

Research on the Design of a Residue Film Collection and Baling Machine Based on the Kano Model

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Abstract:

As people's quality of life continues to improve, the demands for the modeling, ergonomics, and functionality of agricultural machinery are increasing. This study utilizes the Kano model to achieve and improve industrial design in agricultural machinery, effectively exploring the application value of the model in this context. The connotations and need categories of the Kano model are discussed. By proposing design needs, identifying positive and negative design issues, distributing questionnaires, and analyzing the results, this study clarifies the Kano model categories, satisfaction and dissatisfaction levels, and influence of design needs for a residue film collection and baling machine. This provides a method for determining the relationships between agricultural machinery design needs. We conducted design research on a residue film collection and baling machine based on the results of design need analysis using the Kano model, considering creative, functional, structural, human-machine, and modeling design. The research results indicate that the Kano model is applicable to industrial design research in agricultural machinery and can improve the accuracy of user need analysis and the specificity of design solutions in product innovation design.

Keywords:

Kano Model, Residual Film Recycling, Agricultural Machinery, Industrial Design

1. Introduction

Most of northern China is arid and receives little rainfall, so agricultural plastic film is widely used in agriculture to cultivate crops and, in recent years, has become an important means of increasing agricultural production, with mulch cultivation being especially important in dry farming areas. With the increasing use of agricultural plastic film, residual film is accumulating in farmland annually. Dealing with waste agricultural plastic film in farmland has become a difficult problem that troubles many farmers. Improper disposal of agricultural plastic film can easily cause environmental problems such as white pollution, soil compaction, and soil

degradation, which in turn affect the normal growth of crops, leading to a decline in crop yields. In severe cases, it may promote crop disease.

It is imperative to address the issue of white pollution caused by the use of agricultural plastic film. Otherwise, it will cause serious environmental damage. At present, there are two main methods for recycling waste plastic mulch: manual and mechanical recycling. Manual recycling is inefficient, costly, and cannot be sustained over time. Mechanical recycling is currently the primary method for recycling residual film. Although mechanical recycling is highly efficient, it suffers from low collection rates, cumbersome equipment, and a significant impact of the farmland terrain. Yang [1] designed a farmland plastic film recycling machine with a simple and compact structure, easy to manufacture, and a high film removal rate to improve on the low rate in plastic film recycling. Ren et al. [2] optimized the design of the pickup device for a spring-tooth-type residual film recovery machine. They investigated the optimal working speed of the machine, the rotational speed of the residual film pickup roller, and the axial spacing of the spring teeth, providing technical support to improve the pickup rate for residual film on the surface of cotton fields after harvest. Wusman et al. [3] designed a telescopic nail-type residual film recovery machine, while Jiang et al. [4] developed a longitudinal nail tooth chain-type plastic film picking device to address the issues of low picking and high impurity rates in recycled plastic film caused by tears during the operation of plastic film picking devices. Jiang et al. [5] designed a scraper-type film removal device to improve the film recovery rates and operational efficiency. Furthermore, Zhang et al. [6] identified the primary and secondary factors affecting the evaluation indicators of the surface film collection rate, operational efficiency, operational reliability, collected film quality, and sales price of residual film collection machines, with the aim of helping users select the appropriate equipment. Wei et al. [7] designed an automatic hydraulic residual film recovery machine to deal with problems such as unloading difficulties in drum-type residual film recovery machines, and Chen et al. [8] designed an integrated residual film recovery machine to address issues such as the difficulty of separating entangled plastic film and the low recovery rate caused by residual film mixing with the soil during recovery operations, providing a reference for sowing and residual film recovery.

It can be seen that the existing residual film pickup machines tackle issues such as low residual film recovery and removal rates and high rates of debris in residual film. The studies on these machines have primarily considered structural design issues in agricultural machinery, with little research conducted on the human-machine comfort and esthetic design of residual film pickup machines. At the same time, there are few reports on the application of industrial design methods to existing residual film pickers, especially the innovative design of residual film pickers based on the Kano model. Previous research on agricultural equipment has mainly focused on the implementation of functional principles. However, as mechanization has gradually met the needs for agricultural modernization, people have begun to pay attention to products' appearance and human-machine efficiency. At this point, these have become the main factors influencing farmers' purchase decisions.

Some scholars conduct "human-machine" optimization design with products as their research objects, while others attempt to construct human-machine evaluation indicators for agricultural machinery equipment by focusing on its life cycle. Qiu et al. [9] conducted a systematic review using the PRISMA method, summarizing 107 research findings and in-depth studies on ergonomic design and evaluation. In

agricultural machinery and equipment, comfort is an important human-machine design factor and an important indicator for evaluating its overall performance. Currently, research on the comfort and ergonomics of agricultural machinery equipment still lags behind that on automobiles, aviation, and military equipment.

