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Design and Test of a New Film Processing Machinery

[1]Xiangying Meng, [1]Xufeng Wang, [1]Can Hu, [1] Jianyun Jiang and [2]Fengchen Han
[1]School of Mechanical and Electrical Engineering,
Tarim University, Alar, Xinjiang, 843300, China
[2]Agricultural Machinery Manufacturing Co, Ltd., Alar, Xinjiang, 843300, China

Abstract: The influence of sand damage on cotton plantation in southern Xinjiang of China becomes severe. In order to provide prevention and cure to the damage on the film, a stiffener film is developed and a stiffener film machine is designed based on the mechanical dynamics principle. The design is reasonable and the structure is simple. The processing experiment shows that the machine works reliably, the working efficiency is high, the film deformation is small and no damage. While field experiment indicates that mulch sowing is in normal, no anti-wind device on surface of the film, lighting surface increased, the recoveries for film is more than 97%.

Key words: Stiffener film, processing machinery, design, field experiment

INTRODUCTION

Agriculture areas which situate in Taklimakan Desert margin in southern Xinjiang of China affected severely by the sandstorms in spring season. The film is used to resist invasion and improve temperature and water. However, the strength of film in China is low and the damage becomes severe when the windstorms come. Mulch sowing is repeated and the cost increases. Mulch sowing in Xinjiang is widespread and the problem of plastic film collecting gets worse because of film bonds with soil. The rate of edge film collecting is less 8%. A lot of plastic film—polyethylene materials called 'white pollution' retain in the soil and affects crops growth at depth of 20cm. The problem of film collecting has restricted the development of modern agriculture (Wang *et al*., 2011, 2012a). The measure of wind breaks which could prevent the damage of windstorms increases labor and decreases lighting surface. A portion of the increase of labor was used to uncover and pick up the residue film that unable to be thoroughly removed (Zhang *et al*., 2007, 2008; Wang *et al*., 2008; Yang, 2000).

To settle the problems mentioned above, a new type of stiffened plastic film, of which the tensile strength strengthened to withstand wind damage, was developed. In most cases, this kind of film was free of wind damage even when during the time of residual film recovery owing to the help of stiffener rib, thus windproof partitions were not needed any more if it was used, correspondingly prevented the loss of lighting surface of mulch film. The stiffener rib should be extendable, sticky and strong enough. Also, specific processing machinery was designed for mass producing that described detail in this study which was testified by field experiment very suitable to the requirement of cotton production (Zhang *et al*., 2007, 2008; Wang *et al*., 2008; Yang, 2000).

DESIGN OF STIFFENED FILM

Stiffened film is not a new kind of plastic film but a sort of strengthened film by stiffener ribs on across the surface of ordinary film. This kind of stiffened film has at least two advantages: One is that it can prevent windstorms damaging, the other is that it is convenient to recover. The stiffener ribs are made by heating and evenly smearing PSA emulsion onto the surface of scotch tape that out of material of the Bopp (Biaxial Oriented Polypropylene) (Kim and Reid, 2001; Ciark *et al*., 2006). which are about 0.012 mm thickness and 10mm width with the advantage of strong adhesion, high pasting speed and low loss.

To adapt the planting pattern in Xinjiang where has mainly three type of planting pattern: 760 mm row spacing, (680+80)×100mm row spacing and (660+100) ×100mm row spacing, the stiffener ribs are placed on both sides of the seed row according to the planting pattern in adoption. Figure 1 shows the pattern of (660+100) ×100 mm film mulching mode (Chen *et al*., 2008).

