off by the side cutting cutter, which reduces the probability of discontinuity; with the help of the tension mechanism of double-row conveyor chain mechanism, it can effectively prevent the phenomenon of dropping and plug during the process of the seedling transportation. The knife board at the bottom of the potato seedling cutter solves the problem of high rate of injuring potato and high stubble height.

Keywords: potato seedling, recycling, reciprocating cutter, ADAMS, MATLAB

Citation: Wei, L. L., Z. Q. Lv, W. X. Zheng, Y. Lu, Z. D. Liu, B. B. Zhu, and Y. H. Cai. 2017. Design and simulation analysis of chain type sweet potato seedling recycling machine. International Agricultural Engineering Journal, 26(3): 112–119.

1 Introduction

1.1 Environmental conditions

According to a large number of statistical data ridging is mainly applied in sweet potato cultivation in China. The distance of ridges is 600-900 mm and the height of ridge is 250-300 mm in general. The seedling length is up to 1.5-2.5 m. Some can even grow to 4 m. Seedling vine grow vigorously and intertwined between the ridges and the seedling has fibrous roots. The sweet potato seedling will cover the entire field during the maturity period. With the toughness of seedlings, there is a certain degree of difficulty in the process of recycling.

Received date: 2016-12-26 **Accepted date:** 2017-08-23

* **Corresponding author: Lv Zhaoqin,** Professor, College of Mechanical and Electronic Engineering, Shandong Agricultural University, Tai'an, 271018, China. Email:lzqsdau2003@126.com.

Sweet potato is widely recognized as a multipurpose crop. It is not only an important food, animal feed and raw material for industrial production, but also a new energy source and a high-quality anti-cancer health care product. In recent years, China's sweet potato planting area has exceeded 600 million hectares. The total output is about 120 million tons that accounts for about 86% of the world's sweet potato total output. However, the mechanization of sweet potato production is in low level development, especially in the stage of getting rid of seedlings that needs more human labor. The low level of mechanization greatly limits the initiative of farmers. The existing sweet potato seedling machine are converted from the potato or corn machinery that is not suited to the ridge agronomic characteristics and result in low rate of mechanical killing seedlings and high rate of injury. Therefore, the implementation of mechanized seedling

has become an inevitable trend.

1.2 Research status at home and abroad

Foreign sweet potato stem and leaf harvesting machinery development started earlier and has entered a stable development period. There have been many mature products in the market such as Japan's self-walking type sweet potato vine machine, South Korea's small vine machine, the United States of roll vine machine and Holland's pulling vine machine. In recent years, the foreign sweet potato seedling machinery development has entered the joint harvest stage. The mechanical and electrical integration and hydraulic technology have been applied to the seedling processor to reduce mechanical vibration and noise. The production efficiency and stability have been greatly improved and it can complete crushing and collecting work at the same time. However, the price is higher. To some degree, due to the low purchasing power of farmers and the low input and output of agriculture, this limits the farmers' ability to use machine produced by other countries. At present, the domestic seedling processing machine is mainly concentrated on the small and medium-sized machines development and has small-scale promotion, which is far behind the wheat, corn and other joint harvesting machinery level. There are mainly 4UJH-type sweet potato equipment jointly developed by Zhengzhou City, Henan Province Agricultural Machinery Extension Station and Machinery Manufacturing Co. Ltd which is used with tractors and can complete seedling cutting, crushing, field and other operations at once; two rear-wheel drive sweet potato vine machine with four small wheel developed by Xuzhou Jiangsu Sweet Potato Research Center and agricultural machine enterprises which is in the probationary stage; a large double-line of killing vine machine behaved well developed by Jiangsu Province, Lianyungang City Tianyuan Agricultural Research Institute; the 4UL-80-type potato seedling machine developed by Anhui Province, Fuyang City, Anhui Province, which can complete cutting seedlings, cutting roots, collecting seedling work at one time; Shandong Laoling Tiancheng Construction Machinery Co. Ltd. also launched a development of sweet potato seedling processing machinery; Tengzhou Golden potato Wang Agricultural Machinery Development Co. Ltd. developed a 4US-1 seedling machine. The existing sweet potato seedling machine mostly learns from the potato mechanical structure. Because of the differences in growth characteristics between sweet potatoes and potatoes, there are poor effects of existing sweet potato seedling machine. It is prone to have low rate of seedling, high damaged rate, long stubble, low passing rate, poor seedling utilization and damage caused by crushing seedling. At present, there is no good operation for dealing with seedling. Therefore, an economical and suitable sweet potato seedling machine is of great significance for mechanization and sustainable development of sweet potatoes.

