

DESIGN AND EXPERIMENT OF VIBRATION SEPARATION EQUIPMENT FOR WINE GRAPE

Hewei MENG¹, Chengsong LI¹, Za KAN¹, Yaping LI^{1*}, Shixing LU²

The harvest of Xinjiang wine grapes were formerly relied on manpower. In order to solve the high labor intensity and the low efficiency in harvesting Xinjiang wine grapes artificially, a kind of vibration separation equipment for wine grape harvest is designed, which aims at the planting pattern of grapevines buried for wintering. The vibration separation equipment is suitable for the Xinjiang grapes 'tree and leaf canopy shape. The device is mainly composed of rack, driving part, working portion, etc.. By designing and modeling, the movement and the simulation analysis of the device is accomplished. The prototype vibration separation device is constructed and the optimal working parameters are determined by test. The results show that the parameters are 750r/min of motor speed, 550mm of the branch clamping position, and 125mm of vibration rocker length. Wine grape vibration separation effect is best; separation ratio is 95.42% as well, which met the requirements of wine grape harvest operation.

Key words: wine grape; vibration separation; harvesting; test

1. Introduction

Xinjiang is a major wine grape producing area in China. The grape in there is of good quality and high yield. With the adjustment and improvement of agricultural structures in Xinjiang, the planting area has been expanded dramatically and yield of wine grapes has significantly improved in recent years [1-2]. The research shows that the harvest of wine grapes uses the most of workforce during the production phase, and the workforce proportion is more than 50% [3]. At present, the mode of manual operation has been completely unable to meet the needs of the rapid development of wine grapes industry. The problem of harvesting has become a serious bottleneck, restricting the development of grape wine industry. Therefore, the harvest mechanization of grape wine becomes an urgent problem to

¹ College of Mechanical and Electronical Engineering, Shihezi University, Shihezi 832000, China
*(corresponding author)

² Shandong province's Weifang prison, Weifang 261011, China

be solved [4].

Vibration separation equipment is the key part of wine grapes harvesting device. The fruit and pedicel of wine grapes are efficiently separated based on vibration principle. This system has many advantages, such as high efficiency, low environmental requirements, and low manufacturing cost. Thus, it became the main way to harvest wine grapes locally and abroad. It can be divided into two types: the trunk vibration picking device and the center vibration picking device [4]. Orlando F.P. [5] designed the trunk vibration picking device, the horizontal vibration is passed to the top of the vibration arm using a set of parallel steel rail. Grapes got effectively shaken off nearby the trunk. Jarmain P.L. [6], Roger P. [7], Posselius J.H. [8] designed a center vibration picking device based on single point and double point support, respectively, which used two rows of flexible long stick or rib to knock and vibrate vines and make fruit fall off. There has been very little research on the mechanics of vibration separation for wine grapes in China. Yulei Feng, Panpan Yuan, Lihong Wang [9-12] designed a single support wine grapes vibration harvest experimental device, and the preliminary experiment has been carried on. Certain technical equipment is relatively mature abroad, such as the VN2080 highland gap grape harvesting machine from New Holland, and Braud9080L grape harvest machine from The United States, and so on [13]. However, foreign models cannot be simply adopted to wine grapes harvest [14] in Xinjiang area due to the difference in grape tree and leaf canopy shape which results in the planting pattern of grapevines buried for wintering.

For this purpose, this paper presents a type of vibration separation device for wine grape harvesting, with components as rack, driving part, and working portion. The prototype of vibration separation device was constructed and the optimal working parameters were determined by test. The research establishes good fundamental work for wine grapes harvest machine.

2. The general structure and working principle

2.1 The general structure and schematic diagram

The major parts of vibration separation device are: rack, driving part and working portion in the figure 1. The driving part includes the drive shaft, eccentric sleeve, and vibration rocker mechanism, as shown in figure 2. The working portion consists of active rocker, connecting rod, rib components, axis of vibration rocker rotation, the upper adjustable part, axis of driven rocker rotation and the lower adjustable part, as shown in figure 3. The main technical parameters of the mechanism are shown in Table 1.

