

NUMERICAL SIMULATION AND EXPERIMENTATION ON THE PICKING PERFORMANCE OF THE HALF-FEED PEANUT PICKING DEVICE

Xiaolian LÜ¹, Zhichao HU^{2*}, Bing WANG³, Xiaoqiong ZHANG⁴

Three-dimensional motion analysis of the main model is established with the virtual simulation software. The movement characteristics of the picking plate in different structures are tested. The movement characteristic of arc type plate is tested with simulation orthogonal test, the influences of different factors on picking performance are analyzed and simulation results are validated to the peanut picker by test. Results show that hitting force of the straight board type plate is the strongest, a lower hitting force is recorded for the bending blade, and with enhanced brushing force; the weakest hitting force is recorded for the arc blade, and the brushing force is the softest. With the increasing of picking roller rotation speed, hitting and brushing roles enhances and the breakage rate increases, the unpicking rate decreases. With the increasing of the arc radius, the hitting force enhances and the brushing force decreases, the breakage rate increases and the unpicking rate decreases. When the plate arc radius is 35mm, the total loss rate is the lowest.

Key words: picking plate, UG, movement characteristics, simulation, test

1. Introduction

Peanuts are one of the major oil crops, being an important agricultural product for China's exports [1-3]. Peanut picking is an important process in peanut harvesting. Currently, according to feeding modes of the peanut seedling, picking devices are divided into two kinds of half-feed and full-feed. The half-feed peanut picker can be used to pick dry peanuts and fresh peanut harvested directly. Compared to the full-feed picker, it is characterized by small feeding amount, low power consumption, good picking quality, and it has a better market

¹ Professor, College of Machinery and Automotive Engineering, Chuzhou University, Chuzhou, e-mail: lxl500@163.com

² Researchers, Nanjing Research Institute for Agricultural Mechanization Ministry of Agriculture, Nanjing, e-mail: nfzhongzi@163.com

³ Assistant researchers, Nanjing Research Institute for Agricultural Mechanization Ministry of Agriculture, Nanjing, e-mail: 15150570997@163.com

⁴ Lecturer, College of Machinery and Automotive Engineering, Chuzhou University, Chuzhou, e-mail: 307225148@qq.com

value [4-7]. With the improving of computer capacity, virtual simulation technology is widely used in product design and analysis in the field of agricultural engineering [8-14]. In this paper, for a half-feed picker developed by the authors, the picking process is simulated and motion characteristic of the picking parts is analyzed in different structural and operational condition by means of virtual simulation technology. The technical reference for the optimal design of picking device is provided.

2. Structure and working principle

The main parts of the half-feed peanut picker include frame, feeding seedling device, clamp conveyor device, picking systems and transmission system, are shown in Fig. 1.

