Design of Miniature Rototiller based on Modular Concept in Southwest Mountain Area of China

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Abstract

The main purpose of this research is to explore the application of agricultural machinery suitable for the mountainous terrain of Southwest China and the modular concept in the design of rototiller, so as to solve the problems faced in use, realize the multi-purpose of agricultural machinery and save the design and use costs. Based on the actual terrain of the mountainous area in Southwest China, from the perspective of product practicability, we divided the functions of the rototiller and designed it for generalization, and combined ergonomics and product color design to evaluate and improve the plan. Finally, at the end of the article, through the analysis of the difficult problems of agricultural mechanization in southwest mountainous areas, a modular solution is proposed, which provides a new idea for the design of agricultural rototillers suitable for the southwest mountainous terrain.

Keywords

Southwest mountainous area; Modern agriculture; Mechanization; Agricultural rototiller; Modular design

Introduction

In modern society, the degree of agricultural mechanization is an important indicator to measure the level of agricultural development in a country. China is an agricultural power. The agricultural economy plays a vital role in the country's overall economy. Agricultural machinery and equipment is one of the 10 key development areas of "China Smart Manufacturing 2025". It is an indispensable tool for improving agricultural production efficiency, realizing effective use of resources, and promoting sustainable agricultural development. Rural development plays a very important role

(Li, Yao & Zhang, 2017). The development of agriculture solely relying on labor does not meet the standards of modern agriculture. The main path of China's agricultural development should promote the modernization of agriculture through mechanization and automation. Due to the limitations of the old concept of traditional agriculture and the level of science and technology, although China's agriculture has gradually developed to a large-scale, intensive and modern business model, compared with developed countries, there is still a long way to go.

Overview of Agricultural Development in Southwest Mountainous Areas of China

Of all the topography in China, plains account for 12% of the total, hills account for 10%, basins account for 19%, and the remaining 61% are mountain plateaus. The southwest mountainous area has rugged roads, inconvenient transportation, fragmented land, and slow economic development. Most residents have been processing households as a unit. The scale is small and the profit is low. Therefore, the mountainous areas are still in a poor and backward state.

Most of the southwestern region is dominated by mountains, with almost no plains. High altitude and high drop make the machinery unusable, and the land can only be cultivated and fertilized manually. Even if part of the area is plain, the slope around it is relatively large. Moreover, the distribution of plains is very scattered, and there are almost no large areas of plains, so the actual farming environment is poor, which is one of the reasons for the low yield of crops in this area. Under such circumstances, many migrant workers have given up farming in mountainous areas and chose to work in cities and towns. The drastic reduction in the number of migrant workers and low efficiency have slowed agricultural development. In addition, due to the topography and geomorphology, mountainous areas have relatively little contact with the outside world, and farmers' knowledge level is not high enough to occupy a favorable position in the market, which greatly slows down the development of agricultural economy.

Development Status of Agricultural Rototiller in Southwest Mountainous Areas

The level of agricultural development in southwest mountainous areas is relatively lagging. In recent years, the Chinese government is gradually increasing its financial support for agricultural development in mountainous areas, such as by increasing investment in agricultural machinery. However, due to the relatively weak foundation for the development of agricultural machinery in the mountainous areas of Southwest China, it is difficult for the investment funds to meet the needs of agricultural production.

Problems in the Development of Agricultural Rototiller in the Southwest Mountainous Area

(1) The development of southwest mountainous area is greatly affected by the terrain environment. Due to the complex terrain, the level difference between different terrains is large. Many local narrow ridges and corners are not suitable for large-scale rototillers, and it is easy to lead to overloading of machinery and equipment.

(2) The southwest mountainous area is remote and inconvenient. It is difficult for outside machinery producers to make machines for local agricultural activities. Many machines on the market still have many problems in performance, can not well adapt to the southwest mountainous terrain and agricultural production.

(3)Residents in the southwest mountainous areas have a low acceptance of new things and lack a clear understanding of the single-function rototiller. The relevant departments did not make a correct analysis and evaluation of the product's position and development trend in the market, so that farmers rushed to it, causing a waste of resources and some unnecessary economic losses (Xie, Wu & Xiang, 2000).

Development Strategies of Agricultural rototillers in Southwest Mountainous Areas

(1) Making micro rototiller to suit local conditions. In the course of extension of rototiller, we should pay attention to the development and production of suitable rototiller according to the actual situation and agricultural production activities in southwest mountainous area. At the same time, we should produce some light, small and economic rototiller, make full use of the advantages of agricultural machinery, improve agricultural production efficiency, reduce production costs and the burden on farmers, thus improving the utilization rate of agricultural machinery.