Table.1

The main technical parameters of the mechanism

Items	Technical parameter values
Mode of traction	Pull-type
Complete machine size/mm ³	2000×1300×2500
Operation speed/(km·h ⁻¹)	1~1.5
Operation height/mm	500~1500
The number of rows	Single line

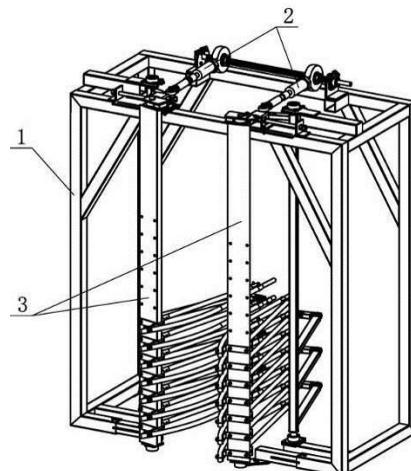


Fig.1 Structure of vibratory separator

(1) Rack; (2) Driving part; (3)Working portion

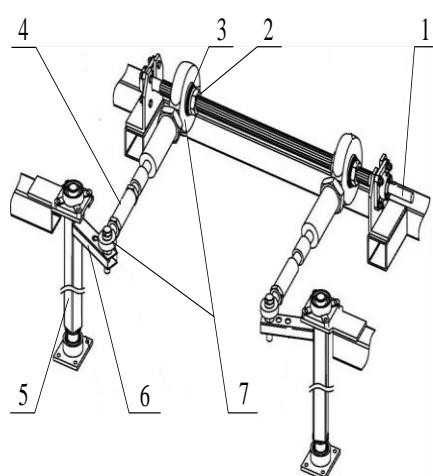


Fig.2 Structure of driving part

(1) Drive shaft; (2) Locknut; (3) Eccentric sleeve; (4) Connecting rod; (5) Axis of vibration rocker

rotation; (6) Vibration rocker; (7) Joint rod end bearings

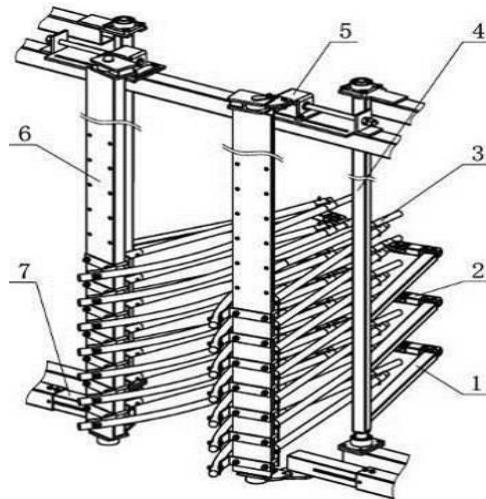


Fig.3 Structure of working portion

(1) Active rocker; (2) Connecting rod; (3) Rib components; (4) Axis of vibration rocker rotation; (5) The upper adjustable part; (6) Axis of driven rocker rotation; (7) The lower adjustable part

2.2 The principle of work

At work, through the importing power from the end of the drive shaft by motor or hydraulic motor, the vibration rocker shaft starts running, then, vibration rocker rotation axis drives active rocker running, consequently, drives the rib component vibration. The fruit grains were separated for the effect of vibration, and the wine grapes harvesting work was finally completed. The component location, spacing, and number of the rib can be adjusted as needed to meet the demands of grape tree and leaf canopy shape, and the amplitude can be adjusted by eccentric sleeve, connecting rod, rib and vibration rocker.

3. The design and analysis of vibration separation device

3.1 The separation mechanism design

In view of the cultivation requirements of Xinjiang wine grapes, which have more lord tendril fan tree shape and length and width leaf canopy shape, the end of the rib driver type vibration separation mechanism was designed for the requirement of big vibration swing and small chaotic vibration. Figure 4 is the structure sketch.

