Symbiotic Exploration of Silage Machinery Based on Technological System Evolution

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Abstract. In order to make each functional module of silage machinery have a high degree of adaptability and meet the market demand of coordinated operation of each functional module, this paper preliminarily explores the symbiosis concept in the field of silage equipment, and applies the technology system evolution theory to the symbiotic design of silage equipment. In the design stage, the designers divide the functional modules of the silage machinery according to the market and user needs, and then analyze the symbiosis of the interrelated modules and screen out the functional modules with weak adaptability, so as to carry out the technical system evolution and optimize each functional module, and then establish the layout scheme between modules, so that the various functional modules of the silage machinery have strong adaptability, improve product quality, reduce design costs, shorten the design cycle, and realize the user’s demand for the coordinated operation of multi-functional silage machinery.

Keywords: Symbiosis, Technical System Evolution, Adaptability, Silage Machinery

1. Introduction
With the rapid development of society, the competition direction of today’s market has also undergone tremendous changes. The traditional silage equipment with single function cannot meet the needs of users. There are some problems in the market of silage machinery for farmers in hilly areas, such as excessive machines, poor adaptability, single function, and relatively fixed use places. Therefore, the design of silage equipment with multiple functional modules and coordinated operation between each functional module has become a very urgent problem in the design of silage machinery [1]. The evolution of any product’s function and technology has to go through a life cycle. Designers can choose the corresponding evolutionary method to optimize the design according to the maturity of the product. Runhua Tan and others have done a lot of research on the evolution of technical system, and have been applied to the development of agricultural machinery [2]. Bo Yang and others have made some research in the conceptual design of product structure based on unit model, and defined functional unit as a set of collection of functions and flows. Since the concept of symbiosis was proposed by Margulis and others, it has been explored in various fields. However, the concept of symbiosis is not unified, and the principle is also vague, lacking the application in the agricultural machinery industry [3]. In view of these status and problems, the symbiotic theory is preliminarily
explored in silage machinery, the basic concepts and principles of symbiotic theory are improved, and a design method to improve the adaptability between functional modules of silage machinery is proposed. This method can quickly integrate the function modules of the equipment in the design stage, and complete the optimization of each module.

2. Preliminary Exploration of Symbiosis Theory

2.1. Research Status of Symbiosis Theory

Everything in the world has a certain symbiotic relationship, or interdependence, or mutual development, which brings symbiotic enlightenment to product design. Therefore, it is of great significance to integrate symbiosis theory into product design. Symbiosis is a theory about the relationship between different organisms, which is put forward by the biologist Marculis and others on the basis of Gaia hypothesis [4].

At present, some experts have made some explorations on symbiosis theory. Yue Zhang mainly explores the man-machine symbiosis relationship in products from the background of intelligence [5]. George explores the serial design method of public facilities and products from the symbiotic mode [6]. Yiping Mo integrates the concept of symbiosis in product design to guide the development of product integration design. Tianhang Li proposed a concept of adaptive structural unit to create a flexible structural form [7]. Mario put forward the theory of technology symbiosis, that is, product technology will accelerate the development driven by long-term symbiosis [8]. Justin and others studied the relationship between users and products, to achieve a deeper level of human-computer symbiosis [9]. Lennart determined the life cycle inventory model of symbiosis concept affecting life cycle assessment, and proposed the life cycle inventory modeling framework [10]. At present, symbiosis theory has been applied in various fields, but the application of symbiosis concept in agricultural equipment, especially silage machinery research is still relatively scarce. Therefore, it is necessary to further explore the symbiosis theory to better guide the design of silage equipment.

2.2. Exploration of Symbiosis Principle

The symbiosis theory studied in this paper is based on the modularization of silage equipment, which cannot include all types of structural forms. The essence of symbiosis is that there is a high degree of adaptability between the two functional modules. The signal flow, material flow and energy flow between the functional modules can flow smoothly without blocking. The output parameters of the former functional module can correspond to the input parameters of the latter module, and then connect the two modules through the connection structure to make the equipment functional modules run smoothly. Through the analysis of symbiotic requirements to guide the evolution of products, it can greatly shorten the time spent in product design stage, so that there is a high degree of coordination and adaptability between functional modules. At present, this theoretical method is still in the exploratory stage and needs to be continuously improved.