(2) Improve the product service mechanism. For ordinary farmers, the purchase of mini rototillers is a considerable expense. If there is a problem with the machine during use, it will cause them great troubles and even reduce their enthusiasm for using the rototiller. In order to avoid the problem of no one providing maintenance services in the face of mechanical failures, consider establishing a unified after-sales service station in mountainous areas to provide local users with technical support and after-sales maintenance services, so that farmers can buy and use rototillers with confidence (Chang, 2019).

(3) Expand the scope of the operation and the functions used. At present, most of the agricultural

rototillers in China are of large size but single function. These characteristics run counter to the requirement of small size, multiple functions and suitable for small plot farming in mountain areas, which has become a bottleneck in the promotion of mechanised agriculture. Agricultural production includes weeding, tilling, sowing, fertilizing, watering and harvesting. By using the modular design method, we can change the function of the rototiller by replacing the module, realize the multiple use of the rototiller, and improve the purchasing rate and utilization rate of it.

Research on the Modular Design of the Mini Rototiller

Modular design refers to dividing and designing a series of products with functional modules based on the analysis of the functions of the products within a certain scope to meet the different needs of the market. This is an organic combination of the similarity of product functions and solutions, standardization and diversification principles (Xu & Xu, 2016). This method will not change the overall power parameters of the rototiller, but you can adjust the original module functions by replacing, adding or reducing modules to form another combined module. The modular design of the rototiller is mainly to divide and generalize the modules. The various options and combinations of modules allow different products to be configured.

Module Division of Rototiller

It can be seen from the above principles that the functions and characteristics of each component of the rototiller are different, and can be roughly divided into a walking module, a power module, a transmission module, and an execution module. Among them, the walking, power and transmission devices of the rototiller belong to the basic functional modules and can be used as general components; the auxiliary function module is the interface part that connects each independent module; the executive module is the special system of the rototiller, and the module needs to be separate design. Therefore, the focus of this design is the execution module of the rototiller (Xu & Xu, 2016). The main work part of the rototiller is the execution system, which can be divided into weeding module, rotary tillage module, ditching module and backfilling module. (As shown in Figure 1)

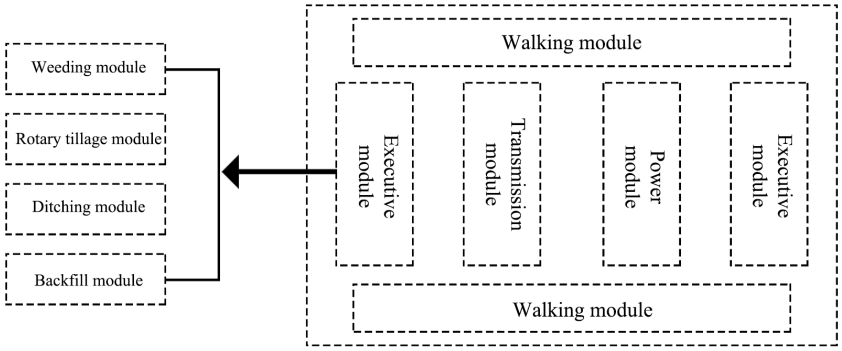


Figure 1. Classification of function modules

General Design of Modules

Module generalization refers to the generalized structural design of products of the same series and the same specification without changing the basic functional modules of the rototiller, so that the products can be adjusted or combined between different modules (Xu & Xu, 2016) . The modular design of the rototiller aims to replace the same functional modules to form different performances of the product, or to appropriately increase/decrease some partial functional modules to change the functions of the rototiller.

(1) Rototiller Module Design with the Same Function

After dividing the rototiller module and analyzing its function, we can divide the rototiller function module into different performance module, so as to make the rototiller adapt to the different environment operation request. The design of the execution module 1 is illustrated here.

The cutter is the main operating element of the execution module 1. When the rototiller needs to weed, the weeding knife becomes the best choice for the execution module; When the rototiller needs to perform rotary tillage operations, the curved blade with low cutting resistance and not easy to wrap around the grass becomes the best choice. In order to facilitate assembly and application, detachable tools should have the same interface module. According to the structural characteristics of the execution module 1, an indirect interface can be selected, that is, the installation of each functional module needs to be connected through an interface module, as shown in Figure 2.