In addition, the existing research has paid little attention to the user experience in the design of agricultural machinery equipment. Most agricultural machinery equipment suffers from issues such as an unattractive appearance, strong mechanical feel, and heavy industrial style. Therefore, further research is needed on the functional innovation, structural optimization, styling design, and human-machine matching of film residue recycling machines.

2. Kano Model Theory

The Kano model was formally proposed in 1984 by Noriaki Kano, a Japanese quality expert and professor at the Tokyo Institute of Technology. It is used to describe the nonlinear relationship between product performance and user satisfaction [10]. Research has found that different types of product quality characteristics play an important role in user satisfaction. The core idea of the Kano model is that different types of needs have distinctly different and nonlinear effects on customer satisfaction, meaning that meeting the design needs for a certain dimension does not necessarily lead to an overall increase in satisfaction. The Kano model can help designers prioritize specific needs and allocate limited resources to areas that will most effectively improve customer satisfaction and loyalty.

Based on the relationship between product attributes and user satisfaction, the Kano model categorizes product attributes into five types: must-be, one-dimensional, attractive, indifferent, and reverse quality [11]. Must-be quality refers to the most basic functions and characteristics that users believe a product must have. When must-be quality is achieved, user satisfaction remains unchanged or improves slightly. However, when it is not achieved, satisfaction drops dramatically. One-dimensional quality refers to the needs clearly expressed by users, and satisfaction is positively correlated with the need satisfaction level. Attractive quality refers to needs that users themselves did not think of and cannot express. When attractive qualities are achieved, the satisfaction levels increase significantly. Conversely, when they are not achieved, the satisfaction levels do not decrease. Indifferent quality refers to a situation where needs are either met or not, or the level of provision is high or low, but this does not significantly affect user satisfaction. Reverse quality refers to a negative correlation between the needs met and user satisfaction.

This paper focuses on innovation design driven by user needs. The Kano model provides a typical method for identifying user needs and categorizing them appropriately. We introduce the Kano model into the attribute hierarchy of user needs, converting subjective needs into traceable scientific data.

3. Design Practice for Residual Film Collection and Baling Machine Based on Kano Model

3.1. Propose Design Needs

The design practice for a residue film collection and baling machine based on the Kano model includes four main stages: determining the design needs, designing positive and negative questions, questionnaire analysis, and design practice.

Through equipment research, design interviews, and product design and function analyses, 15 design needs for a residual film collection and baling machine were proposed. We classified these design needs into five categories—basic functions, innovative functions, appearance styling, human-machine design, and safety performance—and assigned them numbers, as shown in Table 1.

Table 1. Design needs for residual film collection and baling machine.

Need category	Need description	Number
Basic functions	Residual film collection	N1
	Separation of film and debris	N2
	Residual film collection and packaging	N3
	High collection rate	N4
Innovative functions	Dust-free operation	N5
	No film entanglement in the machine	N6
	Adaptable to terrain changes	N7
	Cooperative work	N8
Appearance styling	Impressive styling	N9
	Attractive color scheme	N10
	Feasible production process	N11
Human-machine design	Comfortable operation	N12
	Aligned with human operating habits	N13
Safety performance	Safety protection	N14
	Emergency stop protection	N15

3.2. Designing Positive and Negative Questions

The basic form of a Kano questionnaire consists of positive and negative questions, i.e., “how do you feel when a product has this feature” or “how do you feel when a product does not have this feature”. Each question is evaluated on a five-point scale, ranging from “must have” to “like”, “indifferent”, “tolerate”, and “dislike”, to test users' different responses, as shown in Table 2.

Table 2. Basic form of a Kano questionnaire.

Positive question	How do you feel when a product has this feature?				
	Must have	Like	Indifferent	Tolerate	Dislike
Negative question	How do you feel when a product does not have this feature?				
	Must have	Like	Indifferent	Tolerate	Dislike

The must-be, one-dimensional, attractive, indifferent, and reverse quality are represented by M, O, A, I, and R, respectively. A classification comparison table for the Kano questionnaire evaluation results is shown in Table 3. It consists of a matrix of positive and negative questions for each need, which is used to analyze users' perceptions of the residual film collection and baling machine.

Table 3. Classification comparison table for Kano questionnaire evaluation results.

