Application of Key Techniques for Comprehensive Control of Residual Film Pollution in Xinjiang Cotton Field Irrigation Area

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Abstract. In order to meet the requirements of mechanical recovery of residual film before tillage in Xinjiang cotton field irrigation area, a combined machine for cotton straw returning and residual film recovery with the function of secondary throwing was independently developed, and the field test of scavenging rate and mulching film hybrid rate was carried out to determine the optimized performance of the machine and tools. Moreover, the comprehensive prevention and control technology model of mulching film pollution was established in Xinjiang cotton field irrigation area. In the end, the system and application basic theory of mechanization recovery technology for residual film before tillage in Xinjiang were created, so as to contribute to the "White Pollution" control in Xinjiang.

Keywords: Cotton fields, residual film pollution, prevention and control, control increment, reduce of existing residual film.

1. Introduction
In view of the serious problems of "white pollution", poor recovery effect and low efficiency of residual film, the key patent technologies of crushing and returning straw, membrane separation and field packing have been integrated through many years of research. The key technology and equipment system of surface film recovery mechanization of Xinjiang cotton field before tillage has been formed, which can effectively solve the problem of "white pollution" that troubles the development of modern agricultural cotton, which is of great significance to improving the quality and efficiency of cotton agriculture in China.

2. Working Principle and Performance Parameters of Core Machine and Tools
Combined with the same technology at home and abroad, the working principle of film-picking, film-cleaning and related motion and structure theory parameters are studied independently, and the modern design method and computer virtual design technology are combined. The series of 4JSM (one film, four rows, one film and six rows) of cotton straw returning to the field and residual film recovery combined operation model are successfully developed. As shown in Figure 1, the achievement level reaches the leading level in China. The machine is equipped with large and medium-sized wheeled
tractors to complete multiple functions in one operation, reduce the number of machines and tools, reduce operating costs and reduce tractor exhaust emissions. It uses "straw crushing and throwing back parts" to achieve the function of "membrane and rod separation". It adopts "dump" membrane box to achieve membrane unloading function, and the performance parameters of the machine are shown in Table 1. As shown in Figure 2, the drum for cleaning residual film of curved film picking teeth can not only improve the recovery rate of residual film, but also realize the separation of "membrane soil" and part of "membrane rod", thus realizing the recycling and reuse of waste plastic film. The working principle is that the machine is connected with the tractor through the traction frame, the lifting of the machine is controlled by the hydraulic system, the depth of the machine is controlled by the limit structure on the frame, and the position of the film shovel on the upper part of the frame is adjusted according to the relationship between the plastic film and cotton rod during the operation. When the machine is working, the straw shredding parts will be crushed and thrown to the back of the film box. The loose soil teeth will lose the soil under the film surface within the working scope of the film drum, and the film picking teeth on the film drum will be picked up from the soil. The film removing mechanism will remove the film picking teeth from the film picking drum and transport them to the film box.

![Combined machine for crushing and returning cotton straw and recovering plastic film](image1)

**Fig. 1.** Combined machine for crushing and returning cotton straw and recovering plastic film

Where, 1 = Traction frame, 2 = Hydraulic system, 3 = Main transmission system, 4 = Stalk cutting parts, 5 = Film stripping mechanism, 6 = Capsule collecting box, 7 = Film-picking drum, 8 = Running system, 9 = Lifting system, 10 = Depth wheel, 11 = Support components, 12 = Safety guard plate, 13 = Side film shovel.

![Three-dimensional structure model of residual film collector roller](image2)

**Fig. 2.** Three-dimensional structure model of residual film collector roller

Where, 1 = Residual film pick up drum skeleton, 2 = Roller center shaft, 3 = Cam disc assembly, 4 = Film tooth group, 5 = Drive sprocket combination
3. Field Trials

According to the standards of DG65/T-2011 and GB/T25412-2010 film recovery machine, the project team discussed the recovery rate before and after improvement of the edge collecting film device and the copying device of the residual film recovery machine, the change of the cleaning rate of the recovered film and the working weight. The average value is calculated, and the surface cleaning rate of each measuring point is calculated according to the following formula:

\[ J = 1 - \frac{W}{W_0} \times 100\% \] (1)