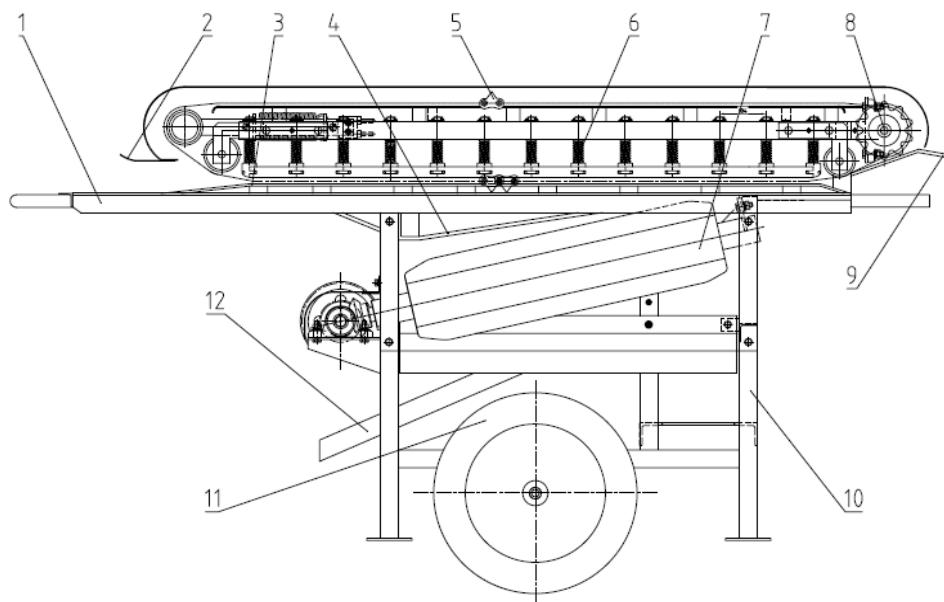


Fig. 1. Structural diagram of the half-feed peanut picker

- 1. Feeding seedling platform; 2. Guide seedling rod; 3. Clamp track; 4. Bending seedling rod;
- 5. Clamp conveyor chain; 6. Clamping force regulator; 7. Picking roller; 8. Main sprocket; 9. Seedling exit; 10. Brace; 11. Walking wheel; 12. Guide peanut bin

When the picker is working, first time, the peanut seedlings are neatly placed by hand on the feeding seedling platform, and then the peanut seedlings are pushed horizontally to the feeding inlet of clamp conveyor device, and driven by guide seedling rod between the clamp conveyor chain and the rails. The peanut seedling is held for moving forward horizontally and uniformly. When passing the

bending seedling rod, the distribution range of peanut pod is bent by compression, and vertically enters the peanut picking area. Under the influence of hitting and brushing of two picking rollers rotating relatively, the pods of peanut seedlings is sequentially picked from top to bottom in the picking area. The picking pods slide into the container at the bottom of the picker through the guide peanut bin. The remaining peanut seedling continues to move backward under the grip transport action of clamp conveyor device, and is discharged out of the picker through the seedling exit.

3. Movement analysis of the picking parts

For simplified analysis process, the pod is assumed static. As shown in Figure 2, the velocity of any point M on the picking plate relative to the peanut pods is decomposed into V_x of the X direction, V_y of the Y direction and V_z of the Z direction. The velocity value of the point is:

$$V = \sqrt{V_x^2 + V_y^2 + V_z^2} \quad (1)$$

Due to $V = \omega R$, it can be got by Figure 2:

$$\begin{aligned} V_x &= V_m \sin \varphi - V_n \sin \beta = V \sin \omega t \sin \varphi - V \cos \omega t \sin \beta \\ &= \omega R (\sin \omega t \sin \varphi - \cos \omega t \sin \beta) \end{aligned} \quad (2)$$

$$V_y = V_n \cos \beta = V \cos \omega t \cos \beta = \omega R \cos \omega t \cos \beta \quad (3)$$

$$V_z = V_m \cos \varphi = V \sin \omega t \cos \varphi = \omega R \sin \omega t \cos \varphi \quad (4)$$

In the formula: ω is the angular velocity of the picking roller; R is the distance between M point on the plate and the axis of the picking roller; φ is the angle between the picking roller and the clamp conveyor chain; β is the horizontal rotation angle of the picking roller.

