Study on the tensile Mechanical Properties of Residual Film in Non Ridge Direction

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Abstract. Aiming at the issue of the bottleneck in enhancing the picking rate, a methodology is devised to boost the retrieval rate of mechanical residual film collectors, leveraging the mechanical property traits of the working target. The 0.01 mm thick plastic film prevalently utilized in the semi-arid regions of Northeast China was chosen as the specimen for investigation. Specialized testing modalities were employed to conduct a comprehensive and detailed examination of the mechanical attributes of the residual film across diverse orientations. In the course of the experiment, it was ascertained that the mechanical characteristics of the film were conspicuously influenced by the pre-tension during sowing processes. Notably, the residual film attains its peak tensile strength at an angle of around 40.6 ° relative to the ridge direction. This crucial datum forms the central foundation for augmenting the picking rate of residual film pickers and can serve as a guideline for the design, structural refinement, and operational parameter optimization of such apparatus.

Keywords: Agricultural Engineering; Residual film tensile strength; Tensile strength coefficient; Non monopolistic direction

1 Introduction

The mechanical attributes of residual film are of vital significance in residual film collection activities and exert a non-negligible influence on the retrieval rate of residual film collectors. In the practical process of residual film retrieval, it was discovered through in-depth probing that there are substantial disparities in the mechanical characteristics manifested by residual films in different directions. Additionally, as time elapses, the mechanical properties of residual film will experience remarkable alterations. Among them, the mechanical features chiefly affecting residual film collection work are mainly manifested in tensile and tearing properties [1-2].

During the utilization of plastic film, a multitude of small cracks will gradually emerge, and the orientation of these cracks is highly random. When the residual film is torn, its tearing direction frequently follows the path of crack propagation. Based on this feature, from a statistical viewpoint, the tearing performance of residual film does not have a pronounced impact on the picking rate of residual film, which has been corroborated by relevant research literature [3-5]. Conversely, the tensile performance of the residual film becomes the central mechanical property factor influencing the residual film picking rate. Further research has indicated that the tensile properties of plastic films are restricted by elements such as the angle between the picking direction and the residual film laying direction, as well as the laying duration.

In light of this, an in-depth exploration of the mechanical properties of spineless residual films is undeniably of paramount value and significance for enhancing the residual film pickup rate. The associated research findings will furnish a robust and dependable theoretical underpinning for the innovation of design philosophies, the optimization and refinement of structural arrangements, and the scientific and rational configuration of operational parameters for residual film pickers. This will actively propel the advancement of residual film recycling technology and make a substantial contribution to safeguarding the agricultural ecological milieu.

1.1 Sample Production

According to the plastic film standard (GB13735-1992 "Polyethylene Blown Plastic Agricultural Ground Cover Film")26, a 0.01mm thick plastic film widely used in the central and eastern parts of Inner Mongolia was selected for testing. Make tensile specimens and mark them, ensuring that there are no visible damages on the surface and smooth edges without burrs. The standard dimensions of A-type transverse and longitudinal tensile specimens are shown in Figure 1. The longitudinal and transverse specimens are taken with a width of 20mm and a length of 150mm, and the distance between the two marked lines in the middle part of the clamp is 100mm.

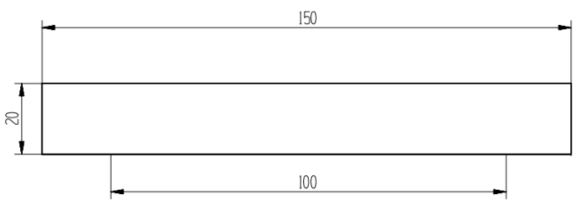


Fig. 1. A-type transverse and longitudinal tensile specimen.

1.2 Sampler Design

In accordance with the plastic film standard (GB13735 - 1992 "Polyethylene Blown Plastic Agricultural Ground Cover Film"), a 0.01 mm thick plastic film commonly employed in the central and eastern regions of Inner Mongolia was chosen for testing. Tensile specimens were fabricated and labeled, with the surface being free from visible defects and the edges being smooth without burrs. The standard dimensions of A - type transverse and longitudinal tensile specimens are illustrated in Figure 2. The longitudinal and transverse specimens were obtained with a width of 20 mm and a length of 150 mm, and the distance between the two marked lines in the central part of the clamp was set at 100 mm.