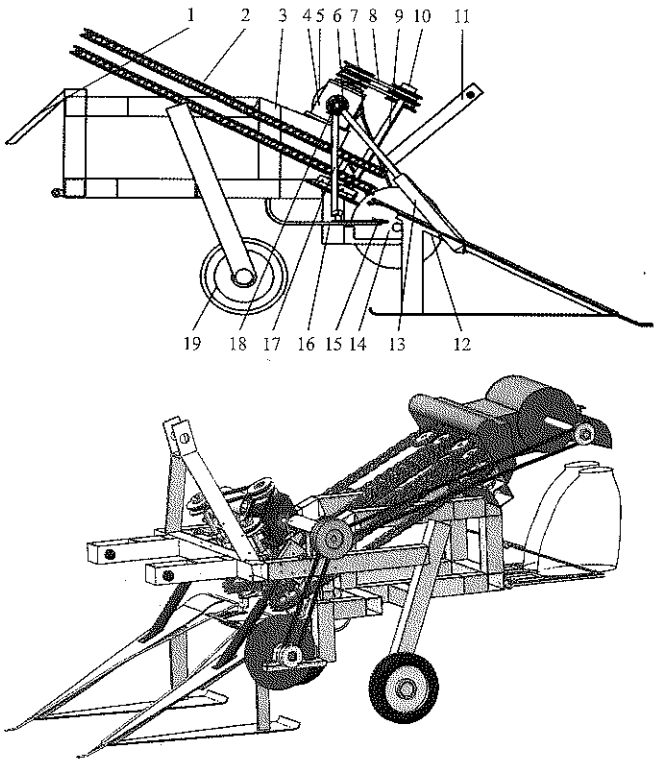
2 Structure design and principles

2.1 Overall structure

The chain-type sweet potato seedling recycling machine is composed of frame assembly, suspension bracket, gear box assembly, contoured picking mechanism, reciprocating cutter mechanism, potato seedling clamping conveyor mechanism, cutting cutter mechanism, transmission device and wheel assembly. Machine structure is shown in Figure 1.

2.2 Working principles

The machine is moving along the ridge direction and it is single ridge operation. The tractor provides the power, which is input to the gear box assembly by the universal drive shaft. After changing direction and speed, the gearbox input the power to the reciprocating cutter mechanism, the chain holding conveyor and auxiliary of potato seedlings harvest (cutting cutter and seeding roller). The copying shovel mechanism installed in the front of the machine raises the seedling of the ridge base and feeds seedlings to the front-stage V-type feed port of holding conveyance mechanism with the auxiliary device of the potato seedling harvesting. When the potato seedlings are raised up by the copying shovel mechanism, the reciprocating cutter under the machine cut the main stem of potato seedlings. The potato seedlings are sent to the rear part of machine with the help of gripping chain and put in the field ridge bottom.



1. Seedling guide plate 2. Gripping chain 3. Frame 4. Gear box 5. Pulley of cutter plate 6. Gear for seedling roller 7. Belt of cutter plate 8. Sprocket belt 9. Sprocket shaft 10. Sprocket pulley 11. Hanger 12. Copying shovel 13. Seeding roller 14 Cutter plate 15. Reciprocating cutter 16. Cutter blade 17.Off center shaft of cutter 18. Gear off center shaft 19. Wheel

Figure 1 Schematic diagram of chain sweet potato seedling recycling machine

2.3 Technical parameters

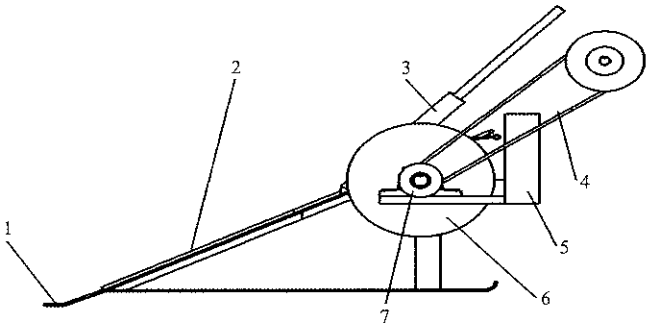
Table 1 Main technical parameters of the chain sweet potato seedling recycling machine