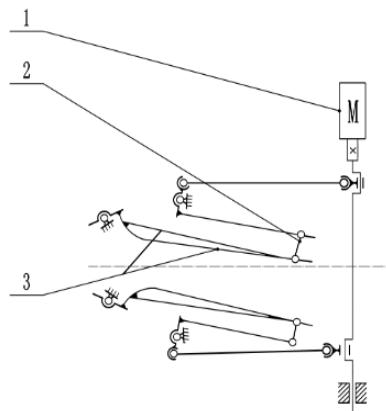


Fig.4 Structure of device

(1) Power source; (2) Connecting rod; (3) Rib components

3.2 The separation device design

The vibration separation device of wine grapes were designed based on the end of the rib driver type vibration separation mechanism, which is composed of driving part and working part. The driving part consists of a pair of mutual symmetry RSSR spatial four-bar linkage, and the cranks of two mechanisms are not only coaxial but also 180° opposed. The swinging rod L_3 of two RSSR four bar linkage and the planar four-bar mechanism active rocker of the working part are fixed on the shaft O_1 . The working part is made up of more pairs of RSSR spatial four-bar linkage, and displacement distribution is pronounced in space. The driven rocker is fixed on the shaft O in the multiple planar four-bar mechanism, as shown in figure 5.

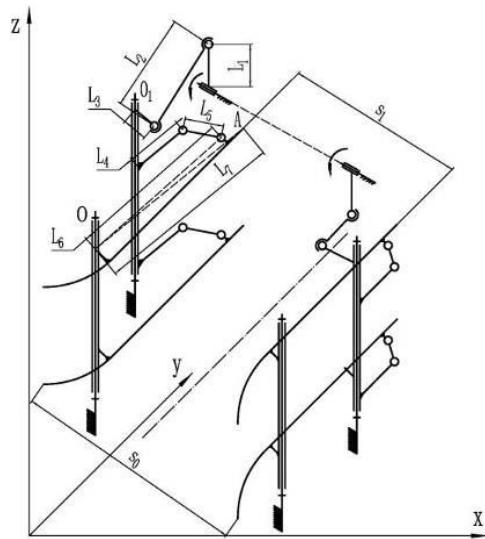


Fig.5 Separation device structure diagram

At work, the rotary motion of power source is translated into the swinging motion of the rocker by RSSR four bar linkage. The swinging motion is passed to the active rocker of the working part by shaft O₁, and drive the rib components for reciprocating swing. When the grape plants move between two rib components along the y axis, which are gathered and compressed by the rib components, the width is compressed from S₀ to S₁. At this moment, the swing motion of the rib components passes the vibration through grape plants and fruit clusters, generating the instantaneous dual directions movement of the fruit grains and overcoming the inertia force of fruit pedicel connection force. Consequently, the fruits are separated from the pedicels and reap the harvest.

According to the width of wine grapes leaf canopy shape, the width of ridge gathered and compression takes to 0.8m, the eccentricity of eccentric sleeve takes to 15mm, the effective length of ridge vibration is 850mm, and the spacing adjustment range of two ribs is 100 ~ 300 mm.

3.3 The kinematic analysis of the separation device

Equivalent planar mechanism method and the complex number vector method are used to analyze each of the mechanisms of vibration separation device of wine grapes^[15-17], and the kinematics and dynamics model is established.

RSSR equivalent planar mechanism of four bar linkage is established on the basis of device structure, as shown in figure 6.

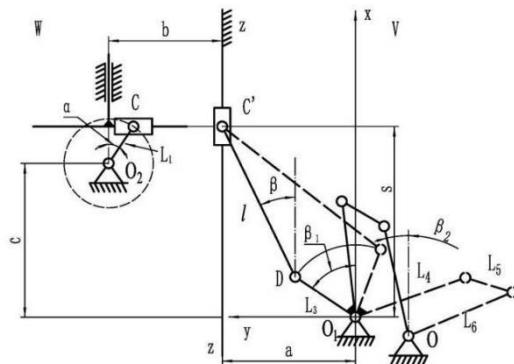


Fig.6 Equivalent planar body device

Through analysis and calculation, the angular displacement is

$$\beta_1 = \pm 2 \arctan \frac{a + \sqrt{a^2 + s^2 - H^2}}{s - H} \mp 90^\circ \quad (1)$$

$$\text{Among, } H = \frac{l^2 - s^2 - a^2 - L_3^2}{2L_3} \quad (2)$$

l --- the length of L₂ projection on the V plane, m

s ---the length of O₁C projection on the x axis, m

a ---the distance from vibration rocker to z axis, m

L_3 ---the length of vibration rocker, m

The analysis graphics of flat double rocker mechanism motion, it is composed of L_4 , L_5 and L_6 , as shown in figure 7, and the kinematic analysis is conducted^[18-21], the angular displacement of rib component L_6 that the effective amplitude can be produced by the end of the rib.