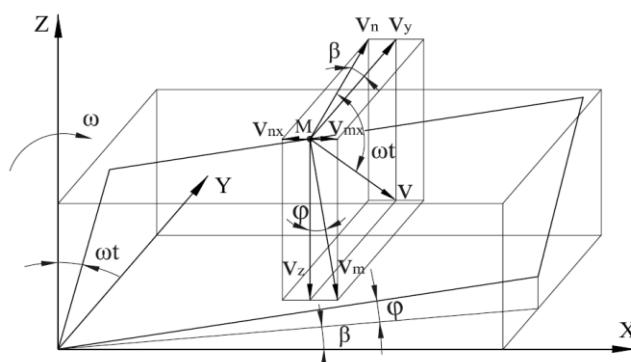


Fig. 2. Motion analysis diagram of the picking plate

According to the formula (2), (3) and (4), it can be known that the three speeds are all affected by angular velocity of picking roller ω , rotation angle of picking plate ωt , horizontal rotation angle of picking roller β , and the angle between the picking roller and clamp conveyor chain φ . When $\beta \neq 0$, they increase with the increasing of ω value. With the increasing of ωt , V_x and V_y decrease gradually, and V_z increases gradually. The value of ω is bigger, the plate hitting and brushing effect is more intense. With the increasing of ωt value, the hitting acts of the plate are weakened and the brushing acts of the plate are enhanced. With the increase of φ , V_z decreases and V_x increases, the horizontal hitting force increases and brushing force is weakened. When β increases, V_x increases reversely and V_y decreases; the hitting force of X direction increases, the hitting force of Y direction decreases, and the effect of clamp conveyor speed on picking quality is greater. When $\beta=0$ and $\varphi=0$, the hitting acts of the plate to peanut pod is zero in the X direction, the clamp conveyor speed is only related to the hitting pods times.

4. Movement simulation of the picking plate

4.1. The establishment of the main analysis model

Establish the main analysis model and simulate the motion to gain the motion characteristics of studying components and the curve of related parameters. Analyze the influence of related factors on machine operation effect [15]. Simulation uses picking blades, whose structural form is straight board type, bending type and arc type, is shown in Figure 3.

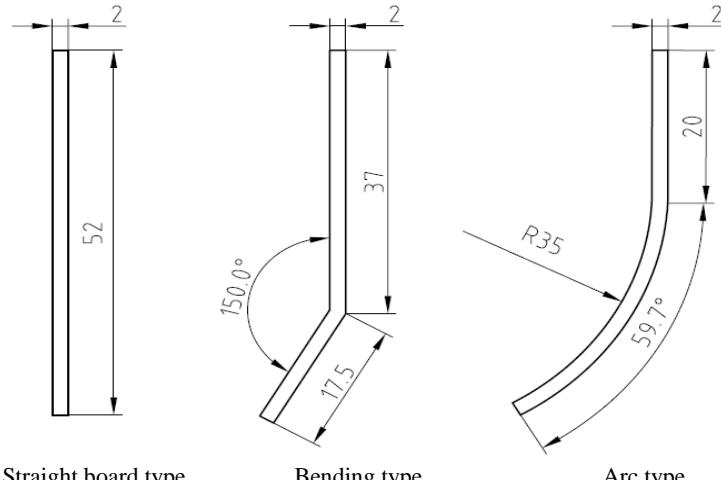


Fig. 3. The structural type and dimension of the picking plate

Three-dimensional solid main mode of the picking device is established with UG NX, is shown in Figure 4. In order to simplify the motion simulation model, the clamp conveyor chain is assumed to static. Set the three-dimensional solid main model through the connection form and force condition of each component in the actual operation. Add boundary conditions, motion loads and joints, and select the type of constraint applied, action point and direction, the main model of motion analysis is established, is shown in Figure 5.

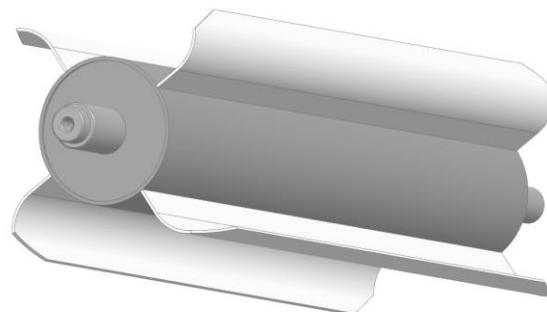


Fig. 4. Three-dimensional solid model of the picking device

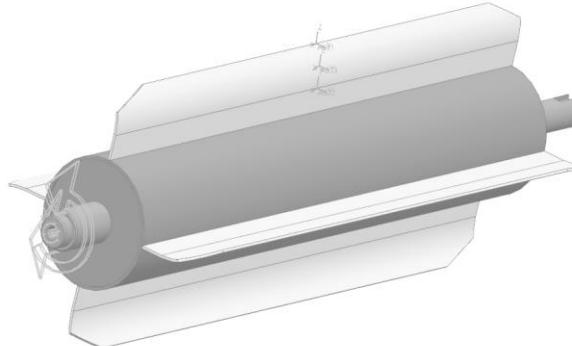


Fig. 5 Motion analysis of the main model of the picking device

4.2. Simulation test and result

Set test points in the effective working area of the picking plate under different conditions. Do simulation scans on test point motion process and gain movement characteristic curve and numerical value in the process of picking. Further analyze the situation of picking force in the picking process.