Product quality		Negative question				
		Must have	Like	Indifferent	Tolerate	Dislike
Positive question	Must have	Q	A	A	A	O
	Like	R	I	I	I	M
	Indifferent	R	I	I	I	M
	Tolerate	R	I	I	I	M
	Dislike	R	R	R	R	Q

3.3. Questionnaire Analysis

In this study, we conducted a Kano questionnaire survey regarding a residual film collection and baling machine. The survey was administered online via the “Question Star” platform and offline using paper questionnaires. The surveyed users had a certain level of understanding of the residual film collection and baling machine. A total of 239 questionnaires were distributed for this survey, which lasted for six days. A total of 220 valid questionnaires were returned, with a return rate of 92.05%.

3.3.1. Statistical Analysis of Need Categories

We classified and summarized the collected questionnaire data according to the classification table for the Kano questionnaire evaluation results. The maximum value from each result category was taken as the Kano questionnaire survey result for that design need. We analyzed users’ categorization of different needs for the residual film collection and baling machine, as shown in Table 4.

Table 4. Kano questionnaire results for the residual film collection and baling machine.

Number	Need statistics						Need classification
	M	O	A	I	R	Q	
N1	127	2	43	48	0	0	M
N2	122	40	47	11	0	0	M
N3	3	123	38	56	0	0	O
N4	121	27	22	50	0	0	M
N5	1	182	4	33	0	0	O
N6	1	120	26	73	0	0	O
N7	3	47	2	168	0	0	I
N8	22	26	158	14	0	0	A
N9	44	39	121	16	0	0	A
N10	22	4	144	50	0	0	A
N11	58	4	144	14	0	0	A
N12	39	143	4	34	0	0	O
N13	22	26	159	13	0	0	A
N14	158	2	24	36	0	0	M
N15	4	58	23	135	0	0	I

Based on the results of the Kano questionnaire, a needs analysis was performed for the residual film collection and baling machine and conclusions were drawn.

The following features were categorized as must-be quality (M): residual film collection, separation of film and debris, safety protection, and high collection rate.

The following features were categorized as one-dimensional quality (O): residual film collection and packaging, dust-free operation, no film entanglement in the machine, and comfortable operation.

The following features were categorized as attractive quality (A): cooperative work, impressive styling, attractive color scheme, feasible production process, and alignment with human operating habits.

The following features were categorized as indifferent quality (I): adaptable to terrain changes and emergency stop protection.

Finally, no features were categorized as reverse quality (R).

3.3.2. Satisfaction

Using the data from the Kano model analysis of the residual film collection and baling machine, the user need satisfaction and dissatisfaction coefficients could be

determined. A higher satisfaction coefficient indicates that users are more satisfied that this need has been met, while a higher dissatisfaction coefficient indicates that users are less satisfied that this need has been met. Setting the Kano model satisfaction and dissatisfaction coefficients as SI and DSI, respectively.

$$SI = \frac{O + A}{M + O + A + I} \quad (1)$$

$$DSI = \frac{M + O}{M + O + A + I} \quad (2)$$

In formula (1), although users may be dissatisfied with a lack of must-be quality (M) functions, the presence of such functions is considered normal by users and does not increase user satisfaction. In addition, indifferent quality functions do not affect user satisfaction. Therefore, there are no must-be (M) or indifferent quality (I) functions in the numerator in formula (1). In formula (2), attractive quality (A) functions have almost no effect on user dissatisfaction, while user dissatisfaction mainly stems from must-be (M) and one-dimensional quality (O) functions. Therefore, there are no attractive (A) or indifferent quality (I) functions in the numerator in formula (2). Based on the results from the Kano questionnaire and formulas (1) and (2) for the residual film collection and baling machine, the Kano model user satisfaction and dissatisfaction coefficients were determined, as shown in Table 5.

Table 5. Kano model user satisfaction and dissatisfaction coefficients.

Number	SI	DSI	Number	SI	DSI
N1	0.205	-0.586	N9	0.727	-0.377
N2	0.395	-0.736	N10	0.673	-0.118
N3	0.732	-0.573	N11	0.673	-0.282
N4	0.223	-0.673	N12	0.668	-0.827
N5	0.845	-0.832	N13	0.841	-0.218
N6	0.664	-0.550	N14	0.118	-0.727
N7	0.223	-0.227	N15	0.368	-0.282
N8	0.836	-0.218			

3.3.3. Influence

We set the influence coefficient of each need in the Kano model as EI. The EI was determined by the satisfaction coefficient SI and the dissatisfaction coefficient DSI, as follows:

$$EI = \sqrt{SI^2 + DSI^2} \quad (3)$$

Based on the value of the influence coefficient, EI, in the Kano model, the order of priority for each of the residual film collection and baling machine's design needs could be obtained, as shown in Table 6.

Table 6. Kano model influence coefficients for the residual film collection and baling machine.