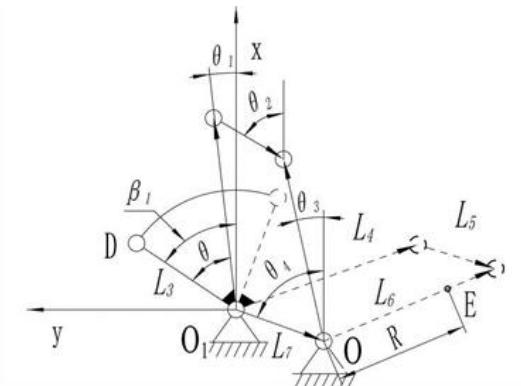


Fig.7 Schematic diagram of flat double rocker mechanism motion

Through analysis and calculation, E point exerts the shaking force \vec{F}_3 on the vines can get,

$$\vec{F}_3 = J_3 \vec{a}_3 / R = m_3 \vec{a}_3 R / 3 \quad (3)$$

$$\text{In the formula (3), } \alpha_3 = \frac{\omega_1^2 L_4 \cos(\theta_1 - \theta_2) + \omega_2^2 L_5 - \omega_3^2 L_6 \cos(\theta_3 - \theta_2)}{L_6 \sin(\theta_3 - \theta_2)} \quad (4)$$

m_3 ---the quality of the rib, Kg

R ---the distance between grape vine and axis plane of two driven rocker shaft, m

a_3 ---the angular acceleration of working parts, rad·s⁻²

It can be seen from the formula (3) that the main factor of impacting F_3 are α_3 and R , that is vibration position.

It can be seen from the formula (4) that the main factor of impacting α_3 are ω_3 , ω_1 and θ_1 , and that the main factor of impacting ω_3 are ω_1 and L_3 , and $\omega_1 = d\theta_1 / dt = d\beta_1 / dt$, the main factor of impacting β_1 is α , and $\alpha = \omega t$, ω is the motor speed, t is time.

But above all, the drive part and working parts are analyzed, the kinematics and kinetic models have been built, and the important factor affecting F_3 is L_3 , ω and R .

3.4 The simulated analysis of the separation device

With ADAMS, the virtual models of vibration separation device are established, and dynamics simulations are conducted.

The device is installed in parallel multiple rib structures, this author only analyzes one group of ribs. In the case of neglecting the uncorrelated non-transmission and ensuring the parts position, and the mechanism is simplified, and the virtual model of the vibration separation device is established, as shown in figure 8.

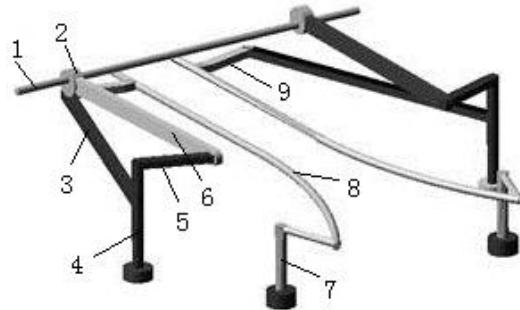


Fig.8 Virtual model of vibratory separator

- (1) Main drive shaft; (2) Eccentric sleeve; (3) Active linkage; (4) Axis of rotation of the vibration rocker;
- (5) Vibration rocker; (6) Linkage; (7) Axis of rotation of the driven rocker; (8) Rib; (9) Linkage

The driving force of the vibration device installs in the crank, and it is set as rotation constraint between the rotating parts, and fixed constraint between the parts of no relative motion. Part of the constraint set as shown in table 2.

