Research Status and Prospect of Residual Plastic Film Pickup Mechanism in China

Yaxin Zhang¹, Jiahua Zhang², Shaohua Li³, Yumei Zhang¹, Hang Li¹

¹ Departments of College of Physical and Intelligent Manufacturing Engineering, University of Chifeng, Chifeng, 024000, Inner Mongolia, China
² School Enterprise Cooperation Division, University of Chifeng, Chifeng, 024000, Inner Mongolia, China
³ Departments of Inner Mongolia Changming Machinery Co., Ltd., Chifeng, 024000, Inner Mongolia, China

Corresponding author. Email: 2017291508@stu.sicnu.edu.cn

Abstract. Plastic film mulching technology not only improves the yield, but also brings white pollution. In order to solve the problem of residual film recovery, a large number of plastic film collecting machines have been designed in China. The film picking mechanism is the key part of the residual film recovery machine. Its mechanism form and operation quality play an important role in improving the recovery rate of the residual film. This paper analyzes the development status of the film collecting mechanism of the residual film recycling machine at home and abroad, briefly introduces the structure and working principle of seven kinds of residual film collecting mechanisms, including Winding type, telescopic rod type, elastic tooth type, gear teeth type, drum type and pneumatic type. This study provides relevant suggestions for the optimization and improvement of the film collecting mechanism in the future.

1. Introduction

With the wide use of Film-mulching technique, the problem of "white pollution" caused by residual plastic film is becoming more and more serious. The use of mulch film in China accounts for more than ninety percent of the world's total, but the recovery rate of residual plastic film is less than sixty percent[1]. A large number of residual plastic film in cultivated soil blocks the flow of water and fertilizer at the roots of crops, worsens the soil structure, and affects seed germination and root growth[2]. The residual plastic film is easy to mix into the feed, and making a large number of livestock sick or dead due to eating by mistake. Not only that, the residual plastic film also has a great impact on the use of farming machines and tools. On the one hand, the residual film hinders the move of agricultural machinery, result in the increase of power consumption of agricultural machinery. On the other hand, the residual film is easy to wrap on the parts of the field operation machinery, which makes the agricultural machinery frequently stop for cleaning. These effects greatly reduce the operating efficiency of agricultural machinery[3].

European and American countries began to use mulch to plant crops first, and also recognized the problem of residual film pollution first. In order to protect their agricultural ecological environment, countries are actively exploring the solution of residual film recovery, in which the use of mechanical equipment for residual film recovery is the most ideal method, and have designed a variety of types of residual film recovery machines. The thickness of plastic film used in developed countries is generally
0.02 to 0.08 mm, and the anti-aging agent is added in the plastic film. The tensile strength of the plastic film is large, and it is easy to recycle[4]. Therefore, the structure of the residual film pickup machine in Europe and America is simple and the pick-up rate is high. In China, the film used in a wide range is thin film with thickness of 0.008-0.01 mm. The thin film is easy to be aged and broken, and its tensile strength is low. Therefore, the foreign residual film picker is not suitable for China's agricultural requirements. Chinese agricultural machinery researchers need to start from scratch to develop a residual film pickup machine suitable for China's national conditions[5-6].

2. Typical pickup mechanism

There are more than 160 kinds of residual film pickers designed in China. These residual film pickers are divided into self-propelled type and traction type according to the traction mode; they are divided into seedling recovery, autumn recovery and land preparation recovery before sowing according to the operation season. The residual film pickup is composed of pickup device, separation device, recovery box device and auxiliary device. The pickup device is the core part of the residual film pickup. At present, the commonly used pickup devices in China are Winding type, telescopic rod type, elastic tooth type, gear teeth type, drum type and pneumatic type.

2.1. Winding type residual film pickup mechanism

The winding type residual film pickup mechanism collects the residual film by winding the roll, which is mainly composed of roll, frame, arc-shaped film guide plate, film shovel, traction device and supporting wheel, as shown in Figure 1.

![Figure 1 Winding type residual film pickup mechanism](image)

1.roll, 2.frame, 3.arc-shaped film guide plate, 4.film shovel, 5.traction device, 6.supporting wheel

The winding type residual film pickup mechanism has the advantages of simple structure and low cost, but it can only be used in the situation where the film is well preserved and the thickness is up to 0.01 mm. In the initial stage and midway of picking up film, the winding type residual film pickup needs manual participation, which greatly reduces the picking efficiency and increases the labor cost. Therefore, the promotion scope of the winding type plastic film pickup machine in China is only limited to a few areas such as Xinjiang.

After 2013, Xinjiang began to vigorously promote the standard mulching film of 0.01 mm or more. The thickening of plastic film brings opportunities to the R & D of winding type film collector, and the typical one is the winding type residual film pickup mechanism designed by Shihezi University. The machine adopts the principle of double roll extrusion, changing the traditional way of collecting residual film, such as wrapping film and binding film, into uncovering and rolling film, so as to ensure the stability and continuity of the machine working process. The test shows that the picking up rate of residual film is as high as 96.8%, which has a significant effect on the protection of soil environment.
2.2. The telescopic rod type film pickup mechanism

The telescopic rod type film pickup mechanism is composed of a drum, a telescopic pickup rod, a guide groove, a rolling bearing and a mandrel. Its core components are shown in Fig. 2. The inner lower side of the drum is installed with a mandrel, and the outer wall of the drum is provided with a guide groove; one side of the telescopic pickup rod is welded on the outer side of the rolling bearing, and the rolling bearing is installed on the mandrel; the other side of the telescopic pickup rod extends through the guide groove to the outside of the drum. When in use, the telescopic pickup rod cooperates with the roller and the spindle; when the telescopic pickup rod teeth are under the drum, it extends the longest to pick up the residual film. When the telescopic pickup rod teeth are located above the drum, the rod teeth extend the shortest, leaving the lifted residual film above the drum to realize the separation of residual film and telescopic pickup rod teeth.

