

The design and test of collecting device and film purge device joint work of residual film recovery machine based on Solidworks & Adams

Haozhou Zhai¹, Jianming Jian^{1,2}, Shulin Hou¹, Yunlong San¹, Wensong Guo¹
Yue Sun¹ and Mingqing Gao¹

1 College of Engineering, China Agricultural University, Qinghuadonglu, Haidian District, Beijing, China

2 Corresponding author. Email jamesjian@126.com

Abstract: The twine of residual film is an essential issue in the process of remnant residue recovery of the residual film recovery machine. It is difficult to clean up the residual film in the residual film recovery operation and to influence the subsequent film efficiency. Therefore, in response to this problem a composite tooth pocket residual film recovery device was designed. In this paper, the structure of the film recovery device design, theoretical analysis, simulation experiments, get the most appropriate film recovery device parameters. In addition, the residual film rate of the membrane is dramatically low, reaching about 1.3% only, and the operation of the whole machine is smoother, and the stability of the work is promoted. The operation of the film recovery device is very obvious. Lifting, in addition to the film rate has also been significantly improved to 93.88%

1 Introduction

With the promotion of mulching and planting technology, the mulching planting area in China is nearly 49.5 million acres, the usage amount of agricultural plastic film is about 2 million 600 thousand tons^[1]. The mulching technology of mulch has helped the growth of crop growth and has been widely applied to the crops of medium and late mature varieties, which can increase the yield^[2-3]. As the cost of picking up the residual film is too high, the mainstream of the residual film picking way is by the machine now^[4-6]. The membrane removal device is an important part of the residual film recycling machine. At work, a large number of residual film will be wrapped on the pick - up elastic tooth^[7]. With the work going on, the residual film will gradually gather, and the ability to pick film will gradually decline^[8]. The film removing device can be used to clean the residual film at the same time, which can improve the working capacity of the machine and ensure the stability of the residual film recycling machine. By using the method of combining theoretical analysis with experiments, the trajectory of pickup teeth as reducing residual film and elastic tooth winding for the purpose of optimal optimal target, developed in the optimal efficiency of membrane device set up in addition to the optimal efficiency of membrane device - scraping film removing device movement. Because the motion of the pick film missile has certain elasticity, the optimization design should be modified according to the actual effect, and further improve the performance.



2 The design of collecting device and the film purge device

2.1 The working principle and the existing problems of collecting device

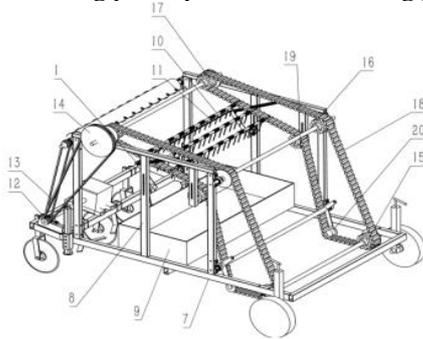


Figure 1. the structure of collecting device.

1. Film purge device 7. Chassis 8. Body frame cleaner 9. Collector steel 10. Elastic teeth axle 11. Elastic teeth 12. 100mm belt pulley 13. Conveyor belt 14. 280 mm belt pulley 15. Lower crawler wheel 16. upper crawler wheel 17. Back crawler wheel 18. Conveyor belt 19. lower crawler wheel 20. Tension pulley

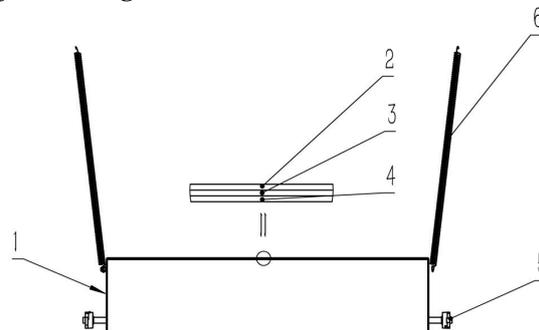


Figure 2. Structural diagram of purge device.