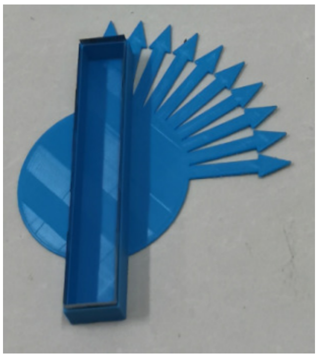


Fig. 2. Residual plastic film sampler with inclination direction.

1.3 Test Piece Clamping

The mechanical stretching apparatus selected is the JHY - 5000 single - arm mechanical testing machine manufactured by Xiamen Jinheyuan Technology Co., Ltd. During the experiment, in order to guarantee that the residual film specimen is free from torsion and has a flat surface when clamped, a pair of origami strips are inserted between the sample and the fixture, as depicted in Figure 3. The stretching clamp secures the origami, and the origami immobilizes the residual film via friction.

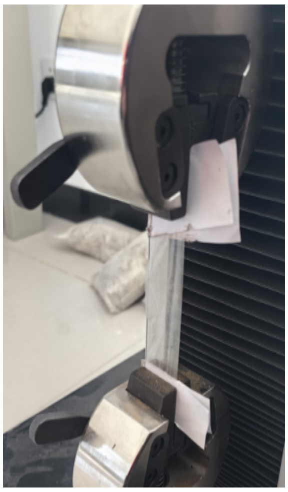


Fig. 3. Clamping method of residual plastic film tensile specimens.

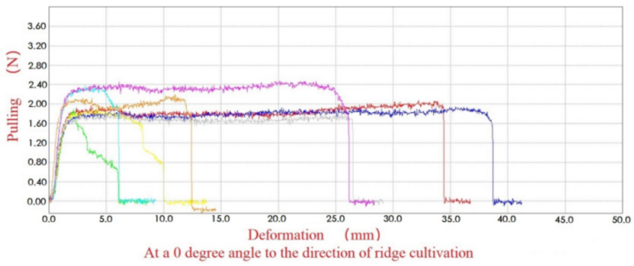
2 Mechanical Testing of Residual Film under Different Directions of Tension

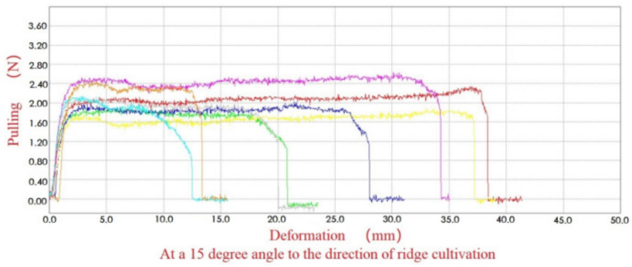
2.1 Materials and Methods

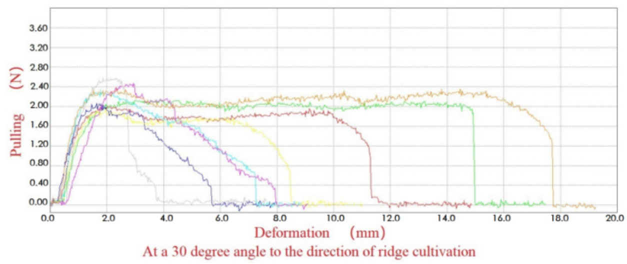
The experimental field is situated in Yikenzhong Township, Ningcheng County, Chifeng City, which represents a typical semi-arid agricultural region in Northeast China. Seven levels of data are selected at angles of 0 °, 15 °, 30 °, 45 °, 60 °, 75 °, and 90 ° relative to the ridge planting direction. Eight samples are chosen for each level for testing, and the average tensile strength and elongation of the samples are computed based on each set of valid data.

2.2 Results

The tensile mechanical properties of residual plastic film at various angles from the ridge planting direction are presented in Figure 4.