Corresponding Author: Xufeng Wang, School of Mechanical and Electrical Engineering, Tarim University, Alar, Xinjiang, 843300, China

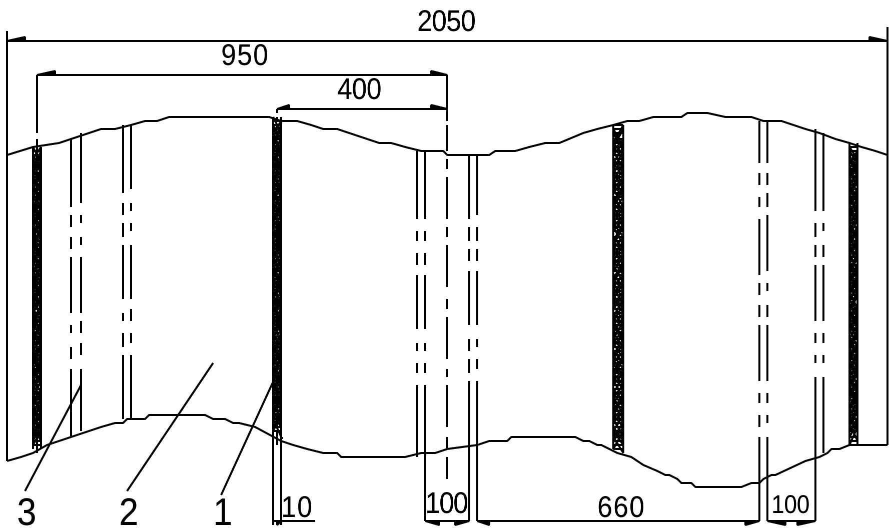

Fig. 1: Schematic diagram of stiffener film, 1: Stiffener ribs, 2: Ordinary film and 3: Row spacing

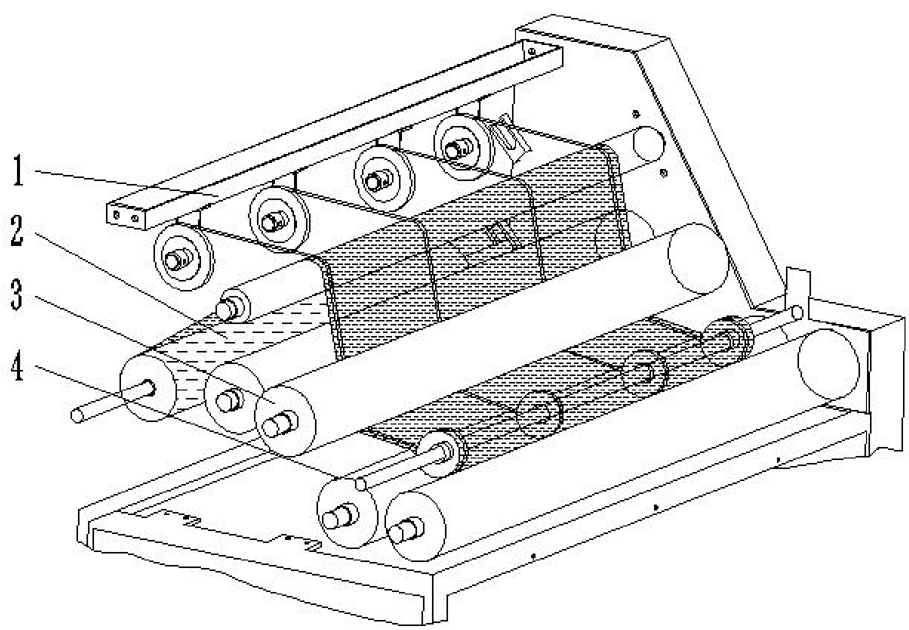

Fig. 2: Schematic diagram of whole processing machinery structure for manufacturing stiffener film, 1: Suspension of stiffener ribs 2: Ordinary film 3: Film spreading device 4: Film rolling device

OVERALL STRUCTURE AND WORKING PRINCIPLE OF STIFFENED FILM PROCESSING MACHINERY

Overall structure: The overall structure of stiffened film processing machinery is designed as in Fig. 2 (Ma *et al*., 1997). Which mainly composes of framework, transmission system, stiffener rib suspension, film spreading device and film rolling device.