1. Alloy steel brace 2. The upper rubber 3. T9 high carbon plate 4. The lower rubber cleaner 4. UCFL206 bearing 5. spring

In order to make the schematic diagram clearer, in figure 1 the elastic gear on the track is hidden, and only the gear shaft in the work is retained. The pick up mechanism of the machine consists of pick - up elastic teeth, conveyor belts, tension wheels and plum wheels. The pick up the work process: elastic teeth shaft connected by both ends and elastic teeth movement in the track, track and force conveying shaft under the gradually descending from the front running into soil to pick up the residual film in the soil, then reverse operation, gradually goes up when running, when running to the plastic film residue plastic film recycling machine in the middle, the most of the residual film drop into the film collector by gravity, the rest of film remaining on the teeth move to the next stage, causing some residual film drop to the soil, reduce the residual film recovery rate, increase the artificial picking up workload; another part of the residual film has been around in the residual membrane shells teeth, and it will gather more and more during work, and also causing teeth surface friction reduced, some residual film slipped from the teeth on the next collecting process.

2.2 The design of film purge device

The basic structure of the film purge device is determined according to the movement mode of the film spring of the residue film recovery machine, as shown in figure 2. The film removing plate made of two rubber cleaners and a high carbon steel plate compounded by bolts to form an integrated structure, the frame through the bearing is connected to the residual film recovery machine, film removing plate frame on both sides from the upper spring is connected to the rear of the frame residual film recovery machine. The spring device makes the film version in the elastic teeth scraping forward in the spring tension to follow teeth forward a long distance, increase the effective working distance of film removing plate. Due to the increase in the effective distance of film removing plate and scraping membrane on the two pieces of plate rubber blown film plate shape with the working process of the change in scratched the surface of the film version of the contact area and friction, greatly enhanced the ability of a film, the film will be relatively tight attachment can be successfully removed.

3 The assignments and force analysis of collecting device and the film purge device joint work

3.1 The assignments of collecting device and the film purge device joint work

The film purge device is installed at the front end of the pick-up spring teeth of the residual film recycling machine, it aims to efficiently clean the residual film attached and wrapped on the teeth of the pick-up spring teeth. The upper end of a film purge device hanging by springs. The film removing plate moves in a circular motion under the thrust of the teeth, the forward and downward movement of residual film achieve the function of cleaning the residual film, in the movement to about 1/ 8 position clockwise circular trajectory, the plate run to bottom of elastic teeth, then the film purge device back to the initial position at this moment, reciprocated in addition to the membrane process.

After the cleaning process, the teeth with no residual film move to the below, take he residual film from soil again and it will drop to the film collector , by comparison with the teeth without cleaning, the residual film will be accumulated, excessive accumulation of residual film will affect the film picking the next tooth pick film work, even it’s hard to pick the films. Therefore, film purge device ensures the stable and continuous operation of the residual film recovery machine, and greatly improves the recovery efficiency of the residual film.

3.2 Force analysis of joint work

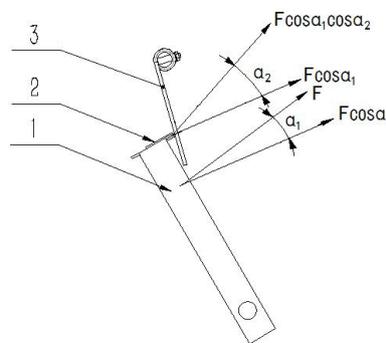


Figure 3. Force diagram of film purge device.

1.force direction of spring 2.removing plate 3.elastic tooth

In order to measure the force of purging residual film wrapping on the teeth, pulling down the film scraping rubber plate to complete the removal of residual film movement by using the electronic tension equipment, recording the force needed to achieve the desired analog measurement of scraping force. And the twenty groups of data measured by the electronic tension equipment will be summary and use the maximum value to represent the maximum tensile force data. On the other hand, the composite rubber and the elastic teeth on the film removing plate form greater friction in the process of movement, and the direction is opposite. The main condition that the residual film can be scraped is that the friction force is greater than the maximum tensile force.

$$f > F_{max} \tag{3-1}$$

$$\left\{ \begin{array}{l} f = \mu F \cos \alpha_1 \cos \alpha_2 \\ F = k(l_2 - l_1) \\ F_{max} = (m_1, m_2, m_3, \dots, m_{18}, m_{19}, m_{20}) \end{array} \right. \tag{3-2}$$

- f —The frictional force between rubber and elastic teeth
- μ —The coefficient of friction between rubber and elastic teeth
- l_1 —The initial length of spring
- l_2 —The spring strength length
- F —The spring tension
- k —spring rate
- F_{max} —Maximum pull of purging the film

m_1 to m_{20} —All the pulls of purging the film in the test.