Number	Parameters	Values
1	Machine size (length×width×height, mm)	2300×1500×1200
2	Raw	Single row
3	Matched power, kW	20.5
4	Operating speed, km/h	4-6
5	Work breadth, mm	750
6	Productivity, hm^2/h	0.3-0.4
7	Stubble height, mm	≤30

3 Design and simulation of main components

3.1 Auxiliary device of harvester

Copying shovel, dripping roller and cutting cutter all belong to the auxiliary devices of sweet potato harvester (Figure 2). Its role is to cooperate with the potato seedling cutting and transportation equipment to improve operation efficiency. During the working process, the spade tip is below the surface of ground. And the coping shovel with rope roller work together and its role is to raise potato seedling of ridge bottom for cutting off the potato seedling stems easily. The picking shovel is hinged with the frame so that it can always be in contact with the floor. The two shovels also welded on the carrier support bar to prevent potato seedlings creep down between the two shovels. The dripping roller is counter rotating, which makes the potato seedlings move the middle of the conveyor chain that facilitates clamping conveyor of potato seedling. The cutting cutter plate is designed to cut off long potato seedlings and prevents seedlings from wrapping up on the frame that affects the machine's normal operation continuity. The cutter plate is driven by the belt pulley. Cutter line speed is selected as 5 m/s and the cutter's diameter is 300 mm.



1. Picking spade's tip 2. Picking spade 3. Rope roller 4. V-Belt of cutter 5. Frame 6. Cutter plate 7. Cutter support

Figure 2 Side-mounted cutter head (anti-wrap mechanism)

3.2 Cutting and conveying mechanism

The sweet potato seedling cutting and conveying mechanism is the main part of the sweet potato seedling recycling machine. It is composed of reciprocating cutter, potato seedling clamping conveyor chain, chain wheel and cutter blades. The main function is to cut off the main stems of potato seedlings and transport the seedling to the back of the machine and put the seedling in the bottom of the ridge ditch.

3.2.1 Clamping conveyor

The clamping conveyor (Figure 3) consists of conveyor chain, sprocket, power train device and tension device. Clamping chain is double row layout, which makes the transport action more reliable. Chain length is 2400 mm and the layout angle is 27°, the front shape of chain is the V-shaped openings. The V-shaped opening in the front of the chain makes the feeding of potato seedlings more convenient. According to the transport seedling volume, the distance H between the clamping chains can be changed under the conditions of chain

tension mechanism, which can make the holding of seedling more reliable. When the conveyor chain works, its speed should be greater than the machine forward speed, which ensures the smooth delivery of potato seedlings. The clamping conveyor speed ratio K=1.2. The chain line speed can be obtained by the following equations:

$$v=v_h/\cos\alpha \quad (1)$$

$$v_h=K\cdot v_1 \quad (2)$$

where, v is the mean clamping chain speed, m/s; v_1 is the mean machine forward speed, m/s; K is the mean clamping conveyor speed ratio; α is the mean angle between the chain and the ground; V_h is the mean chain of horizontal speed.

The chain speed decomposition diagram is shown in Figure 4.

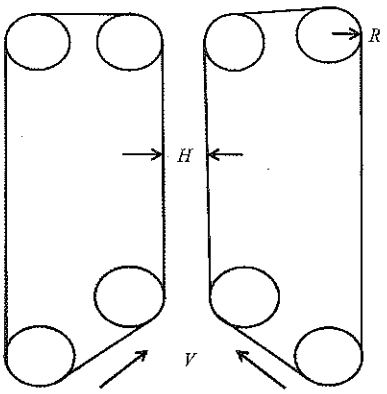


Figure 3 Schematic diagram of clamping conveyor

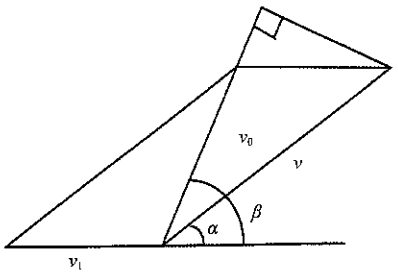


Figure 4 Chain speed decomposition diagram

The conveying speed v_0 of the potato seedling holding is determined by the following equation

$$\vec{v}_0=\vec{v}_1+\vec{v} \quad (3)$$

where, v_1 is mean the machine forward speed, m/s; v is mean the clamping chain speed, m/s; v_0 is mean the Holding speed of sweet potato seedling, m/s.