4.2.1 The effect of picking plate shape

Simulate the motion of three kinds of blades above. When the speed of picking roller is 400rpm, test the horizontal and vertical downward velocity of test points on the picking plate, and the average value of velocity at the same time. The results are shown in Figure 6.

As shown in the analysis of the results, the effective working area of the straight board type plate concentrates on the plate edge. Its horizontal velocity, vertical downward velocity and change rate are large with a more strongly hitting and brushing efficacy; the effective working area of bending type concentrates on bent part. With regard to the above one, its velocity horizontal and vertical downward velocity reduces a bit, and the change is relatively mild. The hitting effect is relatively weakened and the brushing effect is more relaxed. The effective working area of arc type concentrates on curved surface. It is from the most convex parts of the plate along the curved surface in order to pick pods. The arc surface enlarges the contact area of plate and pod. Compare with the straight board type and the bending type, its horizontal velocity is the smallest, vertical downward velocity is relatively small. Hitting and brushing show a relatively soft efficacy.

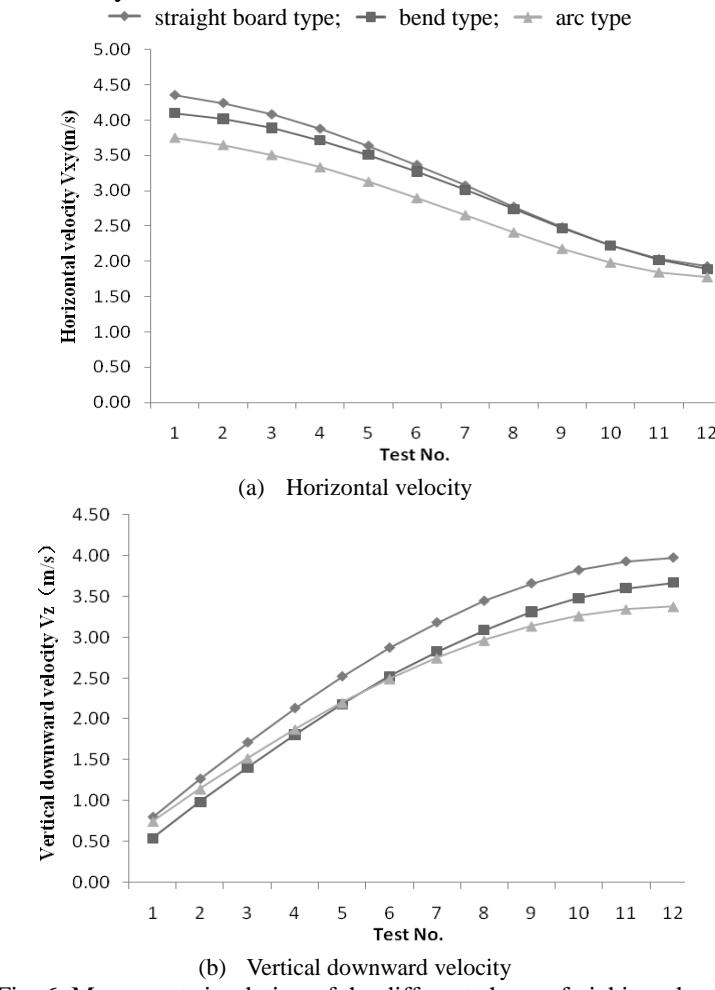


Fig. 6. Movement simulation of the different shape of picking plate

4.2.2 The effects of structural and operating parameters

From the analysis, the radius of arc segment determines the back inclination arc of the plate and size of the effective working area. It will directly influence the effect of the picking process of the plate. In the simulation experiment, select the picking roller speed and arc radius of the plate as factors, and the horizontal speed and vertical downward velocity of the test point on the plate in the range of the picking as index, analyze the simulation results by orthogonal experiment. Test factors level is shown in Table 1. Select $L_9(3^2)$ to arrange test [16]. The clamping conveyor chain speed is 1.0m/s in the test. Test and range analysis results are shown in Table 2, and the effects of different conditions on the results are shown in Figure 7.