Working principle: Figure 3 is the working principle diagram of stiffened film processing machinery. The processing is that the ordinary film will be carried through the top of roller 3; the stiffener ribs fastened to the hitch

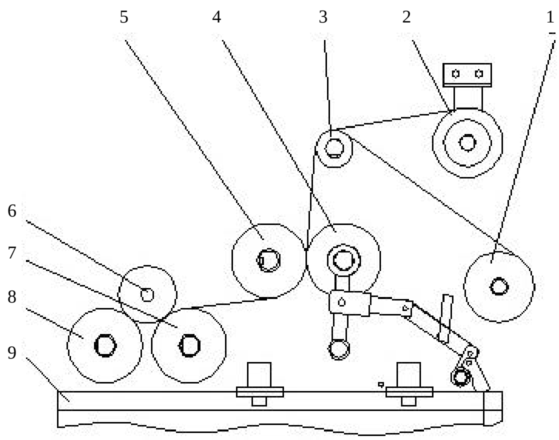

Fig. 3: Working principle diagram of the machinery for stiffener film, 1: Ordinary film 2: Stiffener ribs 3: Roller 4: Driven roller 5: Active roller 6: Eccentric shaft 7: Active roller of film spreading device I 8: Active roller of film spreading device II 9: Frame

device 2 will be pulled out and adhered to the right place 3 on the upper surface of the ordinary film in the light of design. But now the adhesion of stiffener ribs to the film is not strong enough. To make them stick firm, we let the film and stiffener ribs together pass through the active roller 4 and rubber driven roller 5 of the spreading device. Then the stiffened film will be delivered to rolling device 7 and 8 to be rolled up. At last, the stiffened film will be rolled up on the eccentric shaft 6.

MAJOR COMPONENT DESIGNS

Suspension device: The suspension device is composed of frame, crossbeam and suspension shelf as shown in Fig. 4. The suspension shelf is fastened to the crossbeam by bolt. And there is a axial shifting groove on the crossbeam which can be adjusted according to the planting pattern. The positions of the stiffener ribs are symmetrically adjusted to the both sides of the crossbeam center.

Film spreading device: The film spreading device, as shown in Fig. 5, is composed of frame 1, rubber roller 2, active roller 3 and adjustment device 4. The active roller drives the ordinary film in motion by the friction which is ensured by the close contact of the rubber roller with them, with the film being got in close touch with the active roller and firmly being adhered with the stiffener ribs. Also, the tensile deformation along the width direction caused by tearing effect when stick the film with stiffener ribs, will be effectively suppressed by the spreading device.

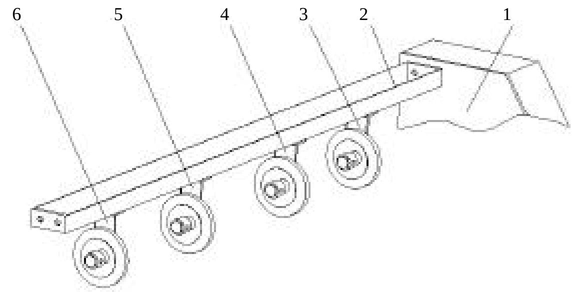

Fig. 4: Structure diagram of suspension device for the stiffener film, 1: Frame, 2: Crossbeam, 3: Suspension I, 4: Suspension II, 5: Suspension III and 6: Suspension IV

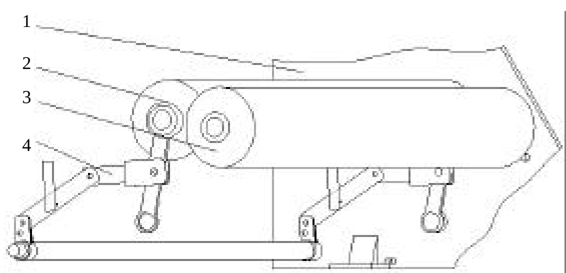

Fig. 5: Structure diagram of device for spreading film, 1: Frame, 2: Rubber roller, 3: Active roller, 4: Adjustment device