3.2.2 Reciprocating cutter mechanism

Reciprocating cutter mechanism consists of moving knife, fixed knife, cutting tool holder and eccentric shaft. And fixed knife is fixed on the cutting tool holder by the bolt and there is a chute on moving knife, which is fit with eccentric shaft. And through this joint, it changes the circular motion of eccentric shaft into reciprocating linear motion of movable knife. At present, the ideal blade shape is triangular or trapezoidal. Because of wearing, the blade edge length of the triangular blade is shortened, and trapezoidal blade edge length will not be reduced. So the machine uses the shape of-trapezoid blade. The two types of blade's situation after wearing are shown in Figure 6.

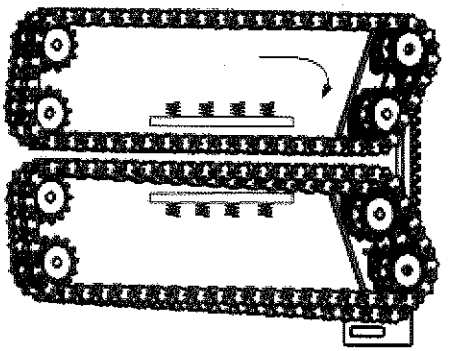


Figure 5 Clamp chain structure

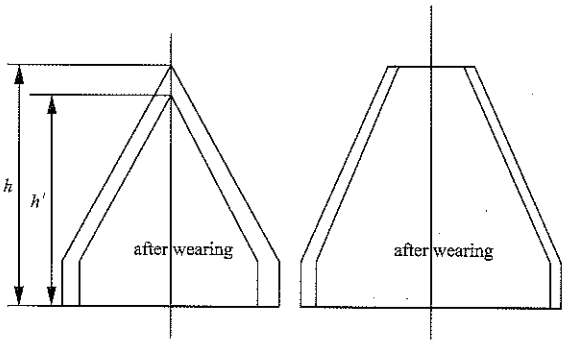


Figure 6 Comparison of blade wear

This design uses standard II cutting knife (According to national standards, cutters can be divided into three categories, and this is one of them). According the standards, its dimensions are h = 55 mm, b = 24 mm, a = 76.2 mm and e = 17 mm. In the Figure 7, a, b, e, f, g, h are the width of the blade, the average width of the blade, the width of the front end of the blade, the actual cutting stroke begins displacement, the actual cutting stroke ends displacement and blade width

In general, the greater the slip angle is, the stronger cutting ability of the cutting knife is and the cutting is easier. However, the range of sliding angle must meet the clamping or bite conditions of seedling. Through literature, if the potato seedling is cut off at once, the speed of knife needs to be above 0.8 m/s (Luan et al.,

2014). Taking the difference between the field work and the experimental environment and the tear of tool into account, the cutting speed of the harvester machine is generally 1.2 m/s.

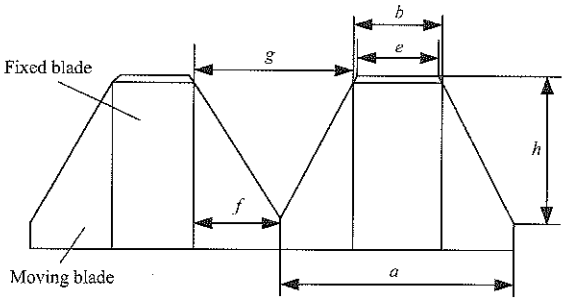


Figure 7 Structural parameters of blade

The reciprocating cutter's cutting effect of harvesting machine is closely related with the relationship of cutting speed and machine's speed. This relationship is usually described by the cutter distance H (the distance of the machine in a cutting cycle) (Yang et al., 2016). The knife and machine speed ratio λ is also a method to describe the cutting effect. When the machine operating speed is in a certain case, the low cutter speeds will lead to leakage phenomenon of cutting, and the machine operating results are not satisfactory. However, if knife speed is too fast, it will lead to repeatedly cutting phenomenon of potato seedlings, which results in energy waste. Therefore, the correct matching of the machine operating speed and the cutting speed is the basis for realizing the reasonable cutting of the potato seedling. The moving blade's displacement x, velocity v and acceleration a in reciprocating motion can be obtained by the following equation:

$$\begin{aligned} x &= \sqrt{(r+1)^2 - h^2} - r\cos\omega t - l + \frac{h^2}{2l} + \frac{rh}{l}\sin\omega t + \\ &\quad \frac{r^2}{2l}\sin^2\omega t + \cdots\cdots \\ v &= r\omega(\sin\omega t + \frac{h}{l}\cos\omega t + \frac{r}{2l}\sin 2\omega t + \cdots\cdots) \\ a &= r\omega^2(\cos\omega t - \frac{h}{l}\sin\omega t + \frac{r}{l}\cos 2\omega t + \cdots\cdots) \end{aligned} \tag{4}$$

There is the case of ignoring r/l and h in some mechanism. The design of the reciprocating cutter in this paper can ignore the impact of these three parameters.

The average speed V_p (m/s) of the cutter is obtained by dividing the integral of one of the reciprocating motion of the lateral speed by the required time and is expressed by the following equation:

$$v_p = \frac{2s \times n}{60} \tag{5}$$

$$H = v_m \times t = 30 v_m / t \tag{6}$$

$$\lambda = v_p / v_m \tag{7}$$

where, S is the mean stroke of cutter, m; n is the mean number of reciprocating motion of the cutter per minute; v_m is the mean machine advancing speed, m/s; v_p is the mean cutting speed, m/s; t is mean the time for the cutter to complete a cutting cycle, s; H is mean the cutting distance, m; λ is mean the knife and machine speed ratio.

3.2.3 Kinematics simulation of reciprocating cutter mechanism based on ADAMS2013

The reciprocating cutter is driven by the eccentric shaft. The two parameters of affecting the speed of cutter are the eccentricity e and eccentric shaft speed n. First of all, under the conditions of the eccentric shaft rotation speed unchanged (n = 500 r/min), the eccentricity of e influence ability on the cutter speed was analyzed. Get some value within the eccentricity e±20% range. The ADAMS simulation results are shown in the following Figure 8.

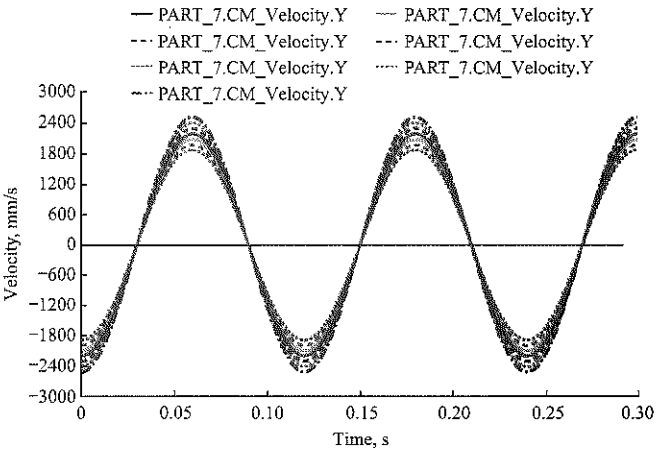


Figure 8 Tool speed-time graph

Although the change of eccentricity e can affect the cutting speed, the eccentricity e can also affect the size of displacement of the moving knife, since a single blade has a certain size. If the eccentricity e is too small, the shear action can't be completed; if choosing a larger eccentricity e, the arrangement of the machine shaft will become a new problem. Moreover, through the velocity-time simulation result, the velocity is less sensitive to the change of eccentricity e. Through the

choice of gear, different tractor engine speed can be obtained. Considering that the tractor engine speed can be changed with different operating speeds in work, so getting different cutting blade speed through changing the tractor engine speed had more practical significance and greater operation ability.

The result of the simulation of the different eccentric shaft speed is shown in the figure below.