The function modules of silage equipment are continuously optimized through the guidance of symbiosis theory to improve the adaptability between modules and make the circulation of material, energy and information highly adaptable. When the silage machinery is modular designed, the symbiotic principle can be used to determine whether there is symbiosis between functional modules, and guide its symbiotic optimization. The basic principles of symbiosis theory are preliminarily established as follows:

(1) Function structure circulation principle

The total input and output of the product are described as the total function, and the total function can be decomposed into functional structure. As shown in Figure 1, the energy, material and signal parameters between the two functional modules should be basically corresponding, so that the function between modules can be well coordinated through the connection structure to achieve high symbiosis.
Figure 1. Functional structure between modules

(2) Principle of homogeneity
For silage machinery, most of them are integrated machines at home and abroad. Each functional component of silage machinery generally evolves at the same time and has the same maturity. The function modules of the same generation have more elements of multi-phase adaptation, relatively easier symbiosis, so try to select the evolution state as the function module of the same generation, of course, do not exclude some non-same generation also have strong symbiosis.

3. Module Symbiosis Optimization Design of Silage Machinery
Through the investigation of user needs, the silage machinery is modularized and divided into modules with independent functions [11]. Then the adaptability of functional modules is analyzed according to the symbiosis concept, and the evolution direction of the module is guided by the evolution of the technical system. Through this design method, the function module of the whole machine can be quickly optimized in the design stage, which effectively improves the efficiency of equipment design. As shown in Figure 2, the optimization process of silage machinery function modules can be divided into five stages: the investigation of user needs, the division of the whole module, the establishment of functional unit model, the symbiosis analysis of function modules, and the technical system evolution of non-symbiotic modules. Through the optimization design of modules, each module has a high degree of coordination and adaptability, which better reflects the significance of module symbiosis.

Figure 2. Silage machinery symbiotic optimization technology route

3.1. Investigation of User Needs
User demand investigation and analysis is the primary link in product design, and the realization of product function is the ultimate goal of product design. Functional design comes from meticulous research on consumers, so as to grasp the law of market demand. Field investigation is conducted by sampling survey method, and then the user demand is analyzed to determine the total energy of products.
3.2. **Partitioning Module**
Module division is an important part of modular design. Based on the needs of users, the whole machine is divided into modules that can be used independently and modeled.

3.3. **Establishment of Functional Unit Model**
The functional unit model of product is the sequence of functional units based on certain flow. In order to establish a reasonable functional unit model, it is necessary to model the relationship between functional units. To establish the functional unit model between modules, it is necessary to analyze the functions between modules and the characteristics of input and output streams, so as to establish the functional unit model between modules.

3.4. **Analysis of Symbiosis**
Through the preliminary exploration of symbiosis theory, the basic principle of symbiosis theory is established. According to the symbiosis principle, whether the material flow, energy flow and signal flow between functional modules can be smooth or not is judged, and whether the loss is within the allowable range of the equipment after the material flow, information flow and energy flow are transformed. If there is no good symbiosis, it is necessary to analyze the evolution direction of functional modules under the guidance of symbiosis principle, and the evolution of functional module technology system.

3.5. **Evolution of Technology Systems**
Qualitative and quantitative analysis of patents related to each functional module can determine the maturity of products [12]. Select the corresponding evolution rule according to maturity and analyze the evolution potential. Evolutionary potential is generated on the evolution rule of functional modules. By judging the current technical stage of functional modules, the evolutionary potential of functional modules can be obtained. As shown in Figure 3, the evolutionary route starts from state 1 and the highest state is 5. If the current evolutionary state is 3, then evolutionary state 4 and evolutionary state 5 are called evolutionary potential. After analyzing and determining the evolution potential of functional modules, it is necessary to preliminarily evolve functional modules to achieve the performance parameters required by users.

![Figure 3. Analysis of evolutionary potential](image)

4. **Engineering Verification Analysis**
Under the guidance of technological system evolution theory and symbiosis principle, the silage machinery was taken as an example to carry out symbiosis optimization. Each module of the silage equipment has a high degree of symbiosis and adaptability after optimization. The total input and output parameters are basically corresponding to ensure that each process can work continuously, and each function module has a high degree of symbiosis.
4.1. Investigation of User Needs
China is a large agricultural country, and Shandong is also a major area for corn cultivation. Due to the influence of topography and farming methods, the requirements for silage machinery in hilly areas of Shandong are complex [13]. As shown in Table 1, through the investigation of farmers in Feicheng, Shandong Province, it can be seen that farmers in hilly areas of Shandong Province have more requirements for the function of silage machinery, but also require strong dynamics.