Tab.2 Definition of partial constraint in ADAMS model

Constraint name	Connecting mechanism		Constraint type
JOINT6	Leitiao2	Liangan2	Revolute Joint
JOINT9	Qianyuan1	ground	Fixed Joint
JOINT11	Qianyuan1	Yaogan1	Revolute Joint
JOINT14	Yaogan2	Tiaojiegan2	Spherical Joint
JOINT15	Tiaojiegan1	Qudongzhou	Spherical Joint
JOINT17	Qudongzhou	ground	Revolute Joint

When the device is working, the frequency of working is modulated by the frequency of source of power. Therefore, it only needs a simulation analysis on amplitude.

Self-check function of the ADAMS/View interface is applied, with self-checking and revising, and the simulation parameter is set, Establish a MARK point interval 20 mm on the Working parts in the horizontal direction, set the rotation speed and time of the drive shaft, the maximum and the minimum of the X, Y coordinates of the MARK points are obtained. Consequently, the amplitude of each point is obtained, as shown in figure 9.

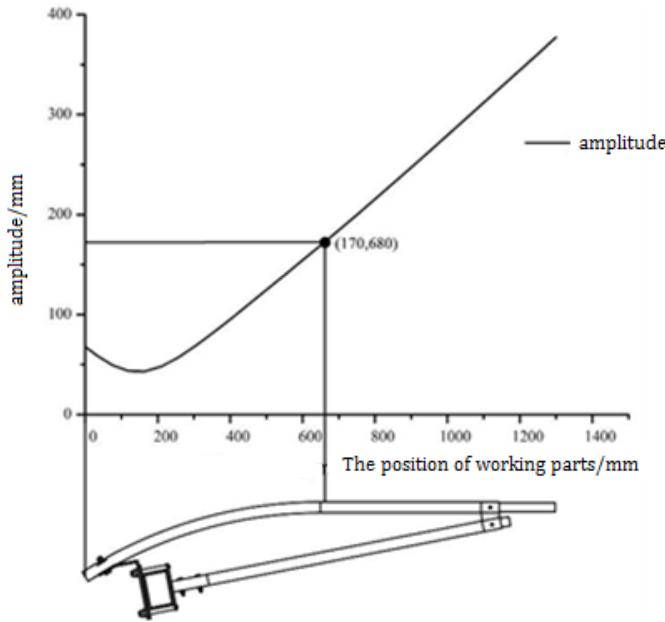


Fig.9 Amplitude of each point

As it is shown in figure 9, the position of working parts is 680 mm, while the amplitude of 170 mm, which satisfy the requirement of vibration separation.

Determine the motor speed range is 450-750r/min, eccentricity is 15mm, the length range of vibration rockers is 120-200mm, using Motor Y100L2-4 from Y series three-phase asynchronous motor and PA6 nylon.

4. Performance testing

The picking net rate of the vibration separation device is analyzed in this test, and the optimal working parameters of device is obtained.

4.1.1 Test materials

Wine grape varieties are cabernet sauvignon, and the origin is the No. 8 Division, (Shihezi) Xinjiang Production and Construction. Sampling time is on

September 14.

4.1.2 Instruments and equipment

Necessary instruments and equipment are adopted, such as the vibration separation device in figure 10, electronic scale (XK3190-A7), transducers (NVF2-5.5), computer, and stopwatch.