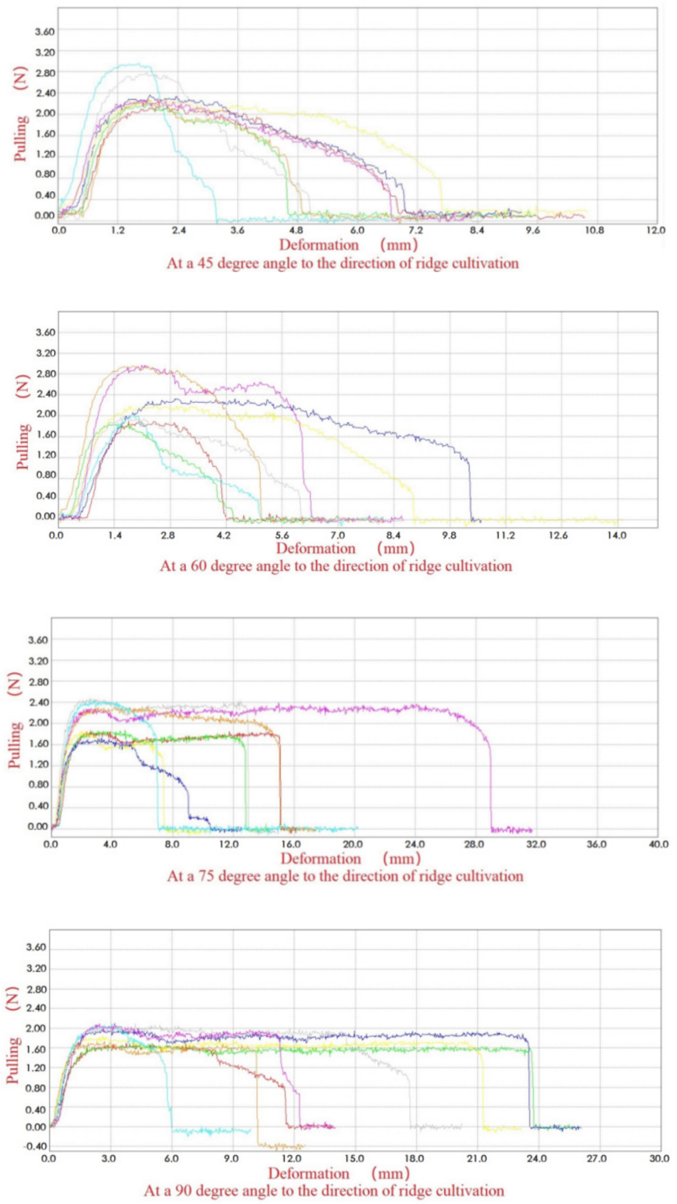


Fig. 4. Tensile curves of residual plastic film in different directions.

The tensile strength and elongation rate of residual plastic film at different angles with respect to the ridge direction are shown in Tables 1 and 2.

Table 1. Tensile strength of residual plastic film at different angles to ridge direction.

Angle with ridge planting direction	Tensile strength (MPa)								Average (MPa)
0	10.	9.4	9.7	9.6	9	11.	12.	11	10.425
15	11.	9.4	10.	9.4	10.	10.	13.	12.	10.9125
30	10.	10.	10.	9.8	12.	11.	12.	11.	11.2
45	10.	11	11.	11.	13.	14.	11.	11.	12.0625
60	9.5	9.2	11.	11.	9.9	10.	14.	14.	11.375
75	9.3	9.4	8.6	9.3	12.	12.	12	11.	10.6
90	8.5	8.5	9.9	9.2	10.	10.	10.	8.6	9.5125

Table 2. Elongation rate of residual plastic film at different angles to ridge direction.