Table 1. User survey analysis

| user requirements       | design requirement        |
|-------------------------|---------------------------|
| cutting comminution      | cutting table device      |
| bale strapping          | binding mechanism         |
| envelope                | wrapping device           |
| Machine flexibility      | modular disassembly       |

4.2. Module Division of Silage Machinery
According to the design requirements of silage machinery, the structure of silage equipment was studied, and the functional modules of silage equipment were determined as cutting device, baling device and coating device.

4.3. Functional Unit Model of Silage Machinery
The functional unit model between the silage mechanical modules is shown in Figure 4. The whole machine provides kinetic energy by the engine. The corn straw is cut and crushed by the cantilever and universal joint control cutting device. The crushed straw is bundled and roped by the electromagnetic valve control baler. The material bundle is coated by the driving roller control coating device to complete the continuous operation process from corn straw to feed bundle.

4.4. Symbiosis Analysis between Modules
For energy flow and signal flow, each module runs smoothly to meet the symbiotic requirements. The material flow can be smoothly circulated in the cutting and crushing process of the cutting platform device, and it can basically meet the requirements in the process of bundling to the coating. However, the material flow is not smooth enough in the process of crushing to bundling. In the prototype test, there are also phenomena such as material blocking of the throwing cylinder or empty rotation of the bundling device. Therefore, it is necessary to optimize the symbiosis between the cutting platform and the bundling device.
4.5. Evolution of Technology Systems
Through the patent analysis of corn cutting platform and baling device, it can be judged that corn cutting platform is in a recession [14]. According to the symbiotic same generation principle, it can be judged that the cutting device and the baling device should be in a recession at the same time, so it is necessary to use the evolutionary rule to the super system under the guidance of symbiosis theory to optimize the symbiotic design of the cutting device and the baling device.

As shown in Table 2, it can be concluded from the analysis of the evolutionary potential of the cutting platform device and the baling device to the super-system evolution law that the final evolutionary state is the integration of multiple systems of cutting, crushing and baling, which is composed of multiple functional modules. It not only has the multi-functional characteristics of cutting, crushing and baling, but also has high adaptability and dynamics. While meeting the functions, modules can be dynamically assembled, disassembled and coordinated. Therefore, the current evolutionary potential is to build a connection system between the cutting device and the binding device to solve the problem of the accumulation of crushed materials at the connection between the cutting device and the binding device.

| evolutionary state | cutting table device | binding mechanism                        |
|--------------------|-----------------------|------------------------------------------|
| state1             | traction and cutting dual system | traction and bundling dual system       |
| state2             | splitting single system | bundled split single system              |
| state3             | adjust adaptive row spacing | picking up and bundling                  |
| state4             | integrated single system |                                         |
| state5             | current evolutionary potential |                                            |
| state6             | cutting, crushing and bundling integrated multi-system |                                       |

4.6. Determination of Modular Silage Machinery Design Scheme
In this paper, the symbiotic optimization design of modular silage equipment is based on technological system evolution, and each functional module is coordinated and optimized. A symbiotic device is constructed between the throwing cylinder of the cutting device and the collecting box of the binding device to coordinate the material transmission between the throwing cylinder and the collecting box. When the symbiotic device detects that the material is blocked in the thrower, it starts to operate and quickly delivers the material to the collector. As shown in Figure 5, the corn straw is cut and crushed by the header device, and then transported to the collection box through the symbiotic device, and then bundled and bundled by the baler, and then coated. The integrated continuous operation of cutting, crushing, baling and coating was completely realized.

![Figure 5. Whole machine scheme](image)

5. Conclusion
The technology system evolution theory is applied in the field of agricultural machinery, and the symbiotic design principle is proposed to optimize the functional modules of silage equipment, so that the silage machinery not only realizes different functional requirements, but also greatly increases the coordination between modules and strengthens the market competitiveness. This has important guiding significance for the development of agricultural machinery industry and even machinery.
industry. However, this paper has some shortcomings in the symbiotic analysis of silage equipment, especially in the quantification of symbiotic parameters.

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