Serial number	EI	Number	Classification	Serial number	EI	Number	Classification
1	0.621	N1	M	9	0.819	N9	A
2	0.835	N2	M	10	0.683	N10	A
3	0.930	N3	O	11	0.730	N11	A
4	0.709	N4	M	12	1.063	N12	O
5	1.186	N5	O	13	0.896	N13	A

6	0.862	N6	O	14	0.737	N14	M
7	0.318	N7	I	15	0.464	N15	I
8	0.864	N8	A				

Based on the influence coefficients in the Kano model for the residual film collection and baling machine, the needs were prioritized according to their influence, resulting in a ranking of their importance in each design requirement category.

The order of priority for the basic functions was residual film collection and packaging > separation of film and debris > a high pickup rate > residual film pickup.

The order of priority for the innovative functions was dust-free operation > cooperative work > no film entanglement in the machine > adaptability to terrain changes.

The order of priority for appearance styling was impressive styling > a feasible production process > an attractive color scheme.

The order of priority for the human-machine design was comfortable operation > alignment with human operating habits.

Finally, the order of priority for the safety performance was safety protection > emergency stop protection.

Therefore, the priority items regarding the basic functions, innovative functions, appearance styling, human-machine design, and safety performance of the residual film collection and baling machine were, respectively, residual film collection and packaging, dust-free operation, impressive styling, comfortable operation, and safety protection.

3.4. Design Practice

3.4.1. Creative Design

We conducted creative design for a film waste collection and baling machine through brainstorming, design orientation, product image analysis, etc. The overall design of the machine was based on a modular approach, with the modularity primarily focused on the coordination between various components. By combining these components in different ways, the machine could perform a variety of operational functions. Based on the results of the Kano model analysis for the residual film collection and baling machine, this paper focuses on five design dimensions: residual film collection and baling, dust-free operation, an impressive appearance, comfortable operation, and safety protection.

Figure 1 shows a creative design plan for a residual film collection and baling machine. The residual film collection device is the core component of the equipment. To avoid generating large amounts of dust during operation, the film pickup device incorporates a wraparound design and dust absorption device. At the same time, specially designed tools and demolding devices are used to reduce film entanglement during operation. The styling design of the cab integrates work functions such as work lights and rearview mirrors. The cab design adopts an integrated fusion solution, with functionality incorporated into the styling and work spotlights designed at the top of the cab. At the front of the cab are large glass windows to provide a wide field of view.

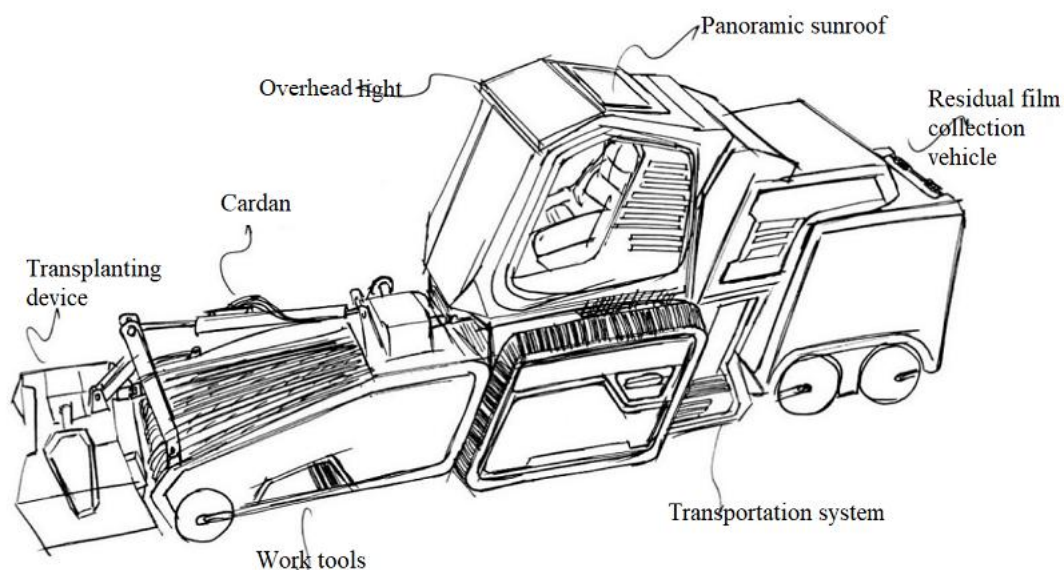


Figure 1. Creative design plan for a residual film collection and baling machine.

