Application and research of modular design for general chassis of garlic machinery

Xiang Gao, Dong Zhao, Shengjie Xu, Cheng Liu and Weitao Huang

Institute of mechanical engineering, University of Jinan, Jinan, Shandong, 250000, China

*Corresponding author’s e-mail: me_zhaod@ujn.edu.cn

Abstract. The traditional research and development cycle of garlic operation machinery chassis is long and the production cost is high, which hinders the development of this product. We can find out the condition that sub-functions become independent modules by the judgment matrix. Sub-functions can be divided based on correlation calculation and module division. The modular design of garlic operation machinery chassis is not only conducive to the innovative design and upgrading but also reducing the cost and the products.

1. Introduction

Garlic is a labor-intensive cultivated crop. In recent years, with the transfer of rural workforce, a shortage of labour and high labor costs have led to higher garlic costs, which seriously restricted the healthy development of garlic industry. Therefore, the realization of garlic mechanized production is of great significance for improving the international competitiveness of China garlic industry, reducing labor intensity and increasing farmers' income[1].

As an important part of the garlic operating machinery, the garlic operating machinery chassis can drive the garlic operating equipment to perfect its corresponding functions. Agricultural mechanization have arisen many problems although it has been popularized on a large scale, for example, problems such as complex structure, high cost, low degree of universalization and many special parts. These problems not only have caused certain difficulties for the production, use, maintenance, upkeep but also been not conducive to the organization of the production, preparation and implementation of parts[2].

With the development of society, the product structure is becoming more and more complex. At the same time the life cycle of various commodities is gradually shortened. Personalized design can meet the needs of different users[3]. The traditional research and development cycle of garlic operation machinery chassis is long and the production cost is high, which hinders the development of the agricultural machinery product. We can learn from research and development process of the automotive modular technology and design the special chassis into a general one. And then the research and development cycle will be reduced and the efficiency will be improved by leaps and bounds.

2. The background and significance of the research and application of chassis modularization technology

2.1. The background of application of modular technology
The function of the general chassis of garlic operating machinery is to support, install the engine and its working parts, form the overall shape of the operating machinery and bear the power of the engine. The good garlic operating machinery can complete the normal driving and the corresponding work (such as sowing or harvesting) under the driver's control. Chassis is the installing foundation of all assemblies and has to bear all kinds of loads from inside and outside the body. The development and research of chassis for the development of the whole car play an essential role.

Comparing with automobile chassis, the design and research of garlic working machinery general chassis are relatively simple. However, many parts on the chassis will affect chassis’ design. The problems such as the universality of the interface between the chassis and the working part, the speed of walking, the matching of power and the location of the parts and so on make the design process of the chassis complex and will restrict the long-term development of garlic working machinery chassis.

2.2. The significance of modular technology application

It is of practical significance to apply the idea of module design to the design of garlic working machinery chassis.

(1) Reduced the huge difficulty of chassis development. Modularity technology improves the design efficiency by reducing the complexity of products. If the parts with complex structure are not subdivided into small modules for modular design but designed directly, it will greatly increase the difficulty of design and increase the design time. Collaborative development is difficult, which hinders product research and development and manufacturing [4].

(2) Shorten the time of developing and manufacturing garlic working machinery chassis parts. Modular design mainly constructs new modules through product mix and then forms a new product, which can save a lot of parts’ design time.

(3) The cost of the product has been greatly reduced, but the quality has been greatly improved. As the design time is shortened and the number of components is reduced, the management is simplified and the labor cost is reduced accordingly. The modular design can improve the reliability and quality of the product. At the same time, the product's using time and service life get longer as well as the performance is significantly improved.

(4) Easy maintenance. When the chassis fails, the module can be disassembled for maintenance. The fault is easy to judge, and the inspection time is shortened. The module is used as a unit to repair the chassis will greatly improve the maintenance conditions.

3. Definition of modularity and functional analysis of chassis parts

3.1. Definition of modularity

The basic definition of module and modularity should be clarified and the functions of the chassis should be divided on this basis before the modular design.

A module is an independent unit with a specific interface. It has the same function and can be combined into one system. Modules shall also have the following characteristics:

(1) Module is a set of components and assemblies for independent function, which is a part of an whole system. It has a specific combination and can be replaced and separated respectively.

(2) Module can achieve the required function, performance and technical target.

(3) A module includes one or more functions and is characterized by generalizability among modules.

(4) When the modules are combined, there will be no interference between the ingredients.

(5) Each module has its own interface. When the modules are combined to form a system, there is a one-to-one correspondence between the interfaces. And the interface has a wide application range.

Modular design is the process of dividing parts into functional independent subunits according to some rules or standards. The division of modules is the most fundamental basic of modular design.
3.2. Functional analysis of chassis parts
The function is the main characteristic of the chassis. And the structure of the chassis is also constructed on its function. First, in order to the modular design, the garlic working machinery chassis should be divided based on its functions, which is the basis for the modular design. According to the function of the chassis of the garlic operation machine, it is necessary to bear the quality of the whole vehicle, generate and transmit power. At the same time, it is necessary to realize the control functions of the garlic working machine such as powering, steering, driving and braking. In addition, it needs to complete the rising and falling of the working parts and other auxiliary work. The garlic operating machinery can complete the corresponding functions according to the intention of the driver by the functional construction and performance matching of the chassis system. Figure 1 is the utility system of the garlic working machinery chassis.