α_1 —The angle between spring pull and film purging force directions

α_2 —The angle between elastic teeth and film purging force directions

Simultaneous equation (3-1) and (3-2)

$$k > \frac{F_{\max}}{\mu(l_2 - l_1) \cos \alpha_1 \cos \alpha_2} \quad (3-3)$$

By type (3-3) can obtain the required minimum spring stiffness coefficient through access to relevant literature, and considering the influence of spring vibration during the movement of other factors will determine the scope of spring, so it is between 38mm~41mm, finally according to the actual production standard and the principle of economy is determined using 40mm tensile spring .

4.The working process simulation of film purge device

4.1 Solidworks 3 dimensional model design

In this paper, ADAMS and Solidworks are used to complete the simulation test, and the simulation scheme is aimed at the simulation operation effect of the film purge device. The operation effect of the device is directly related to the effect of its practical work. In this paper, Solidworks and Adams software are used to simulate the membrane removal device. Which draw each parts to a substantial proportion of 1:1 model by using Solidworks,then the CAD model into PARASOILD model and introduced into the dynamic simulation software ADAMS for dynamic simulation.

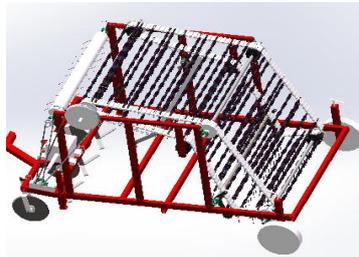


Figure 4. Solidworks 3D model

This experiment is aim at finding the most suitable plate height film elastic teeth to operate film removing, the simulation experiment will be working within the selected film removing plate distance of elastic teeth top from 2.0cm to 6.0cm height ,and they will be simulated in the simulation, the initial selection of the height is 2.0cm and 4.0cm and 6.0cm respectively in the preliminary test, the running speed of film board X, Y, Z sets are regarded as the standard, through the experimental results. The better performance range is from 2.0cm to 4.0cm, so the refinement test are operated in the second experiment, with 0.1cm as the interval, through simulation that the most appropriate height is 3.1cm.

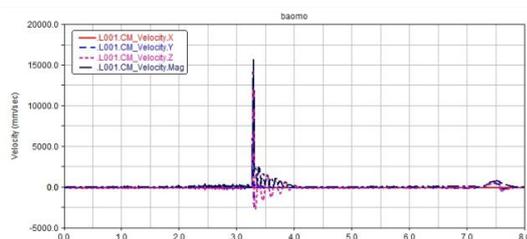


Figure 5. motion simulation of 6.0 cm

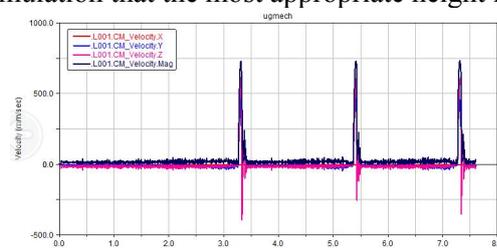


Figure 6. motion simulation of 3.1 cm

The figure 5 is representative of the height of 6.0 cm, due to the first film wiped action after springback wiped film face with elastic teeth cause rear operation cannot be carried out at a standstill, so the movement is stuck in the first session. When the height is adjusted to 3.1 cm, the simulation results shown above, Velocity. X, Velocity. Y, Velocity. Z values have reached a relatively stable state at the same time period, Velocity. Mag values also showed a consistent, indicating that in this position,

the membrane device has good stability, can work continuously in film motion to meet request. From the above analysis it can be concluded that when the elastic teeth top distance is in 3.1cm, the optimal motion effects of the velocity as shown in Figure 6, can smoothly complete the wiped film movement, and in second and third motion waveform showed a good stability, the results show that the film removing device installation location and elastic teeth movement has a high degree of fit.

5 Field test and analysis

5.1 Experimental environment

The field test of film purge device and collecting device was carried out in Liuquan potato film farmland Guan town Hebei Province, film thickness used for field is 0.008mm, flat terrain, and soil is in operation loam, soil hardness is 5.9kPa, the moisture content is 26.1%, the film had been broken, the experimental environment meet the most common cultivated land, so the working environment is generally representative. The power plant is supplied by Dongfanghong 40 tractor, with a speed of 3.0~4.0m/s and a working width of 1800mm.