Angle with ridge planting direction	Elongation rate (%)								Average (%)
0	36.8	8.7	41.2	13.8	29.1	9.3	28.3	14.5	22.71
15	41.4	23.5	31.1	39	23.2	15.6	35	15.6	28.05
30	14.9	17.5	7.9	11	7.6	8.9	9.1	19.2	12.01
45	10.5	9.6	9.3	10.6	8.5	6.6	8.3	7.5	8.86
60	6.6	6.4	10.6	14.1	8.7	8.1	8.6	8.1	8.90
75	16.2	14.4	12.5	10.4	14.8	20.2	31.7	17.5	17.21
90	13.9	26	23.1	20.2	9.8	14.0	12.5	26.1	18.20

3 Statistical Analysis

Given the complex working conditions of plastic film coverage, the mechanical characteristics of residual plastic film possess a high degree of randomness. The tensile test results of 0.01 mm thick residual plastic film in the central and eastern parts of Inner Mongolia at different angles to the ridge planting direction were analyzed using Design Expert software, as illustrated in Table 3. The P - value of the non-ridge tensile strength of residual plastic film is 0.0366; the P - value of the ridge elongation test of residual plastic film is less than 0.0001, and a P - value less than 0.05 implies a significant statistical difference.

Table 3. Statistical analysis of tensile test results with different angles between residual plastic film and ridge planting direction.

Dependents	Sum of Squares	df	Mean Square	F-value	P-value	
Tensile strength	0.712	6	0.1187	2.47	0.0366	significan
Elongation rate	2492.76	6	415.46	7.71	<0.0001	significan

The relationship between the tensile strength of 0.01 mm thick residual plastic film and the angle of the ridge planting direction is depicted in Figure 5.

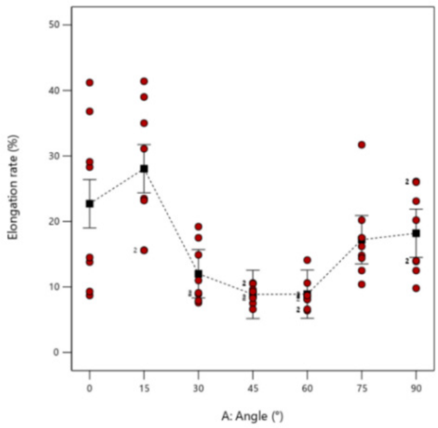


Fig. 5. The relationship between the elongation of residual film and the ridge angle.

The tensile strength of residual plastic film presents a tendency of initially rising and subsequently declining as the angle with the ridge planting direction augments. The tensile strength of the residual film either along the ridge planting direction or in the perpendicular direction to it is not at its peak. The maximal tensile strength of residual plastic film emerges in the direction approximately 45 ° relative to the ridge planting direction.

The correlation between the elongation and the angle formed by the ridge direction of a 0.01 mm thick residual plastic film is illustrated in Figure 5. Evidently, the elongation of the residual plastic film displays a U - shaped pattern as the angle enlarges, attaining its minimum value around 45 °. Further investigations have uncovered a negative association between the tensile strength and elongation of residual plastic film, i.e., the lower the elongation, the greater the tensile strength. It is remarkable that the maximum tensile strength and minimum elongation of residual plastic film do not occur at the position conventionally assumed to be in line with the ridge direction but at a 45 ° angle between the residual plastic film and the ridge direction, which challenges traditional perception.

4 Conclusion

In the central and eastern regions of Inner Mongolia, comprehensive tensile strength and elongation tests were carried out on 0.01 mm thick residual films which are commonly used. During the testing, detailed measurements were made at different angles relative to the ridge direction to deeply investigate the mechanical properties of the residual films. The direction of the maximum tensile strength of the residual film is not constant but is closely related to the stress the film endures during sowing. After numerous rigorous experiments, it was discovered that under specific experimental circumstances and conditions, the residual film had the highest tensile strength when the testing direction was at a 40.6 - degree angle to the ridge direction. This crucial data serves as an important foundation for the optimization design of the residual film picker. In the design process of the residual film picker, after comprehensive consideration and selection, the swing adjustment mechanism with a deviation of ± 15 ° from the ridge direction was ultimately chosen as the core picking mechanism. Thus, in practical application, operators can flexibly adjust the direction of the strong tensile strength of the residual film to ensure that the picking mechanism can better conform to the characteristics of the residual film, thereby remarkably enhancing the picking rate of the residual film, reducing farmland residual film pollution, and facilitating the sustainable development of agriculture.

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