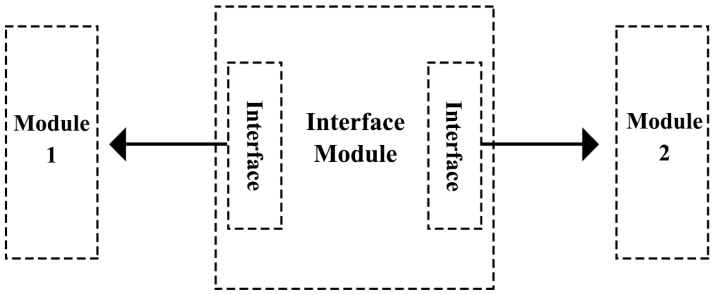


Figure 2. Indirect interface

(2) Rototiller Design with the Increase/Decrease Combination Module

Applying different series of modular design methods to the agricultural rotary cultivator to be designed, and by appropriately increasing or reducing the combination of modules, the functions of agricultural machinery can be enriched. Table 1 is an example of several module combinations.

Table 1. Several typical module combinations

Number	Model name	Module combination
1	Rototiller	1 basic module
		2 walking module
		3 interface module + tiller mechanism
2	Weeder	1 basic module
		2 walking module
		3 interface module + weeding knife
3	Trencher	1 basic module
		2 walking module
		3 interface module + ditching knife

Note: Basic modules include power modules, transmission modules, etc.

Demonstration of Rototiller Products Adapted to the Environment of Southwest Mountainous Areas

Design Concept

Through the research and analysis of agricultural development and agricultural rototillers in southwest mountainous areas, we used modular design methods to brainstorm several problems, and tried to use mind maps and user journeys (as shown in the figure) 3) to explore the needs of users in different farming stages for rototillers. In addition, we also conducted a series of researches on the color, structure, and function of the rototiller, and launched a design concept based on the target population's body size and activity methods.

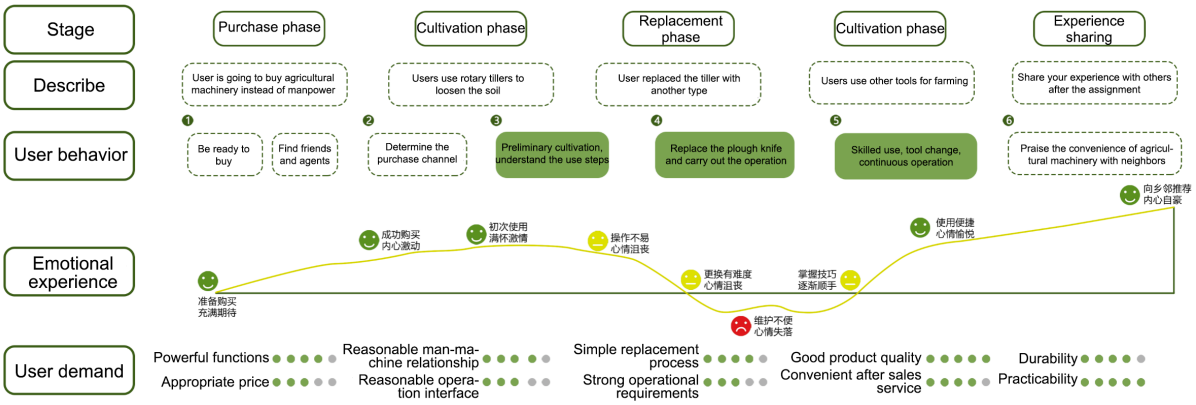


Figure 3. User journey

Design Positioning

(1) Target Group

The target population of the rototiller is farmers in the southwest mountainous area. Due to the special terrain of the mountainous area, ordinary agricultural machinery is difficult to adapt to the local conditions, so most areas rely on farmers to operate. For them, if they can use micro-machines to replace human operations, it will not only liberate and save labor, but also promote economic development and the process of agricultural mechanization in mountainous areas.

(2) Color Positioning

Color is an important consideration in plastic arts. Reasonable application of colors can make the appearance of agricultural machinery more prominent and more eye-catching. And proper color matching can coordinate or make up for some shortcomings in product modeling (Wang & Zhang, 2019). The environment in the southwest mountainous area is complex, so to improve work efficiency, it is necessary to achieve a harmonious unity of color and environment. Since agricultural machinery such as rototillers and weeders operate in an outdoor environment, bright green, blue or red can be used. According to the field survey method, we found that if we look for the color suitable for the agricultural environment in the southwest mountainous area according to the color theory, the final result is green (C:M:Y:K=82:40:98:2) with gray (C:M:Y:K=84:80:78:64) as the main color of the product.