![Figure 2 Schematic diagram of telescopic rod type film pickup mechanism](image)

1.Drum  2. Telescopic pickup rod  3.Guide groove  4.Rolling bearing   5.Mandrel

The retraction rod tooth type residual film recovery mechanism is mostly used in the recovery after autumn because of the strength of the telescopic rod is higher than that of other types of residual film pickup teeth. The application of telescopic rod type plastic film pickup machine is mainly concentrated in Xinjiang, Inner Mongolia, Gansu, Shanxi and other northern provinces. The typical ones are the 4JSM type pickup machine developed by Xinjiang Agricultural Mechanization Institute and the 1FMG-850 type plastic film recycling machine developed by Gansu Agricultural Machinery Extension Station. But in practical use, due to the adhesion and electrostatic effect, when the rod teeth retract into the cylinder, it is easy to take the residual film into the drum.

2.3. The elastic tooth residual film picking up mechanism

The elastic tooth residual film picking up mechanism is the simplest and most common small residual film collecting mechanism, which is widely used in northern mountainous and hilly areas. According to the structure, the spring tooth residual film picking up mechanism is divided into single row, double row and multi row. The three row elastic tooth picking up mechanism is composed of frame, traction hanger, short elastic tooth row, medium length elastic tooth row and long elastic tooth row. The traction hanger is installed on the upper side of the frame; the short elastic tooth row is installed at the front of the lower side of the frame; the medium length elastic tooth row is installed in the middle of the lower side of the frame; and the long elastic tooth row is installed at the rear of the lower side of the frame.
The three row elastic tooth picking up mechanism has the advantages of simple structure, low cost and low failure rate, which can effectively solve the problems of blockage and hip building-up. The recovery rate of residual film on flat land is high, but the phenomenon of film leakage and jumping will appear in uneven farmland. Manual participation is needed to unload the film, which has poor continuous performance and low efficiency.

2.4. Gear teeth type residual film pickup machine

The gear teeth type residual film pickup machine is composed of shell device, residual film pickup roller mechanism and flexible film stripping roller mechanism. The residual film pickup roller mechanism is installed at the front of the inner side of the shell device, and the flexible film stripping roller mechanism is installed at the rear of the residual film pickup roller mechanism mechanism. Its structure is shown in Fig. 4

The gear type film pickup mechanism has the advantages of simple structure, strong continuous picking up ability and automatic film unloading ability. The disadvantage of the pickup machine is that it is easy to mix Platycodon grandiflorum and broken soil blocks in the process of film collection, and it is difficult to pick up the fine residual film, and it is difficult to determine the ratio between the rotation speed of the pickup roller and the traveling speed of the tractor, and the phenomenon of film tearing often occurs.
2.5. *drum type film pickup mechanism*

The drum type residual film pickup mechanism is also called spade type residual film pickup mechanism. It is composed of squirrel cage type roller and residual film shovel, as shown in Fig. 5. The residual film shovel rotates with the roller and shovels the residual film and soil block from the ground. The mixture of residual film and soil block enters into the squirrel cage roller under the action of inertia. Under the action of the squirrel cage roller, the residual film is discharged from the rear of the squirrel cage drum, and the soil blocks fall from the gap of the side wall of the squirrel cage roller.

![Figure 5](image_url)

1. squirrel cage type roller 2. residual film shovel

Figure 5 Structure diagram of drum type residual film pickup mechanism

Drum type residual film pickup mechanism has the advantages of reliable operation, simple structure, low failure rate, high pick-up rate and wide popularization range. But the work resistance is huge, the energy consumption is high, the need for high-power agricultural machinery to drive, for the clay soil pickup separation effect is poor, noise, smoke and dust.

2.6. *pneumatic type residual film pickup mechanism*

The pneumatic type residual film pickup mechanism is composed of suction fan, semi closed film collecting shell and fixed rake teeth. The suction fan is installed on the upper part of the semi closed film collecting shell; the lower part of the semi closed film collecting shell is opened; a row of fixed rake teeth are installed in the front of the semi closed film collecting shell.

![Figure 6](image_url)

1. suction fan 2. semi closed film collecting shell 3. fixed rake teeth.

Figure 6 Structure diagram of the pneumatic type residual film pickup mechanism

The pneumatic type residual film pickup mechanism is simple, and it is easy to pick up Platycodon grandiflorum pieces or grass stalks, and it has a wide range of applications. It can not only be used as
the picking up mechanism of farmland residual film, but also can be used for collecting residual film at the edge of cultivated land, roadside, and bush.

3. Prospect

1) The sensor technology and hydraulic pneumatic technology are used to improve the mechanical automation of the film pickup mechanism. The research and development of the compound operation type residual film pickup machine can reduce the number of times of the machine entering the field and damage to the crop and soil structure and reduce the operation cost, so as to improve the economic benefits of the residual film recovery machine, and also conducive to the popularization and promotion of the residual film pickup machine.

2) According to different ground conditions, different principles of residual film pickup are designed. Most of the residual film collectors have good recovery effect for the residual film with good integrity and large piece, but the recovery effect for small residual film is poor. Therefore, the design of film picking mechanism for small pieces of broken film can effectively reduce the power loss and increase the picking up rate of residual film.

3) The pattern recognition technology is used to distinguish the residual film from the debris of Platycodon grandiflorum or weeds, and pick up different mulching films. The use of pattern recognition technology can increase the collection efficiency of residual film and reduce the separation process of residual film and impurities.

4) Aiming at the residual film on low shrubs or branches, a new method was adopted to pick up the residual film on different spatial dimensions, and the picking direction was adjusted from multiple angles.

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