Table 1
Levels of test factors

Level	Factors	
	A rotational speed (rpm)	B Plate arc radius /mm
1	300	30
2	400	35
3	500	40

Table 2
Experiment results

No.	Test factors		V_L Horizontal velocity/(m/s)	V_H Vertical downward velocity /(m/s)
	A	B		
1	1	1	2.05	1.89
2	1	2	2.15	1.64
3	1	3	2.16	1.58
4	2	1	2.45	2.66
5	2	2	2.71	2.19
6	2	3	2.74	2.08
7	3	1	3.02	3.30
8	3	2	3.24	2.85
9	3	3	3.30	2.66
V_L	k1 k2 k3 Range	2.120 2.633 3.187 1.067	2.507 2.700 2.733 0.226	
V_H	k1 k2 k3 Range	1.703 2.310 2.937 1.234	2.617 2.227 2.107 0.510	

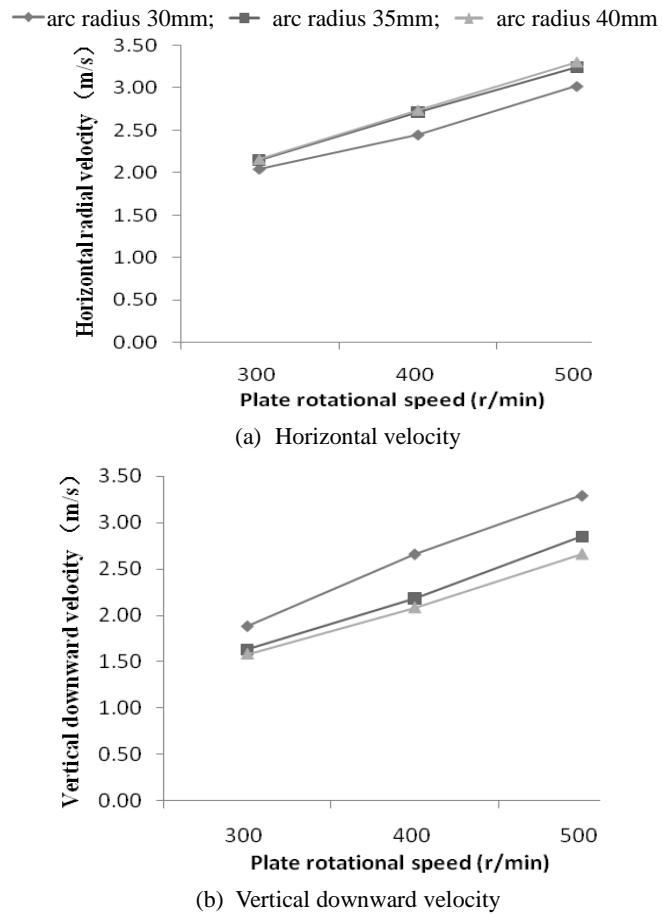


Fig.7. Influence of the structural and working parameter of the picking plate on picking effect

From the analysis of the results, the effect of the rotational speed of picking roller A on the picking performance is greater than blade radius B. The influence degree of various factors on the experimental results as: influence of the horizontal velocity is A3>A2>A1, B3>B2>B1; influence of vertical downward velocity is A3>A2>A1, B1>B2>B3; From Figure 7, with the increasing speed of the picking roller, the horizontal velocity and vertical downward velocity of the picking plates increase obviously. Hitting and brushing effect significantly strengthens. The arc radius of plate has a direct influence on the back-inclination arc of the plate and the effective working length of picking, and has a further impact on picking effectiveness of the plate. The plate arc radius is smaller, the back-inclination arc of the plate is larger and the effective length of picking is greater; the horizontal velocity relatively decreases and vertical downward velocity relatively increases, hitting effect is weakened and brushing effect is enhanced. Picking action shows a relatively soft efficacy. Therefore, under the

precondition of ensuring the hitting force to ensure the net rate of picking, the arc radius of plate should be as small as possible.