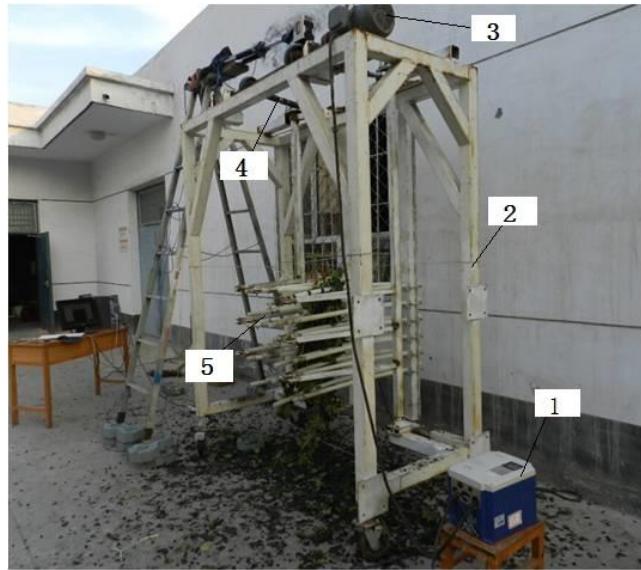


Fig.10 Device of vibratory separator

(1) Frequency converter; (2) Rack; (3) Motor; (4) Drive parts; (5) Working parts

4.1.3 The evaluation index

The picking net rate mainly reflects the harvesting effect of the vibration separation device, calculated by the formula (5).

$$\varphi = (M_1 - M_2) / (M_1 - M_3) \times 100\% \quad (5)$$

-- The initial weight, kg

-- The weight after vibration separation, kg

-- The weight of branches, kg

4.1.4 Test arrangement

Based on the preliminary design, the level of motor speed is set as 450r/min, 600r/min and 750r/min respectively. Meanwhile, the clamping position of branches are 250mm, 550mm and 250mm respectively, and the length of the vibration rocker are 125mm, 160mm and 195mm respectively. 9(34) table is selected in the test, and orthogonal test is shown in table 3.

Table. 3

Table of orthogonal test

Test Numbers	Numbers		
	Motor speed A (r/min)	Clamping position of branches B (mm)	Length of the vibration rocker C (mm)
1	450	250	125
2	600	550	160
3	750	850	195
4	450	550	195
5	600	850	125
6	750	250	160
7	450	850	160
8	600	250	195
9	750	550	125

4.2 The results and discussions

The vibration separation test results are shown in table 4.

Table 4

Test result of vibratory separator

Test Number	Test Index			Picking net rate
	/g	/g	/g	
1	3.64	2.52	0.80	39.44
2	3.80	1.38	0.86	82.31
3	3.94	0.98	0.84	95.48
4	3.32	1.84	0.82	59.20
5	3.68	1.78	0.88	67.86
6	3.26	2.22	0.83	42.80
7	3.14	1.38	0.74	73.33
8	3.32	2.44	0.84	35.48
9	3.78	0.86	0.72	95.42

The analysis of range is implemented by Minitab software, and the results of data analysis are shown in table 5.

Table 5

Experiment result analysis

Level	Motor speed A	Clamping position of branches B	Length of vibration rocker C
1	57.32	39.24	67.57
2	61.88	78.98	66.15
3	77.90	78.89	63.39
Range	20.58	39.74	4.19
Rank	2	1	3

It can be concluded that the sorting of various influential factors is B>A>C, and the optimal combination of working parameters is A₃B₂C₁ from Table 4. That means 750r/min of motor speed, 550mm of the branch clamping position, and 125mm of vibration rocker length brings the optimal working effect.

5. Conclusions

Considering that the features of Xinjiang wine grapes are fan main vine, long and wide leaf canopy shape, vibration separation device for wine grape harvest is designed. It is mainly composed of rack, driving part, working portion, and the addition experiment is completed. The optimal combination of working parameters of the device is obtained. The experimental results show that vibration separation plant meets the work requirements.

(1)The factors of impacting vibration of vibration separation device are the distance between grape vine and axis plane of two driven rocker shaft, angular acceleration of working parts and the quality of rib.

(2)Simulation analysis determines that the grape fruit grain can be effectively shaken off at the end of the rib components. The device can meet the requirement of vibration separation of wine grapes harvest in the process of moving.

(3)The working parameters of vibration separate device for wine grapes are 750r/min of motor speed, 550mm of the branch clamping position, and 125mm of vibration rocker length. The working effect is optimal, and the picking net rate could reach 95.42%, which also meets the requirements of wine grape harvest.