The structure of film spreading device can be simplified as in Fig. 6: Driving link a, two force member b, support c and roller Y (Wang *et al*., 2012b). The total compressive stress of the roller on the film can be expressed as $F = F_1 + F_2$, where:

$$F_1 = \frac{m \times d \times kx \times \cos(\alpha) \times \cos(\gamma)}{a \times c \times \cos(\beta) \times \cos(\delta)},\ F_2 = \frac{G(e - 2R)}{f}$$

$$\cos\alpha = \frac{\sqrt{4(a-m)^2(kx+z)^2 - \left[(a-m)^2 + (kx+z)^2 - s^2\right]^2}}{2(a-m)(kx+z)} \quad \cos\beta = \frac{i}{a}$$

$$\cos\gamma = \frac{\sqrt{4d^2n^2 - d^4 - n^2 + 2b^2d^2 - b^4}}{2bd}$$

$$\cos\delta = \frac{f}{\sqrt{f^2 + e^2 + 4R^2 - 4eR}}$$

Where:

- **k:** Spring constant
- **G:** Gravitational force of the rubber roller, N

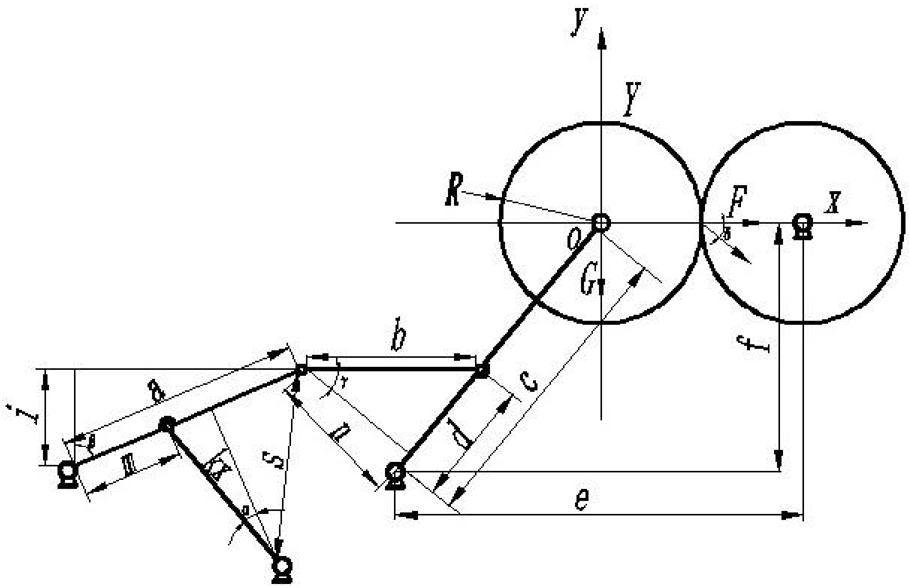

Fig. 6: Working principle diagram of spread film device

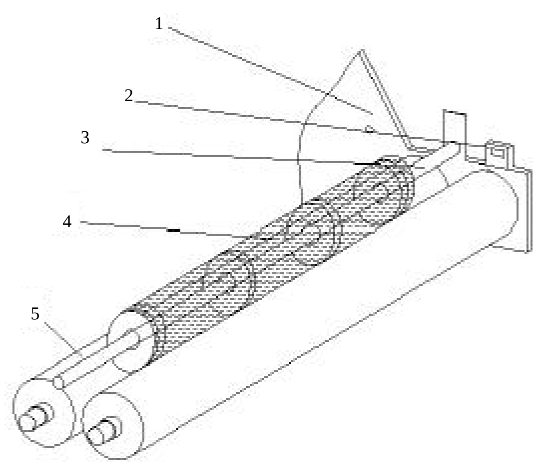

Fig. 7: Schematic diagram of film roller, 1: Frame, 2: Meters, 3: Eccentic shafts, 4: Stiffened films and 5: Roller