5. The performance test of peanut picker

Make straight board type, bending type and arc type of picking plates. The structural dimensions are shown in Figure 3. When the picking roller speed is 400rpm, test the breakage rate, unpicking rate and impurity rate of the three kinds of plates of picking pods respectively, results are shown in Table 3. When the radius of circumference contains the starting point of the plate arc and the radius of the picking roller radius are set, the radius of arc segment determines the back inclination arc of the plate and picking quality. When the picking roller speed is 300rpm and 400rpm, test the breakage rate, unpicking rate and impurity rate respectively, when the different arc radius of picking plates of pick pods, results are shown in Table 4.

Table 3

Effect of plate shape on picking quality

Index	Plate shape		
	Straight board type	Bend type	Arc type
Breakage rate (%)	3.6	2.5	1.2
Unpicking rate (%)	0.5	0.6	0.7
Impurity rate (%)	20.2	18.7	12.4

Table 4

Effect of plate backward radian on picking quality

Index	Picking roller rotate speed (r/min)	Plate arc radius (mm)		
		30	35	40
Breakage rate (%)	300	0.7	0.8	1.1
	400	1.0	1.1	1.6
Unpicking rate (%)	300	1.4	1.2	1.1
	400	0.9	0.7	0.7
Total loss rate (%)	300	2.1	2.0	2.2
	400	1.9	1.8	2.3

According to experiments, the hitting and brushing effect of the straight board type of picking plate are intensely. Pull on branch, leaves and stalk of peanut seedling severely, pod breakage rate is high, and produce a large number of broken branches and seedlings, has a low unpicking rate. The hitting and brushing effect of bending type of picking plate is relatively weakened compared with the straight board type plate. Bending type has a lower breakage rate, less broken branches and seedlings, and increase relatively in the unpicking rate. Arc

type of picking plate has a softer hitting and brushing effect than the bending type and the straight board type. It can effectively reduce pod damage, pulling seedling vine, broken branches and broken seedlings. In the test, the unpicking rates of the bending type and straight board type are both less than 1%. The unpicking rates of arc type are higher than the above two, but still at a low level. The back inclination arc of the plate has a greater impact on the breakage rate and unpicking rate of the pod. The arc radius of the plate is bigger, and the back inclination arc of the plate is smaller, the breakage rate of the pods is higher, and the unpicking rate of the pods is smaller. The influence of the arc radius of the plate is different from the picking quality at different speed of the picking roller. With the speed increasing, the breakage rate of the pod reduces, and the unpicking rate increases. When the arc radius is 30mm, the total loss is the smallest in the picking stage.

6. Conclusion

(1) The influence of the structure and parameters of the picking component is analyzed by simulating the picking movement. The rationality of the structure designed is preliminarily verified, and the reliability of the simulation results is verified by prototype test.

(2) The straight board type plate has the strongest picking effect. It has the highest breakage rate and unpicking rate of picking pod, the phenomenon of the broken branches and seedling is serious; the arc type plate in the picking operation has the smallest hitting intensity and the softest brushing effect compared with the bending type plate and the straight board type plate. The structure effectively reduces the problems of pod damage and broken branches, seedling in picking process.

(3) The rotating speed of the picking roller and arc radius of the picking plate has great influence on the picking quality. With the increasing speed of the picking roller, hitting and brushing effect have a clear trend of strengthening, the breakage rate and impurity rate of the pod increase relatively, the unpicking rate decreases; The radius of the plate arc is larger, and the picking force is larger, the breakage rate is higher, and the unpicking rate is lower. The radius is smaller, the effective picking segment is longer, and the breakage rate is relatively reduced.

Acknowledgements

The study was supported by the National Natural Science Foundation of China (51375247) and the Natural Science Foundation of Anhui province of china (1408085ME103).