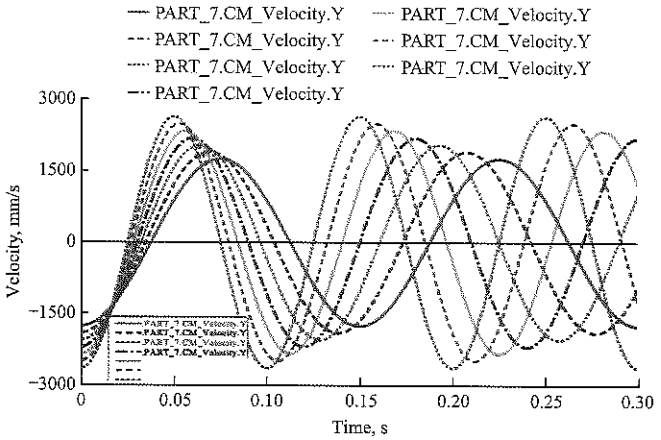


Figure 9 Tool speed-time graph

Figure 9 shows the simulation results in the range 500±100 r/min of eccentric shaft's rotation speed. It can be seen that the change of the shaft speed had a great influence on the cutting speed. Taking into account that the bigger shaft speed, the greater the vibration of the machine, and the part life and the cutting effect can also be affected. So the speed 500 r/min of the spindle speed was selected and the cutting speed at this time was above 1.2 m/s, which means that in a certain period, the speed of the cutter is greater than 1.2 m/s. Through the simulation analysis, when the speed of the eccentric shaft is 450-550 r/min, the potato stem can be cut off once.

By comparing the two simulation results, the effect of eccentricity on the speed of cutter is eliminated.

3.2.4 Draw the reciprocating cutting tool drawing based on the MATLAB7.0

The cutting effect of the reciprocating cutter is related to the blade and machine speed ratio λ. λ value is too large, the machine re-cut area is large; λ value is too small, leakage cut area is bigger and the stubble cutting height is irregular. The following Figure 10 shows the machine cutting plot in MATLAB when λ is 0.7, 1, 1.4. By plotting the cutting plot, it can be seen that the value of λ has a great influence on the cutting quality. For getting a better quality of work, the optimal value of the knife speed ratio λ need to be 0.8-1.2. By the presetting speed of the cutter linear velocity, the machine speed is calculated that is 4.2 to 6.3 km/h, which is within the selected machine operating speed range

Through the cutting chart of reciprocating cutter (Figure 10), it can be seen that in order to achieve better cutting quality, λ value range is generally 0.8-1.2. The following figure is the cutting plot in MATLAB. The relationship between the cutting effect of the reciprocating cutter and the λ speed ratio with the knife is obvious. If the λ value is too large, the re-cut area is too large; λ value is too small, the cut crop height is untidy and leakage cut area is too large. Through analysis, it is clear that the value of λ has a great influence on the cutting quality. And by plotting the cutting plot, it is possible to determine the optimum speed ratio λ, typically λ = 0.8 to 1.2. It can be calculated that the speed of the machine from the preselected line speed of 1.17-1.75 m/s. And the range 4.2-6.3 km/h is within the six selected machine operating speed ranges.