\( J \) is the removal rate (%), \( W \) is the surface residual film quality (unit: g), and \( W_0 \) is the surface or deep residual film quality (unit: g). The formula of residual film mixing rate can be obtained through testing, comparing and analyzing the efficiency, so as to provide a reliable basis for the follow-up study of residual film recovery machine. The surface residual plastic film of 3 measuring points before and after the operation in the two measuring areas are taken respectively, and the residual plastic film taken out at each measuring point according to the levels is washed and dried, and its weight can be measured.

\[ W_s = \frac{G_{mq} - G_{mh}}{G_{mq}} \times 100\% \] (2)

\( W_s \) is the residual film mixing rate, \( G_{mq} \) is the total weight of the original film, and \( G_{mh} \) is the residual film weight.

It can be seen from Table 2 and Figure 4 that in view of the problems existing in the early stage, the improved and optimized design of the edge film collecting device and the copying device of the residual film recovery machine is carried out. The removal rate of the residual film is increased by 5.63% and the mixing rate of the residual film is reduced by 2.05%.

Fig. 3. Residual plastic film pick-up sampling
| Serial number | Clean-up rate (%) | Plastic film confounding rate (%) |
|---------------|-------------------|----------------------------------|
|               | Before optimization | After optimization | Before optimization | After optimization |
| 1             | 78.78              | 82.89              | 10.81               | 11.05               |
| 2             | 89.55              | 90.78              | 13.49               | 11.87               |
| 3             | 83.41              | 92.41              | 11.25               | 8.00                |
| 4             | 77.31              | 80.54              | 8.45                | 5.78                |
| 5             | 75.86              | 94.23              | 8.34                | 6.24                |
| 6             | 83.43              | 87.47              | 11.25               | 9.45                |
| 7             | 84.55              | 92.1               | 8.83                | 6.53                |
| 8             | 84.12              | 81.63              | 9.78                | 7.26                |
| Average       | 82.12              | 87.75              | 10.28               | 8.23                |

Fig. 4. Main performance changes before and after structural optimization of residual film

4. Application of Key Technologies for Prevention and Control of Plastic Film Pollution

4.1. According to the requirement of mechanical recovery of residual film before tillage in oasis irrigation area, a combined operation machine of returning cotton straw to field and recovering residual film with secondary throwing function was developed [1-2].

First, continuous innovation is carried out on the original 4JSM series cotton field residual film recycling machines and tools in Xinjiang. The crushed cotton straw is sent back by the "secondary throwing mechanism", which can keep the plastic film surface clean and improve the cleanliness of the residual film recycling. At the same time, the crushed straw can be evenly sprinkled, which is convenient for mechanized operation of rotting and returning to the field and later tillage and finishing land, and increases soil fertility. Second, under a series of measures, such as using straw crushing knife shaft and adding wind force, the film surface of cotton field is optimized, and the recovery rate and cleanliness rate of residual film are improved.
4.2. Construction of a comprehensive control technology model of plastic film pollution in cotton field of oasis irrigation area

First, the technical model of comprehensive prevention and control of plastic film pollution in cotton field is based on the law of cycle change of cotton field growth, using the core technology "residual film recovery technology before tillage" and "residual film recovery technology before sowing" to control the residual plastic film recovery node, selecting the standard thickness (strengthen the standardized production control of plastic film, and strictly implement the national standard of plastic film thickness $\geq 0.01$ mm) for plastic film to facilitate mechanical recovery, fertilization and resource utilization [3-5]. Key technologies such as chemical control, straw returning [6-10], bundles [11-13] and matching technique [14-15] can give full play to the role of various functional departments, use farmers' cooperatives for training and operation of technical specifications, carry out on-site observation meetings and technical guidance of machinery and tools extension departments, and actively improve the technical optimization and upgrading of scientific research departments, as well as policy guidance, market supervision and recovery policy subsidies of government departments, so as to achieve a more complete technical model for comprehensive prevention and control of plastic film pollution that can guide production.