![Garlic Working Machinery Chassis Utility System](image)

**Fig 1. Garlic working machinery chassis utility system**

4. Module division of garlic working machinery chassis
To analysis the chassis of the garlic working machine, the chassis is divided into several modules. The structure that connecting to different modules is called an interface. The interface should have several functions, such as connection structure, transmission power and motion. Each module has an independent interface and it is required to be employed universally within a certain range.

4.1. Module division conditions
For the functional analysis of the garlic working machinery chassis, it needs to be divided into a series of sub-modules. The chassis’ reconstruction is done by dividing the modules, which needs to be divided according to a certain method. If one of the following conditions is satisfied, it can be divided into a separate module.

1. Heredity: the construction of sub-functions may be utilized by the next generation of products.
2. Technological innovation: in the product life cycle, the implementation technology of sub-functions may be replaced by new technologies.
3. Planned change: the sub-function is a characteristic carrier to be changed in a planned way.
4. Variation of Technical Parameters: sub-functions will reflect the variation of the technical parameters.
5. Style: with the influence of the trending or popular the form, color and other characteristics of the sub-function carrier will change also.
(6) General unit: there are sub-functions of the same carrier in all products, which is called the universal unit.

(7) Process/organization: sub-functions as separate modules will facilitate separate organization of production or have special production cycles.

(8) Individual laboratory: the function and performance of a sub-function can be tested separately.

(9) Independent circulation: sub-functions can be marketed as "black boxes" and circulated independently.

(10) Maintenance services: the sub-functions are more easily serviced and maintained as separate modules.

(11) Upgrade: the sub-functions are easy to upgrade as the separate modules.

(12) Recycling: The material of the sub-functional carrier is recyclable.

4.2. Correlation analysis of chassis modularity

According to the total function of the garlic working machinery chassis, it is decomposed into seven sub-functions represented as \( f_1, f_2, ..., f_7 \). There are four relationships between the function elements: functional relationship, assembly relationship, spatial relations and information relationship. The degree to which a sub-function \( f_i \) is related to another sub-function \( f_j \) is related, expressed with \( r_{ij} \).

\[
0 \leq r_{ij} \leq 1
\]

By formula

\[
r_{ij} = \sum_{k=1}^{4} w_k r_{i,j}^k
\]

Where \( n \) is the correlation type between sub-functions, \( n=4 \). There are four \((k=1, 2, 3, 4)\) kinds of correlations: functionally related, assembly related, spatially related and information related, respectively. Determine the impact coefficient for each correlation \( w_k \). That is to determine the weight. The weight calculation result is \( w_1=0.445, w_2=0.263, w_3=0.141, w_4=0.141 \). Then the correlation degree between the functions of garlic working machinery bottom plate was calculated through the judgment matrix of independent modules in Table 1.

| Sub-function | Power | Transmission | Bearing | Braking | Steering | Driving | Power output |
|--------------|-------|--------------|---------|---------|----------|---------|--------------|
| Genetic      | √     | √            | √       | √       | √        | √       | √            |
| Technological Innovation | √     | √            | √       | √       | √        | √       | √            |
| Plan change  | √     | √            | √       | √       | √        | √       | √            |
| Technical Parameters | √     | √            | √       | √       | √        | √       | √            |
| Style        |       |              |         |         |          |         |              |
| General unit | √     |              |         |         |          |         |              |
| Process/Organization |       |              |         |         |          |         |              |
| Individual laboratory | √     |              |         |         |          |         |              |
| Independent Circulation | √     |              |         |         |          |         |              |
| Maintenance Services | √     |              |         |         |          |         |              |
| Upgrade      | √     | √            |         |         | √        | √       | √            |
| Recycling    |       |              |         |         |          |         |              |

Each sub-function will be compared with an independent condition and the matrix will be filled if the condition is satisfied. The sub-functions weather or not satisfy the conditions of the independent module can be seen from the longitudinal direction of the matrix. The sub-functions that can be separated an independent module can be performed the correlation calculation according to formula (1). The calculated correlations between the sub-functions are filled in the correlation matrix (Table 2).
It is stipulated that when the correlation exceeds 0.5, it should belong to the same module. According to the data in Table 2, a preliminary module division of the garlic operation machinery universal chassis can be performed. The overall function of the chassis is divided into power source module, carrier module, drive module and power output module. And the drive module includes more compact modules: drive module, travel module, steering module and brake module. Each module has its own independence characteristic and exists as a separate product.

5. Conclusion
The application of the modular design of garlic working machinery chassis is not only conducive to the innovative design of products and the realization of product upgrading but also conducive to the reduction of costs and the development of products by a long way.

Reference
[1] Cui ,R. Zhang, H.Xu, W.Discussion on the Present Situation and Development Strategy of Garlic Mechanization Production in China.(2015) Agricultural Mechanization Research,3:264-265.
[2] Wu,F.Wang,D.Li,R.Shang,S.Design and Experimental Study no Garlic Harvesting Machine.(2017)Agricultural Mechanization Research,12:89-93.
[3] Zhao,Y.Review of Auxiliary Facilities(Vehicle)of Underground Trackless Mine .(2007)EXPRESS INFORMATIONOF MINING INDUSTRY,4:4-7.
[4] Ulrich,K.Tung,K.(1991) Fundamentals of Product Modularity. In:Atlanta,GA. November. pp. 73-79.