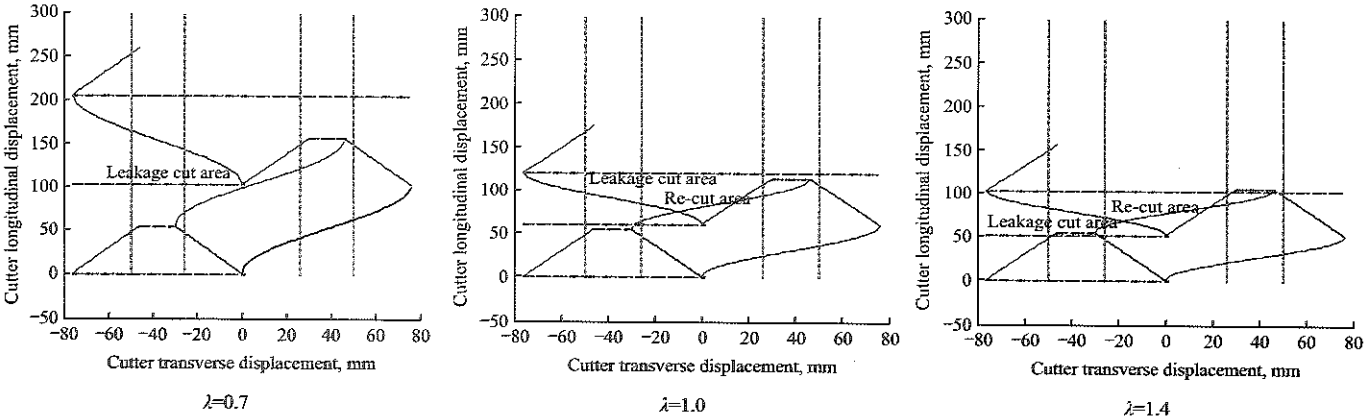


Figure 10 Reciprocating cutter cutting engineering drawing

4 Discussions

(1) In the two factors of influencing the moving knife's speed, the eccentricity was eliminated by analysis of ADAMS and the method of changing the speed of the moving knife by adjusting the speed of the spindle speed was obtained.

(2) Recycling mode of operation can improve the efficiency of potato seedling. Although the advantage of the recycling mode is not obvious for small plots of sweet potato planting, it puts forward new ideas for large-scale sweet potato planting operations in the future.

(3) Cutting cutter plate can cut longer potato seedlings and avoid potato wrapped around the rack, improve the work fluency and efficiency.

(4) The picking height of picking mechanical device should be higher than the height of ridge. It not only improves convenience in cutting seedling for the cutter, but also reduces the damage rate of sweet potatoes. For the method of reducing stubble height of potato seedlings, the design program is that adjust the rack height by human observation to ensure the smaller stubble height before the work of machine. This approach cannot adjust rack height based on ridge at any time and the cutting knife may come into the soil where the potato ridge is higher, which can cause damage to the cutter. Such defects can be solved by installing hydraulic control systems and monitoring devices, which can achieve adjustment of rack height at any time to ensure a small stubble height.

5 Conclusions

1) The existing problem that it is not suitable for sweet potato planting characteristic in seedling processing machinery was solved by the chain type of sweet potato recycling machine.

2) Three-dimensional design and virtual assembly of the chain type of sweet potato seedling recycling machine were carried out by Solidworks.

3) The parameters eccentricity e and eccentric shaft speed which influence the cutter speed are parametric design in ADAMS. The simulation results showed that the eccentric shaft rotation speed had a great influence on the cutting speed and the eccentricity e had little influence on the cutting speed. The speed of the eccentric shaft 450-550 r/min was also obtained when the seedling can be cut off at once.

4) Through MATLAB, the cutting plot is obtained. And the speed of the machine in line with the speed of the machine 4.2-6.3 km/h was got and can meet the machine operating speed requirements.

Acknowledgement

This work is supported by Foundation of Modern Agricultural Technology System Innovation Team Expert in Shandong Province (NO.SDAIT10-22-10).

[References]

[1] Ge, M., H. G. Jia, and B. Liu. 2011. Contact-impact analysis with clearance hinge in flexible multi-body system. *Yichang: Proceeding of the IEEE International Conference on Electrical and Control Engineering, 3406–3409.*

[2] Hou, J. L., T. Jiang, and Y. Q. Wu. 2014. Design and experiment of wheat straw cutting reciprocating test bench. *Transactions of the Chinese Society of Agricultural Machinery*, 2014(45): 101–105. (In Chinese with English abstract)

[3] Hu, L. L., G. P. Wang, and X. Y. Ling. 2015. Mechanical properties of sweet potato vine and stalk during harvest. *Transaction of the Chinese Society of Agricultural Engineering*, 31(9): 45–49. (In Chinese with English abstract)

[4] Hu, L. L., L. J. Tian, and F. L. Ji. 2011. Analysis and discussion on the restriction causations for harvesting mechanization of sweet potato in China. *Chinese Agricultural Mechanization*, 2011(3): 16–18. (In Chinese with English abstract)

[5] Hu L. L., L. J. Tian, and F. L. Ji. 2014. Research on the working mode of sweet potato production mechanization. *Journal of Chinese Agricultural Mechanization*, 35(5): 165–168. (In Chinese with English abstract)