Second, the core technologies of integrated plastic film prevention and control technology model include pre-sowing residual film recovery technology, that is, before sowing, the residual film in 0-15cm soil is recovered once by means of a rake or a special residual film recovery machine before sowing, as a supplementary way to achieve the goal of "reducing stock" [16]; residual film recovery technology before tillage, that is, after the crop is finished, the performance indexes of plastic film are relatively complete at this time, and the operation period is longer than that of other periods, and
mechanized recovery is adopted [17-21]. According to the appraisal report of agricultural and animal husbandry machinery appraisal station of Xinjiang, the recovery rate of residual film reaches over 87% and the reliability of the machinery and tools reaches 98%, providing reliable residual film recovery machinery and tools for solving the "white pollution" of cotton fields in China.

4.3. The technology system of mechanization recovery of residual film before tillage in Xinjiang oasis is created and the basic theory of application is formed

First, the application basic theory of kinematics, dynamics and structural parameters values of a complete set of relevant moving working parts, including raising film [22], feeding film [23-24] and unloading film, with cleaning film lifting drum as the core, is proposed and proved by production practice. It is proved by production and application that the parameters are relatively scientific and reasonable, which can meet the requirements of "separation of membrane, soil and membrane and rod" for the recovery of residual film, and provide a reference basis and technical platform for the domestic research and production of similar machines and tools [25-28].

Second, the motion model of the film-lifting teeth is constructed, and the motion trajectory equation, the absolute motion trajectory equation and the motion trajectory differential equation are established, so as to obtain the absolute velocity diagram and the absolute acceleration diagram of the curved film-lifting teeth end for the first time [29], as shown in Figure 7. The relationship between the speed of the lifting drum and the forward speed of the machine is the basis of the transmission and structure design of the machine, which is directly related to the film picking effect. It is found that the film picking up effect is better when the ratio of relative linear speed to the forward speed (\(\lambda = \omega R/V_m\)) of the tractor is between 0.75 to 0.88, breaking through the restricted zone of motion parameters design of the same kind of machine and tools in China.

Third, for the first time, a comparative study of various types of membrane drum components has been carried out in China. The mechanical characteristics and working performance of "arc tooth swing type" and "telescopic stick type" film lifting drum are different [30]. The results show that the telescopic scraper drum is sensitive to the deformation of the rod teeth under stress and the failure rate is high. The arc tooth of arc tooth lifting drum is not easy to deform after bearing force, and is not sensitive to deform after bearing force, so the failure rate is low. Under the same load condition, the acting force on the telescopic boom roller is greater than that on the arc tooth film roller. Therefore, the working performance of the arc tooth film drum is better than that of the telescopic rod film drum.

![Fig. 7 Trajectory of pick membrane tooth](image)
Fourth, the application of the scientific arrangement of the film teeth on the whole roller surface is studied. In order to avoid frequent contact between the film teeth and the straw stubble, reduce the failure rate, and better adapt to the main cotton-picking pattern in Xinjiang cotton region, the staggered method is adopted to arrange the film teeth in the axial direction on the drum. After strict calculation and production practice, it is concluded that the axial distance c=150mm between the film teeth is more scientific [31-32].

Fifth, a mathematical model is established for the optimal design of fixed cam mechanism with the maximum production efficiency and minimum contact stress as binocular targets. The difficulty of cam mechanism design lies in the complex diversity of cam mechanism and the variation diversity of follower rule. The basic task is to design its contour curve. MATLAB, ANSYS, Solidworks, UG and other virtual design software optimization functions are used to optimize and improve the cam mechanism, providing a design method to reduce wear of cam mechanism and improve working reliability [33-35].

5. Summary
In the treatment of farmland plastic film pollution, in order to recover the residual plastic film more and better, the matching use of the core equipment plays a most important role. Both the ideal flanging mechanism and the core components of the pre-tillage residual film recovery machine arc reciprocating play an important role. Therefore, the reasonable design of the machines and tools can improve the reliability of the machines and tools, and the comprehensive control technology model of oasis irrigated cotton field "control increment, reduce stock" mulch film pollution can better support agricultural production. The next step of the team will adopt a highly intelligent control system to improve the adaptability and performance of machines and tools, including residual film recovery and work efficiency. According to the modern agricultural machinery design requirements of large and medium-sized, intelligent and compound agricultural machinery, the residual film recovery machine is upgraded intelligently, and the working condition of the machine is monitored in real time, including working condition, working area, and working place. It can not only reduce labor intensity for the mobile phone, but also provide a basis for the agricultural sector to engage in relevant subsidies.

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