Journal of Electrotechnology, Electrical Engineering and Management (2024)
Clausius Scientific Press, Canada
DOI: 10.23977/jeeem.2024.070201
ISSN 2560-6697 Vol. 7 Num. 2

# *Optimization of agricultural broken film cleaning device based on electrostatic adsorption principle*

**Chenyang Li[1,*]**

[1]*Wuhan University of Technology, Wuhan, China*
[*]*Corresponding author*

***Keywords:*** Agricultural mulch, broken film pollution, electrostatic adsorption principle, microwave drying technology

***Abstract:*** Mulch planting and cultivation technology, known as the "second revolution" of agricultural production, is widely used in the development of agricultural production and promotes the increase of farmers' income. However, due to the difficult degradation of agricultural film materials and improper treatment methods, a large number of agricultural film fragments remain in the deep soil, causing great pollution to the soil environment. In this paper, through the analysis and research of the pollution status of agricultural broken film and the application status of agricultural film recycling device, it is proposed that the principle of electrostatic adsorption is used to adsorb and remove the small particle broken film in the deep soil, and the microwave drying technology is used to reduce the adhesion between the broken film and soil, so as to achieve the optimization of the existing device. The experimental results show that the optimized cleaning device can effectively remove the residual broken film in the deep soil, effectively reduce the white pollution in the soil, and provide a reference for the treatment of broken film pollution.

## 1. Research background of works

In recent years, with the extensive use of mulch film in our country, the problem of recycling residual broken film has gradually attracted people's attention. According to existing data, China uses more than 2 million tons of agricultural plastic film every year, of which plastic film accounts for 90% of the global total. However, about 18.6% of agricultural film remains in farmland in China every year, and 64.89% of these broken films remain in the 0-10cm soil layer, and the residual strength increases with the increase of film mulching years.

These broken films can not be decomposed in the natural environment in a short time, not only will lead to the loss of soil fertility in some cases, affecting the yield of crops, but also will collapse into smaller plastic particles under the action of repeated weathering and degradation, and spread to the soil and watershed, causing serious white pollution. As shown in figure 1.

Therefore, the recycling technology of agricultural residual film has been developed, mainly including artificial pickup technology and mechanical recycling technology, which can solve the problem of agricultural residual film to a certain extent. However, with the longer the age of residual film, the higher the degree of fragmentation of residual film and the residual film fragments move down to the deep soil layer year by year, and it is difficult to effectively remove artificial

pickup and mechanical recycling technology. Most of the existing plastic film recovery devices can only recover and treat the complete plastic film and residual film in the soil surface and shallow soil above 10cm, and the recovery rate of deep soil residual film and broken film is low, and the treatment effect is not good. Therefore, aiming at the problem that agricultural broken film in the deep soil is difficult to remove, this project designed a new agricultural broken film removal device based on the principle of microwave drying and electrostatic adsorption[1-2].

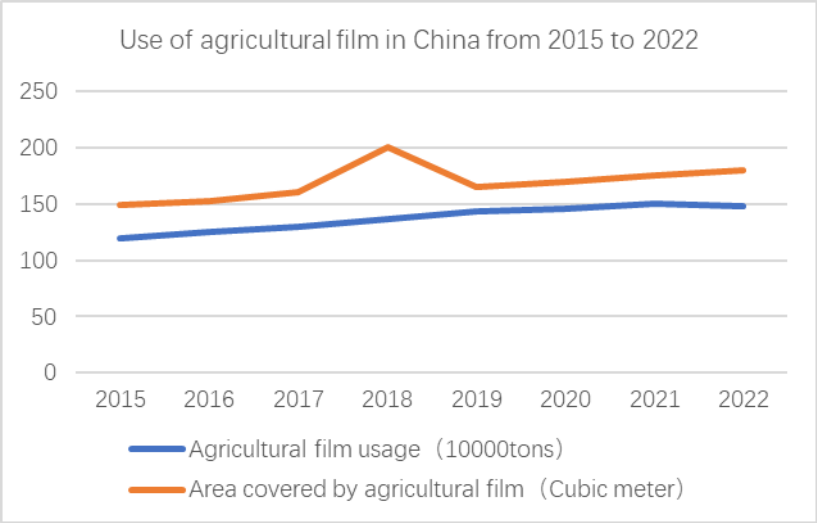


Figure 1: Use of agricultural film in China from 2015 to 2022

At present, North China grows the most crops and uses the largest amount of agricultural film, which is extremely harmful to the environment. According to statistics, the deep broken film can be removed in each hectare of field in 1300g-4100g, and as shown in Figure 2, the amount of broken film and the broken rate of agricultural film increase with the increase of film coating years, endangering the growth of crops and causing serious pollution to the environment. The residual amount of deep broken film per hectare in farmland with continuous film coating for 10 years was 2229g-4239g, and the residual amount of deep broken film per hectare in farmland with continuous film coating for 20 years was 2720g-4350g.