- **z:** Original length of the spring, mm
- **F_1:** Compressive stress of the roller on the film, N
- **F_2:** Compressive stress of G on the film, N
- **R:** Radius of rubber roller, mm
- **a, b, c, d, m:** Member length, mm
- **e, f, i, s:** Distances shown in the figure, mm

Film rolling device: The film rolling device, as shown in Fig. 7, is composed of frame 1, Meters 2, eccentric shaft 3 and rollers 5. The speed of the two rollers can be adjusted in the range of 0.1- 0.5 m sec^{-1}. The two rollers are driven by electric motors with the same speed and direction. To prevent tearing the film, the eccentric shaft on between the top of the rollers will roll with the same line speed with the rollers because of the friction which can be adjusted according to the increasing radius of stiffener film (Cheng and Wu, 1998; Chi and Kuxhwaha, 2001).

EXPERIMENTS

Method: The production rate of the processing machinery is tested when using it to produce films. Figure 8 is the processing live of stiffener film. The test speed of the processing machinery is set at 0.4 m sec^{-1}. The thickness of films without stiffener ribs, produced by our machinery, is 0.008 mm. To test the distortion and contraction of the stiffened films processed by our processing machinery, we randomly take twenty five samples from both the ordinary films and stiffener films respectively for the comparisons. Also the production costs are interested in this test.

Result and analyses

Production rate: We can see the data in Table 1 based on our tests that the auxiliary operations, such as replacing tapes and processed film rolls, will mainly affect the production rate. The overall production rate is 1126.6 m h^{-1} while the pure production rate is 1877.8 m h^{-1} which is decreased about 40%. So, in the

Fig. 8: Processing live of the stiffener film

Table 1: Processing productivity of the stiffener film

Groups	Pure productivity (m h^{-1})	Overall productivity (m h^{-1})	(Pure P- Overall P) P %/ Pure
First	1875.0	1125.0	40.00
Second	1866.0	1120.0	39.97
Third	1898.0	1138.0	40.00
Firth	1870.0	1115.0	40.37
Fifth	1880.0	1135.0	39.62
Mean	1877.8	1126.6	39.99

Table 2: Result analysis of deformation in the stiffener film

Test groups	Mean pre-processed width (mm)	Mean processed width (mm)	Contraction (mm)	Percentage of Contraction
1	2016.0	2006.0	10.0	0.496
2	2017.0	2008.0	9.0	0.446
3	2019.0	2009.0	10.0	0.495
4	2017.0	2006.0	11.0	0.545
5	2017.0	2005.0	12.0	0.594
Mean	2017.2	2006.8	10.4	0.515

light of analyses above, reducing the time used in the auxiliary operations is the key means to improve the processing productivity.

Contraction and distortion: The contractions and distortions caused by tearing when in processing are displayed in Table 2. The mean widths of pre-processed and processed films are, respectively 2017.2 and 2006.8 mm. The mean percentage of contraction is 0.515% which is so trivial that will not affect seeding and planting.

Cost comparison: The cost of processing stiffened films will increase 20% (2.5 yuan kg^{-1}), including the cost of stiffener ribs (about 1.8 yuan kg^{-1}) and mechanical processing (0.7 yuan kg^{-1}), with the ordinary film of which the cost is12.5 yuan kg^{-1} by our tests. This growth rate of cost is still acceptable considering the benefits that will be brought by it.

CONCLUSION

- The structure of this processing machinery is tested to be reasonable, simple and applicable to the requirements of processing stiffened films by entity simulation and prototype manufacturing and actual processing
- This processing machinery is reliable, efficient and easy to operate through our tests
- The contraction of the stiffened film processed by our machinery is small and free from the seeding and planting
- The increase of the cost is economically acceptable. Although the cost of processing film increases, the total planting cost decrease

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