Acknowledgment

This work is supported by program of industrial and hi-tech scientific attack and commercialized findings plan of Xinjiang Production and Construction Corps(2013BA009)

R E F E R E N C E S

- [1] Zhonghua Zhao. Application status and development direction of Xinjiang grape production machinery [J]. Agricultural Technology and Equipment, 2008(4): 33-34.
- [2] Pei Xinmin, Jin Xiaoqing. Status and development suggestions of Xinjiang wine grape production machinery[J]. Agricultural Development and Equipment, 2014(8): 6-8.
- [3] Li Chengsong, Gao Zhenjiang, Kan Za, etal. Experiment of fruit-pedicle vibration separation of wine grape[J]. Transactions of the Chinese Society of Agricultural Engineering(Transactions of the CSAE), 2015, 31(9): 39-44.
- [4] Li Chengsong, FengYulei, Wang Lihong, etal. Analysis of structure and application status of the foreign wine grape harvester vibration separate parts[J]. Jiangsu Agricultural Sciences, 2014, 42(3): 335-337.
- [5] Orlando F P, Schultz D R, Scott P R. Pivotless mechanical grop harvester[P]: US, 5921074A. 1996-11-18.
- [6] Jarmain P L. Grape harvester with beaters adjustable for different row widths[P]: US, 6145291A. 1997-06-06.
- [7] Roger P, Gialis J M. Shaker with adjustable stiffness for harvesting machines and harvesting machines using such shakers[P]: US, 7841160B2. 2009-07-27.
- [8] Posselius J H, Larson D W. Fruit harvester with system and method for detecting and reducing forces exerted against rigid standing objects[P]: US, 20090401180. 2009-03-10.
- [9] FengYulei, KanZa, Li Chengsong, etal. Design of wine grape picking test device based on mechanics of vibration[J]. Jiangsu Agricultural Sciences, 2013, 41(11): 404-406.
- [10] Yuan Panpan, Zhang Xuejun, Kan Za. Design and analysis of end driven separation mechanism for wine grape[J]. Journal of Agricultural Mechanization Research. 2016, 38(9): 104-107.
- [11] Yuan Panpan, Wang Meng. Experiment of Wine Grape Harvester Conveyer[J]. Journal of Agricultural Mechanization Research, 2016, 12: 198-201+259.
- [12] Wang Lihong, Yuan Panpan. Analysis of Vibratory Mechanism Movement for Wine Grape and Design of Virtual Prototype Research Platform[J]. Journal of Agricultural Mechanization Research, 2015, 08: 53-56+61.
- [13] Wu Qingfen. VN 2080 Ground Clearance Grape Harvesting Machine of NewHolland Company[J]. Agricultural Engineering, 2013, (3): 105-107.
- [14] Li Chengsong, Gao Zhenjiang, KanZa. Operation mechanism of double support vibration separation device for wine grape berry[J]. Transactions of the Chinese Society of Agricultural Engineering(Transactions of the CSAE), 2015, 31(4): 22-26.
- [15] D.L.Peterson, S.D.Wolford. Mechanical harvester for fresh market quality stemless sweet cherries[J]. American Society of Agricultural Engineers. 2001. 44(3): 481-485.
- [16] Miao Hongbin, Qiao Fengli. Kinematics characteristics analysis research of spatial RSSR mechanisms[J]. Machinery Design and Manufacture, 2008(2): 7-9.
- [17] Hua Danian, Hua Zhihong. Linkage design and application innovation[M]. Beijing: Mechanical industry press, 2008.
- [18] Chang Rong, Yang Fufu, Li Yanping. Study on the performance and design diagram atlas of special crank and rocker RSSR mechanisms based on auxiliary angle method[J]. Machinery Design and Research, 2008: 142-145.
- [19] Wang Xiaohua. Displacement analysis and coupler curve drawing of 4-bar linkage[J]. Journal of Dalian Institute of Light Industry, 1999, 04: 326-328.

- [20] Wang Honglei, Han Janyou, Li Wei, Shao Jian. Hinge four-bar linkage analysis and development and application of the comprehensive software system [J]. Shandong agricultural machinery, 2005, 04: 8-11.
- [21] Zhang Xuejun, Chen Xiaozhen. Analyzing rigid body motion and its optimization design of the planar four bar mechanism[J]. Science Technology and Engineering, 2004, 06: 446-448.