[6] Hu, L. L., Z. C. Hu, and Y. Z. Xie. 2011. Study on the route of mechanization of sweet potato (ipomoea batatas lam.) production technology in China. *Chinese Agricultural Mechanization*, 2011(6): 20–25. (In Chinese with English abstract)

[7] Liu, Z. L., X. D. Zhang, and X. Zhang. 2012. Analysis process of grabing corn seed of vertical disc air- suction metering device. *Journal of Agricultural Mechanization Research*, 2012(7): 73–77. (In Chinese with English abstract)

[8] Luan, G. D., Q. W. Sun, and Y. Y. Wang. 2014. Design and test of clamping and collection device of 2 ridges and 4 lines peanut combine harvester. *Journal of Agricultural Mechanization Research*, 2014(1): 132–135. (In Chinese with English abstract)

[9] Ma, B., L. L.Hu, and L. Y. Xu. 2013. Status about sweet potato planting and its production machinery in China. *Journal of Chinese Agricultural Mechanization*, 34(1): 42–46. (In Chinese with English abstract)

[10] Ma, J. F., J. H. Cheng, and J. Wang. 2012. The development of sweet potato industry at home and abroad. *Journal of Jiangsu Agricultural Sciences*, 40(12): 1–5. (In Chinese with English abstract)

[11] Pfeiffer, F., and C. Glocker. 2000. Contacts in multibody systems. *Applied Mathematics and Mechanics*, 64(5): 773–782.

[12] Shen, C., X. W. Li, and B. Zhang. 2016. Bench experiment and analysis on ramie stalk cutting. *Transactions of the Chinese Society of Agricultural Engineering*, 32(01): 68–76. (In Chinese with English abstract)

[13] Shi, Z. H., L. L. Hu, and N. Wu. 2015. Potato and sweet potato planting and its harvest machinery. *Journal of Agricultural Mechanization Research*, 2015(4): 263–268. (In Chinese with English abstract)

[14] Song, Z. H., H. L. Song, and Y. F. Yan. 2016. Optimizing design on knife section of reciprocating cutter bars for harvesting cotton stalk. *Transactions of the Chinese Society of Agricultural Engineering*, 32(6): 42–49. (In Chinese with English abstract)

[15] Xia, P., S. Yin, and L. Q. Chen. 2007. Numerical simulation of cutting pattern of a reciprocating cutter. *Transactions of the Chinese Society of Agricultural Engineering*, 38(3): 65–68. (In Chinese with English abstract)

[16] Xu, X. Y., W. Q. Zhang, and H. M. Yang. 2011. Design and kinematic analysis of double-acting cutting device of walk-type pasture reaper. *Transactions of the CSAE*, 27(7): 156–161. (In Chinese with English abstract)

[17] Yang, R. B., H. G. Yang, and S. Q. Shang. 2016. Design and test of poking roller shoving type potato harvester. *Transactions of the Chinese Society of Agricultural Machinery*, 47(7): 119–126. (In Chinese with English abstract)

[18] Yang, R. B., Y. B. Fan, and S. Q. Shang. 2016. Design and experiment of twice-receiving device on 4HBL-2 peanut combine. *Transactions of the Chinese Society of Agricultural Machinery*, 47(9): 114–120. (In Chinese with English abstract)

[19] Yang, S. C., Y. W. She, and S. M. Yang. 2005a. Computation numerical value about three regions' area in cutting graph by using MATLAB. *Journal of Agricultural Mechanization Research*, 2005(5): 66–67. (In Chinese with English abstract)

[20] Yang, S. C., Y. W. She, and S. M. Yang. 2005b. The influence from the speed of harvester to triangle area on incise diagram. *Journal of Agricultural Mechanization Research*, 2005(3): 114–116. (In Chinese with English abstract)

[21] Zhang, Y. N., Y. Y. Shi, and X. C. Wang. 2016. Design on flexible clamping-conveying mechanism of orderly harvester for stems-leafy vegetable. *Journal of Chinese Agricultural Mechanization*, 37(9): 48–51. (In Chinese with English abstract)

[22] Zhang, Z. L., Z. D. Han, and S. J. Li. 2016. Simulation and test on straw cutting and clamping device of corn combine harvester for stalk and ears. *Transactions of the Chinese Society of Agricultural Machinery*, 2016(47): 215–221. (In Chinese with English abstract)