Figure 7. Fields trial of residual film device



Figure 8. Enlargement of work results

5.2 Test scheme

In order to ensure the stability of the test and scientific comparison. The test will be divided into two schemes: install film purge device and uninstall film purge device. For each scheme is divided into 4 groups, in the experimental conditions permit in large extent to reduce the influence of random factors in the field, each test 2 times and take the average value, a single test with distance of 200m, taking into account the residual film recycling machine working efficiency and the applicable speed range of two factors, the operation speed is in the range of 2.0m/s ~ 3.5m/s test group A walking speed was 2.0m/s, test group B, walking speed is 2.5m/s, test group C, walking speed is 3.0m/s, test group D, walking speed is 3.5m/s.

The measurement method of residual film is: in each test residual plastic film left will be pick up by manual work and the film picking up by machine is also collected, then were washed and dried, weighed, and draw the final quality. The calculation formula of pickup rate is as follows:

$$S = \frac{m_u - m_c}{m_u} \times 100\%$$

S—Film cleaning rate

m_c —The quality of residual film after installing the film purging device

m_u —The quality of residual film before installing the film purging device

5.3 Test result

In the test, the film purge device is running closely to the design trajectory, the experimental results and simulation results are slightly different, but in the acceptable and reasonable range. When the velocity is between 2m/s ~ 3m/s, the membrane removal effect is good, and the recovery effect of residual film can be greatly improved. Among them, the running speed of 2.5m/s is the best, residual film recovery increased 6 percentages. At the same time, residual film recovery effect in speed 3.5m/s the residual film recovery appears to reduce the abnormally that residual film recovery machine was

unstable in high speed operation, so it need to observed for further studies in the following work.

Table 1. The testing result of purge device.

Test serial number	Speed m/s	Twine film quality without device m_u / g	Twine film quality with device m_c / g	Rate of cleaning %	Film collecting rate with device %	Film collecting rate without device %
A	2.00	25.71	1.31	95.0	85.58	91.42
B	2.50	33.16	1.42	95.8	87.17	93.88
C	3.00	28.64	1.28	95.6	86.43	90.21
D	3.50	30.32	1.61	94.7	79.96	83.22

Table 2. Significant analysis of collecting experiment.

Difference source	SS	df	MS	F	P-value	F crit
Rows	116.81	1	116.82	11.20	0.0441	10.13
Error	31.28	3	10.43			
Total	148.09	4				

(Note: $p < 0.01$ is extremely significant; $0.01 < p < 0.05$ is significant; $p > 0.05$ is not significant)

Through the analysis data in the table 2, we get the experimental results $F=11.20$, $P=0.0044 < 0.05$, which shows that film purge device has remarkable effect on improving film collecting rate.

6. Conclusion

According to the circumstance that the residual film twines with the elastic teeth during the working process of film recovery machine, a following type film removing device is designed, its working principle is analyzed, and proved the feasibility for the device through the field test, suitable for elastic teeth type residual film recovery machine, the film recovery rate promotion effect is prominent, the quality improved obviously, so it is worth popularizing widely cultivated land in the application of residual film recovery machine.

Reference

1. China statistical bureau *China statistical yearbook national bureau of statistics of the people's republic of China Beijing* China Statistics Press 2015.
2. Hou S L Hu S Y Kong J M, Research status of residual film recycling machine in China *Transactions of the Chinese Society of Agricultural Engineering*, 2002, Vol. **2** pp 186-190.
3. Li M Y Ma S H The current research on the residual film recycling machine in China and suggestion *Journal of Agricultural Mechanization Research*, 2014, Vol. **36 (6)** pp 242-245,252.
4. Chen D W 2014 The residual film promotion of recycling machine *Agricultural Science & Technology and Equipment* Vol. **7 (7)** pp 34-35.
5. Qin W Popularization and suggestion of residual film recycling machine *Rural Science & Thchnology*, 2013 Vol. **7** pp 74-75.
6. Chang L R Pei Z L Cao L Review of mechanical technology for waste film recycling *Auhui Agricultural Science Bulletin*, 2013 Vol. **9** pp 153-155.
7. Mu D H Yao W Z Design and Experimental Research on elastic tooth pick up mechanism of residual film recycling machine *journal of agricultural mechanization research*, 2015 Vol. **11** pp 91-94.
8. Chen F Shi J X Zhao H J Optimum design of fixed cam residual film pickup mechanism *Transactions of the Chinese Society for Agricultural Machinery*, 2005 Vol. **3 (12)** pp 43-46.