3.4.2. Functional Design

Considering that residual film collection and packaging, adaptation to terrain changes, high pickup rates, and residual film pickup capabilities are basic functions that a residual film pickup and baling machine must possess, we conducted research using a combination of functional, human-machine, and styling design. The innovative functions proposed in this paper are as follows:

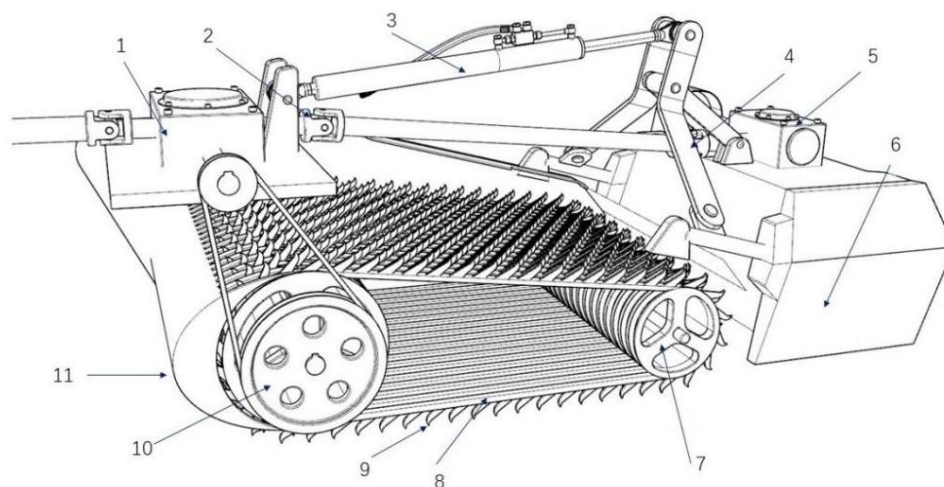
- (1) Dust-free operation: The problem of dust generation in traditional equipment can be solved by wrapping up specific parts of the machine and installing dust removal devices.
- (2) No film entanglement in the equipment: By designing special blades and film removal devices for the picking equipment, the problem of film entanglement in the equipment during operation can be reduced.
- (3) Mobile collection device: A mobile film collection device can be pulled forward by a tractor. It has a larger overall capacity and can collect a large amount of film at one time, which is convenient for film recovery in large farmlands.

3.4.3. Structural Design

(1) Overall structure

The overall structure of the integrated film picking and baling machine includes a transmission, universal joint, hydraulic rod, rice transplanting machine bracket, rice transplanting machine transmission, rice transplanting machine inner cover, picking blade flywheel, rake tooth belt, picking blade, picking blade pulley, and demolding device, as shown in Figure 2. The power output for the machinery is provided by the universal joint, which transmits power from the tractor to the transmission and converts it to a specific speed, then transmits it to the residual film pickup flywheel and the rice transplanting machine flywheel. The rake belt pulley rotates counterclockwise, driven by the belt, causing the rake belt on the flywheel to rotate counterclockwise as well. In this study, we carried out the structural design of an integrated residual film collection and baling machine, considering the overall

structure, residual film collection and removal device, conveying and transportation device, and residual film baling device.

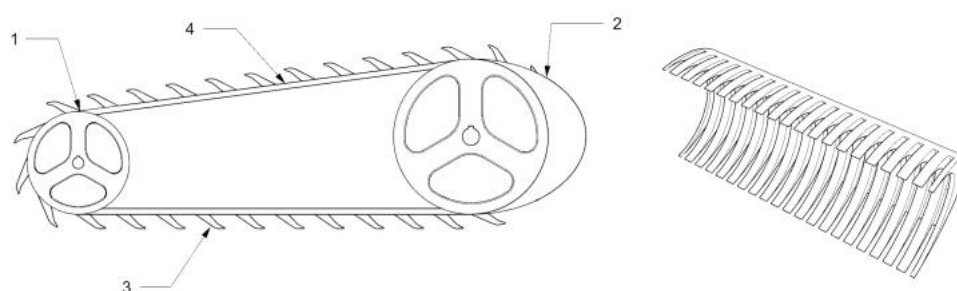


1. Transmission; 2. universal joint; 3. hydraulic rod; 4. rice transplanting machine bracket; 5. rice transplanting machine transmission; 6. rice transplanting machine inner cover; 7. picking blade flywheel; 8. rake tooth belt; 9. picking blade; 10. picking blade pulley; 11. demolding device.

Figure 2. Overall structure of the residual film collection and baling machine.

(2) Residual film collection and film removal device

The structure of the residual film pickup and demolding device is shown in Figure 3. A residual film pickup blade is installed on the belt. During the belt rotation process, the blade teeth rake out the residual film from the soil. When the scraped-out residual film reaches the front end of the demolding device, the rake teeth slide into the demolding device groove, and the residual film is scraped off and dropped onto the conveyor belt for transport to the collection device. The demolding device takes the form of a rack, and only rake teeth are allowed to pass through the grooves. When the residual film is picked up by the rake blade, it is lifted by the rack of the demolding device and slides onto the conveyor belt. The rake blade can then rotate downward through the rack groove. The design of this structure can effectively prevent residual film entanglement in the rake teeth, reducing the time required for manual cleaning equipment after completion of the operation.