R E F E R E N C E S

- [1] *Zhang Zhimeng, Hu Wenguang, et al*, “The Advantage Analysis and Development of the Peanut Production of China”, *Journal of Peanut Science*, **vol. 34**, no.3, Mar. 2005, pp. 6-10.
- [2] *Wang Bokai, Wu Nu, Hu Zhichao, et al*, ‘Experience and thought of development of peanut harvesting mechanization at home and abroad”, *Chinese Agricultural Mechanization*, no.3, Mar. 2011, pp. 6-9.
- [3] *Lü Xiaolian, Wang Haiou, Zhang Huijuan, Hu Zhichao*, “Present Situation and Analysis on Peanut Picking Technology and Equipment”, *Hubei Agricultural Sciences*, **vol. 51**, no.18, Jun. 2012, pp. 4116-4118.
- [4] *Hu Zhichao, Peng Baoliang, Yin Wenqing, et al*, “Design of 4LH-2 type half-feed and self-propelled peanut combine”, *Transactions of the CSAE*, **vol. 24**, no.3, Mar. 2008, pp. 148-153.
- [5] *Xie Bin, Li Jingjing, Lu Qianqian, Mao Enrong*, “Simulation and experiment of virtual prototype braking system of combine harvester”, *Transactions of the Chinese Society of Agricultural Engineering*, **vol. 30**, no. 4, Apr. 2014, pp. 18-23.
- [6] *Zhao Yun, Zhu Huixuan, Xin Liang, Zhou Maile, Feng Jiang, Zhang Min*, “Mechanism analysis and experiment of transplanting mechanism with fitting gear five-bar for rice pot seedling”, *Transactions of the Chinese Society of Agricultural Engineering*, **vol. 32**, no.1, Jan. 2016, pp. 12-21.
- [7] *Liu Jing, Shi Kanle, Yong Junhai, et al*, “Generating smooth Bspline curves using control-point interpolation”, *Journal of Computer Aided Design & Computer Graphics*, **vol. 23**, no.5, May. 2011, pp. 813-819.
- [8] *Lin Jing, Qian Wei, Li Baofa, et al*, “Simulation and validation of seeding depth mathematical model of 2BG-2 type corn ridge planting no-till planter”, *Transactions of the Chinese Society of Agricultural Engineering*, **vol. 31**, no.9, Sept. 2015, pp. 19-24.
- [9] *Chen Haitao, Zhao Yang, Hou Shouyin, Cong Guangbo, Xu Yuan*, ‘Kinematics simulation and parameter optimization experiment for transplanting synchronous puncher”, *Transactions of the Chinese Society of Agricultural Engineering*, **vol. 32**, no.11, Nov. 2016, pp. 25-30.
- [10] *Zhao Manquan, Zhang Ning, Yang Tiejun*, “Design and experiment of virtual prototype of double disc mower cutter”, *Transactions of the Chinese Society of Agricultural Machinery*, **vol. 45**, no.8, Aug. 2014, pp. 101-105.
- [11] *He Junlin, Tong Jin, Chen Zhi, et al*, “Virtual design and kinematic simulation for feed-in mechanism with finger rotor”, *Transactions of the Chinese Society for Agricultural Machinery*, **vol. 38**, no.6, Jun. 2007, pp. 53-56.
- [12] *Jia Jingxia, Zhang Dongxing, Hao Xinming, et al*, “Parametric modeling and computer simulation of potato harvester parts”, *Transactions of the Chinese Society for Agricultural Machinery*, **vol. 36**, no.11, Nov. 2005, pp. 64-67.
- [13] *Du Yuefeng, Zhu Zhongxiang, Mao Enrong, et al*, “Simulation on small-scale corn harvester for hilly area based on ADAMS”, *Transactions of the Chinese Society for Agricultural Machinery*, **vol. 42**, no.12, Dec. 2011, pp. 1-5.
- [14] *Chen Haitao, Dun Guoqiang*, “Optimization of parameters for soybean lifter based on

dynamic simulation of virtual prototype”, Transactions of the Chinese Society of Agricultural Engineering, **vol. 28, no.8**, Aug. 2012, pp. 23-29.

[15] *LÜ Xiaorong, Zhang LiHua, et al*, “Virtual Simulation Analysis of punching Film and Caving Hole Performance of the Precision Dibbler”, Journal of Northwest A & F University (Nat. Sci. Ed.), **vol. 42, no.7**, Jul. 2014, pp. 217-222.

[16] *Li X Z, Du S Q*, “Experimental optimization design and statistical analysis”, Science and Technology Press, Bei jing, 2010.