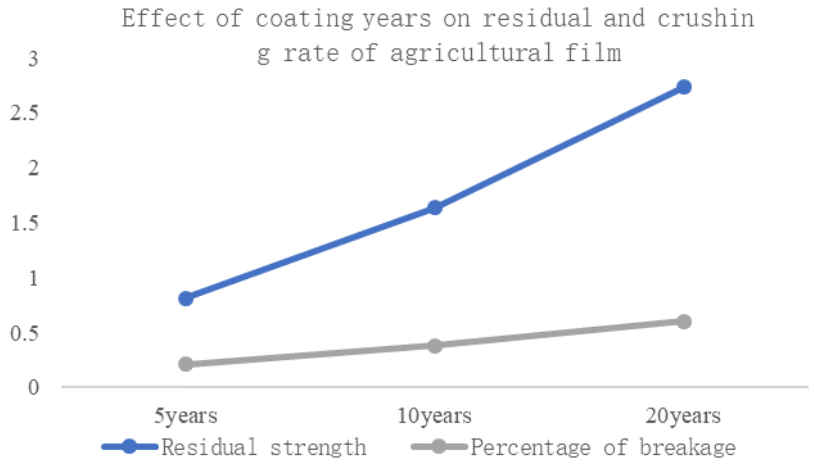


Figure 2: Effect of coating years on residual and crushing rate of agricultural film

## 2. Overall scheme designs

In this paper, the modular design idea is used to optimize the agricultural broken film cleaning device based on the principle of electrostatic adsorption and microwave drying. The design is mainly composed of five parts: crushing module, microwave drying module, adsorption module and recovery module. As shown in figure 3.

Microwave drying module adopts microwave drying technology, which has less impact on the soil through experimental verification, and compared with other drying technologies, microwave drying technology has better drying effect and drying efficiency, and can be better matched with subsequent processing module. At the same time, the conveyor belt is used in the module to transport soil, so that the transport process of soil and the drying process are carried out at the same time, compared with the step method, can effectively reduce the working time of the device and improve the working efficiency[3-4].

The adsorption module adopts the principle of electrostatic adsorption, which can effectively adsorb the broken film in the ground by setting an electrostatic magnetic field around the ground. Through secondary electrostatic adsorption, the module can improve the adsorption effect of broken film, so as to remove the difficult agricultural broken film in soil.


Figure 3: Schematic diagram of the overall device mechanism

## 3. Design of the main part of the deep agricultural broken film cleaning device

### 3.1. Crushing module design

The crushing module is a module that breaks the soil for the first time and lifts it to transport it to the inside of the device. It is installed at the very front of the machine to achieve the crushing and transportation of deep soil. In order to achieve soil crushing, a roller is used in this paper, which is connected to the overall device through a mechanical arm. The roller rolls the soil containing broken film in the field through the movement of the mechanical arm, and implements the initial crushing of the soil. After the crushing, the roller is moved to the rear through the movement of the mechanical arm.

The chassis in this paper adopts a fixed connection with an inclination Angle of 45 °. In order to realize the rotation and inclination of the bucket, the bucket and the chassis are connected through a flat four-link mechanism, and the connecting rod connects the bucket, chassis and flat four-link structure. By designing two rotating devices, the bucket is more stable in the rotation process. The bucket drives the movement of the bucket through the rotation of the plane four-link mechanism, adjusts the height of the bucket, and realizes the effective lifting of the bucket. At the same time, the broken soil is shoveled up, and the inclination Angle of the bucket mouth is adjusted through the

connection of the connecting rod, and the direction and Angle of the bucket opening are adjusted. During the transport of soil, the rotating device continuously adjusts the height, inclination and opening orientation of the bucket, so that the bucket can accurately and smoothly transport the soil to the inside of the device[5-6].

### 3.2. Drying module design

Because the soil contains a certain amount of water, and the water in the soil gradually increases with the increase of the soil depth, the broken film will adhere to the soil inside, and it is difficult to remove it by electrostatic adsorption. Therefore, before electrostatic removal of the broken film, a drying module is set in this paper to dry the soil, remove most of the water in the soil, reduce the soil moisture content, and make the soil structure more loose, which is conducive to stripping the broken film from the soil.

By comparing various drying methods, this paper chooses the microwave drying method, as shown in Table 1. Compared with the traditional hot air drying method and other drying methods, the microwave drying method has the advantages of high drying efficiency, uniform drying, etc. Compared with the infrared drying method, the microwave drying has lower energy consumption, and the soil treated by microwave can still be put into agricultural use. It can effectively prevent soil-borne diseases and pests.