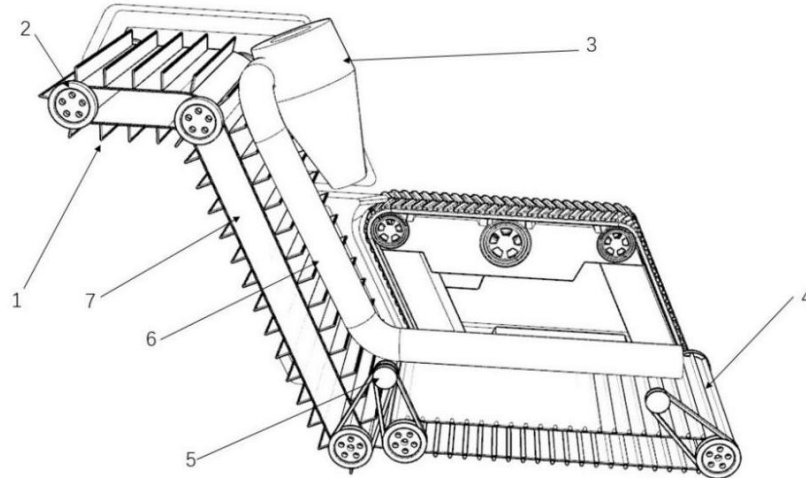
1. Belt roller; 2. demolding device; 3. rake tooth; 4. rake tooth belt.

Figure 3. Structure of the residual film collection and removal device.

(3) Conveying and transporting device

The main function of the conveying and transporting device is to transport the collected residual film to the collection box. The design of this device includes a two-stage conveyor belt. When the transport device operates, the first and second

conveyor belts rotate counterclockwise, driven by the output flywheel. The residual film that falls onto the first conveyor belt is transported to the lower end of the second conveyor belt. The serrated plate of the secondary conveyor belt scrapes off the residual film, at which point the film sweeping blade moves upward to transport the residual film to the collection box, as shown in Figure 4.

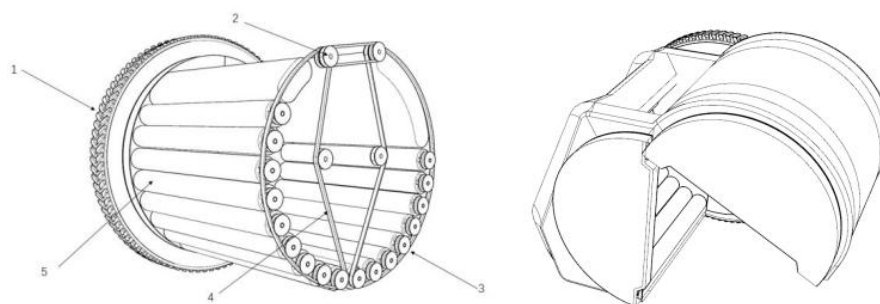


1. Film sweeping blade; 2. conveyor wheel; 3. cyclone dust collector; 4. first conveyor belt; 5. output flywheel; 6. vacuum tube; 7. second conveyor belt.

Figure 4. Conveying and transporting device.

(4) Residual film baling device

The structure of the residual film baling device is shown in Figure 5. It is cylindrical in shape, with tires on both sides. During operation, the baling device is suspended from and pulled forward by the tractor. The front side of the residual film collection device picks up the residual film and transports it to the top of the collection device via a conveyor belt. After the residual film falls into the collection device, it rotates on a roller. The collection device is designed with several rollers that rotate in the same direction and are driven by a belt pulley, thereby rolling and bundling the residual film. When the residual film collection device is full, a hydraulic rod lifts the other half of the device, opening it, the residual film falls, and the film unloading process is completed.



1. Tire; 2. drive pulley; 3. roller pulley; 4. belt; 5. roller.

Figure 5. Structure of residual film baling device.

3.4.4. Human–Machine Design

We used the Siemens Tecnomatix Jack to conduct human–machine design analysis on a residual film collection and baling machine, meeting human–machine design

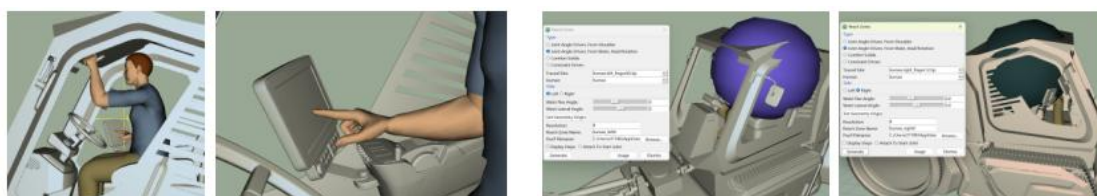
requirements determined using the Kano model for comfortable operation and alignment with human operating habits. We conducted human-machine simulation analysis considering the visual field of operation, visible, reflection, and reachable ranges, and comfort level. From the simulation results, we found that the digital human could always see the rearview mirror and the working environment to the side of the machine after turning their head to the left and right to the limit value, as shown in Figure 6. Therefore, during the actual driving process, the operator could adjust their working status by looking at the rearview mirror and the environment on both sides. The results of the visible range analysis show a white area representing the visible range of the digital human. This covered the entire operating area, including the steering wheel, instrument panel, and center console screen areas. Therefore, an operator could observe each operating area and instrument display in real time during operation.



Figure 6. Visible range analysis.

The reflection range was used to assess the visible range of the digital human in the rearview mirror. It could be used to determine blind spots and assess whether they affect the operation. The analysis results show that the blind spots in the driver's cab were mainly concentrated behind the machine. In the area in front of the driver's cab, the blind spot was small and had little impact on the driver's operation of the equipment.

The reachable range was used to analyze the range that the driver could reach when operating the controls by hand. The main operations performed within the machine's reachable area included pressing the buttons on the ceiling and operating the central control screen. From the simulation results, it can be seen that the reachable range of the digital human's left and right hands covered the instruments in the driver's cab, so met normal operational requirements, as shown in Figure 7.



(a) Operating gestures.

(b) Partial reachability analysis.

Figure 7. Reachability analysis.

Comfort analysis was conducted based on Porter's (1998) comfort data. The results of the comfort analysis regarding the driving posture are shown in Figure 8. Based on these, when the driver operated the residual film collection and baling machine, most

of their joints were within the comfort range, with their left upper arm, right thigh, and left thigh showing some degree of fatigue. Considering the actual driving process, both legs needed to operate the foot pedals to complete the machine's operations. Fatigue could be alleviated to a certain extent through foot and leg movements. Therefore, the overall comfort of the residual film collection and baling machine met the requirements.

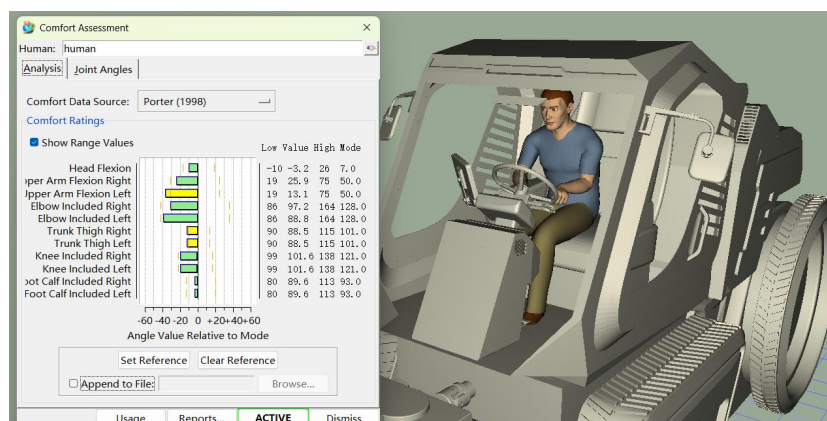


Figure 8. *Comfort analysis.*

3.4.5. Styling Design

In order to further meet the requirements for impressive styling and appealing color matching based on the Kano model analysis, we created three styling design schemes for a residual film collection and baling machine. Considering the morphological changes in the residual film collection and baling machine in terms of its creative, functional, and structural design, the differences between the three design schemes were mainly in the color and material characteristics. A satisfaction survey was conducted on the three design schemes, with a total of 72 valid questionnaires distributed and 65 returned. The survey results showed that the design satisfaction rates for the three schemes were 84.31%, 81.54%, and 72.62%, respectively. Based on the survey results, the color expression, material texture, color matching, and design details of the residual film collection and baling machine were optimized. The color scheme used yellow and black, and the final design scheme was basically developed based on the results from the satisfaction survey, as shown in Figure 9.