Table 1: The advantages and disadvantages of various drying methods.

| Drying method | Advantage | Disadvantage |
|---|---|---|
| Hot air drying | Wide application range, simple and easy to operate | Low efficiency, long drying time |
| Drum drying | Material and hot surface in direct contact, no medium | Uneven drying, not easy to control, product quality is not high |
| Freeze drying | It can keep the original composition of the soil from being destroyed | High energy consumption, high cost, low drying rate |
| Infrared drying | High drying efficiency and uniform absorption | It kills microorganisms in the soil and consumes a lot of energy |
| Microwave drying | High drying efficiency and uniform heating | High equipment cost |

### 3.3. Adsorption module design

The function of the adsorption module is mainly to map the residual broken film in the soil. Since the degree of soil breakage in the crushing module is low, it is not conducive to the occurrence of electrostatic adsorption. Therefore, before electrostatic adsorption, this paper sets a secondary crushing structure and realizes the secondary crushing of soil through the roller structure.

The roller structure is mainly composed of fixed roller and transport roller, and the main motor provides power for the roller structure. Among them, the fixed roller is supported on the bearing, the total motor drives the fixed roller to rotate, and the fixed roller is driven by the cone teeth meshing between the two rollers, so that the two rollers rotate in the opposite direction at the same speed, and the roller is set at both ends of the heart-shaped sheet to seal the roller and prevent the soil from being discharged from the gap of the roller under the action of high pressure. When the dried soil moves to the end of the conveyor belt, the soil falls into the roller structure under the

action of gravity, and under the action of the shear force of the two rollers, the dry soil is broken into fine soil. Since the broken film is soft and only 0.0008mm thick, the broken film will not be broken and will remain in its existing state. In the process of soil secondary crushing, the mixture of broken film and dry soil is crushed, at this time the large pieces of soil fall off into small pieces, the broken film from the original wrapped state into a bare state, and then separated from the soil, providing the necessary conditions for the electrostatic adsorption device.

The electrostatic adsorption device is composed of an electrostatic generator and an electrostatic plate to adsorb the broken film in the soil. Due to the large mass density of the soil, the electrostatic force generated under the electrostatic induction is difficult to overcome its own gravity, so the electrostatic plate is difficult to adsorb the soil, so that the soil and the broken film can be effectively separated. The clods separated from the broken film will move forward with the conveyor belt and finally return to the soil.

## 4. Conclusions

Through the analysis of various agricultural plastic film cleaning devices, it is found that the existing plastic film recycling devices are mostly used to collect complete plastic film, and it is difficult to complete the cleaning of broken film and deep residual film. To solve this problem, in order to reduce the soil pollution caused by broken film and residual film and to deeply clean up the white pollution in soil, this paper optimized the existing plastic film cleaning device, determined the technical route of broken film removal by crushing and drying first, and electrostatic adsorption after drying and secondary crushing, and designed a cleaning device capable of handling residual broken film in the soil depth of 10-30cm. It has the advantages of simple structure, low cost and high working efficiency, and provides ideas for the optimization and upgrading of the deep broken film cleaning device in the future.

## References

*[1] Dandan H , Dongxing Z , Li Y ,et al.Optimization and Experiment of Inside-filling Air-blowing Seed Metering Device Based on EDEM-CFD[J].Transactions of the Chinese Society for Agricultural Machinery, 2017.DOI: 10.6041/j.issn. 1000-1298.2017.11.006.*

*[2] Wang Zhichao. Effect of agricultural film residue on soil water transport and simulation study [D]. Inner Mongolia Agricultural University, 2017.*

*[3] Wang Fuyi. Development of potato residue mulch recovery device [J]. Agricultural Science & Technology & Equipment, 2013(4):35-36. (in Chinese) DOI:10.3969/j.issn.1674-1161.2013.04.017.*

*[4] Xue Yinghao, Li Jianhua, Feng Haojie, Zhou Tao, Jin Tuo, Xu Zhiyu. Practice and prospect of extended producer responsibility system for pollution control of agricultural mulch film in China [J/OL]. Agricultural resources and Regionalization in China: 1-10[2022-07-20].*

*[5] Borovska T, Shulgan I .Optimization of agricultural enterprises based on the methodology of optimal aggregation [J]. IEEE, 2015.DOI:10.1109/STC-CSIT.2015.7325466.*

*[6] Xu Gang, Du Xiaoming, Cao Yunzhe, et al. Study on residual levels and morphological characteristics of agricultural mulch in typical areas [J]. Journal of AgroEnvironmental Sciences, 2005, 24(1):79-83. (in Chinese) DOI:10.3321/j.issn:1672-2043.2005.01.018.*