Figure 9. *Final scheme for residual film collection and baling machine.*

The residual film collection and baling machine designed in this study has a clear overall outline with sharp edges and no unnecessary curves, presenting a strong sense of modern machinery and industry. It conveys strength, power, and professionalism, consistent with the durable and reliable image of agricultural machinery. The machine adopts a modular structural design, with a uniquely shaped front-end pickup device

that has clear functional markings, intuitively conveying the core task of picking up residual film. The central cockpit adopts a square cabin design with large glass windows providing excellent visibility, emphasizing the core role of human-machine interaction and control. The rear baling device was designed with a huge cylindrical roller, which conveys the baling and collection functions and is the most distinctive design element of the entire machine.

The residual film collection and baling machine uses large areas of highly saturated engineering yellow as its main color. The colors are very eye-catching and vibrant, providing high visibility and warnings in the field environment and thereby improving work safety. Black is used as a complementary color for the chassis, key structural components, and decorative details. This provides a visual anchor and sense of stability for the overall design. The color ratio is well balanced, with yellow clearly dominating to ensure visibility and brand recognition, while black is effectively interspersed to prevent the overall appearance from being too flashy. The combination of yellow and black has high contrast and complementarity, creating a sophisticated, professional, and reliable image for this agricultural machinery.

4. Conclusions

The paper describes the design and research of a residual film collection and baling machine using the Kano model to effectively identify the importance of different design needs. Five design need categories and 15 items were identified for residual film collection and baling machines, including basic functions, innovative functions, appearance styling, ergonomics, and safety performance. Through the design of positive and negative questions, questionnaire distribution, and result analysis, we derived the must-be, one-dimensional, attractive, indifferent, and reverse quality functions for a residual film collection and baling machine. We designed such a machine using the Kano model, considering five dimensions: creative, functional, structural, human-machine, and styling design. The feasibility of applying the Kano model in the industrial design of agricultural machinery was verified. The results indicate that the innovation design of agricultural machinery equipment using the Kano model can improve the accuracy of design need identification, functional satisfaction, and aesthetic appeal. This study conducted design research on a residue film collection and baling machine using the Kano model from an industrial design perspective, without involving component stress calculations. Future research directions include the innovation design of agricultural machinery based on the integration of multiple design methods.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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References

- [1] Yang, J. Design and Test of the Pickup and Automatic Film Removal Device for Broken Residual Film. Hunan Agricultural University, 2020.
- [2] Ren, W.; Wu, Z.X.; Han, X.J. et al. Design and Parameter Optimization of the Pickup Drum for a Spring-Tooth Type Residual Film Recovery Machine. *Journal of Northwest A&F University (Natural Science Edition)*, 2025, 11, 1-12.
- [3] Wusman, W.; Sattar, S.; Keram, R. et al. Cost Saving and Efficiency Improvement Design and Optimization of Telescopic Spike-tooth Type Residual Film Recovery Pick-up Device. *Journal of Agricultural Mechanization Research*, 2025, 47(05), 75-81+87.
- [4] Jiang, D.; Yan, L.M.; Chen, X.G. et al. Improved Design and Test of Longitudinal Nail-tooth-chain Plastic Film Pickup Device. *Transactions of the Chinese Society of Agricultural Machinery*, 2025, 56(01), 267-281.
- [5] Jiang, Y.X.; Qu, H.; Liu, X.F. et al. Design and Experiment of Spade Tooth Film Lifting Device for Residual Film Recycling Machine. *Transactions of the Chinese Society of Agricultural Machinery*, 2025, 56(01), 282-289.
- [6] Zhang, L.; Liu, X.F.; Zhou, X. et al. Rapid Selection Model Method of Residual Film Recycling Machine Based on Analytic Hierarchy Process. *Agricultural Mechanization Research*, 2025, 47(09), 28-34.
- [7] Wei, L.; Liu, X.L.; Sun, W. et al. Design and Testing of an Integrated Corn Stubble Residual Film-Recycling Machine. *Agriculture*, 2024, 14(10), 1809-1809.
- [8] Chen, Y.Z.; Xing, R.F.; Liu, X.L. et al. Design and Test of Potato Seedling Killing and Residual Film Recycling Integrated Machine. *Agronomy*, 2024, 14(10): 2269-2269.
- [9] Qiu, B.B.; Zhou, J.P.; Zheng, Z. X. et al. Study on Lifecycle Ergonomic Evaluation Index System for Agricultural Equipment. *Mechanical Design and Manufacturing*, 2018, 12, 230-233.
- [10] Zhu, S.Y. Research on the Design of Park Streetlight Shapes Based on the Kano Model. *Beauty and the Times*, 2023, 12, 144-147.
- [11] Zhou, Q.; Li, X.F.; Chen, Y.Y. Research on the Design of Household Aquaponics Planting Products Based on Kano Model. *Industrial Design*, 2022, 11, 64-67.



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