(3) Human-machine Positioning

The height of the human body determines whether the mechanical system is easy to manipulate. In order to make the design object conform to the physiological characteristics of human beings and make people in a comfortable state when using the product, we must fully consider the various scales of human beings (Li & Cao, 2017). According to the principle of ergonomics, combined with relevant scientific research data and standards at home and abroad, various design parameters of the control surface, buttons and other components of the micro rototiller are determined (Qian, & Ji, 2020). Combining the table data of "The relationship between height of equipment and appliances and height" listed by Ding Yulan in *Ergonomics*, we calculated that the average height of adult men in southwest China is 168.9cm, and the average height of adult women is 158.9cm. Through calculation and analysis, the most suitable height of the rototiller and the size of the control surface are finally obtained: the height of the control surface should be 849-911mm. Taking into account that this product will be applied to mountainous terrain, the shape is small, so the length of the rototiller is 1,450mm, the width is 800mm, and the height is 900mm.

Design Deployment

(1) Design Goals

The mountainous roads are rugged and the terrain is uneven. Therefore, the development of agriculture is mainly carried out by human farming, which is time-consuming and laborious. In order to promote the development of mountainous agriculture in the direction of mechanization and modernization, modular micro-agricultural machinery will become the future development trend. The modular design method is used to realize the transformation of multiple operation modes and achieve the effect of one machine with multiple functions.

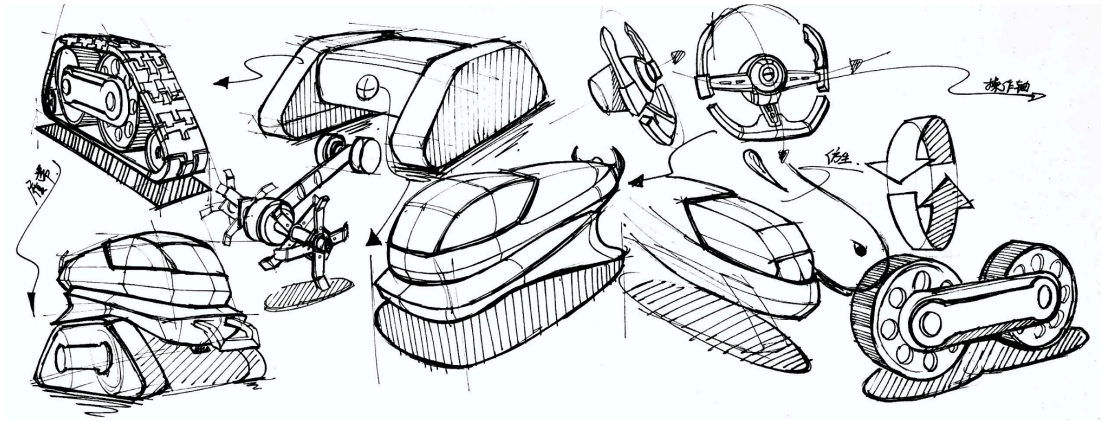


Figure 4. Scheme sketch

(2) Modular Design Scheme

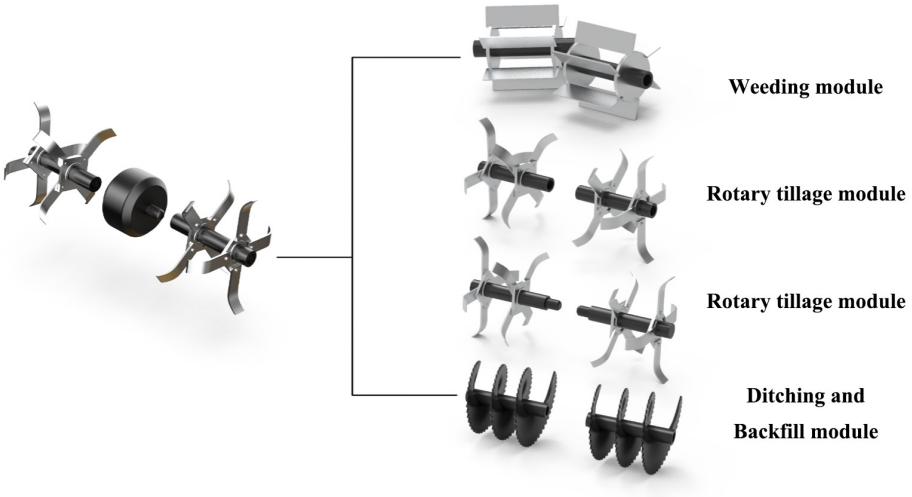


Figure 5. Module selection

In the design of the rototiller, we took into account its practicability and economy, combined with the general farming process, and designed with a tiller module, a weeding module, a trenching

module, and a backfilling module, etc. (Figure 5). According to the requirements of different agricultural production activities, you can choose to replace different modules. At the same time, in the use of each module, the number of modules can also be increased or decreased to adapt to different sizes of space and improve efficiency.

(3) Design Presentation



Figure 6. Design renderings

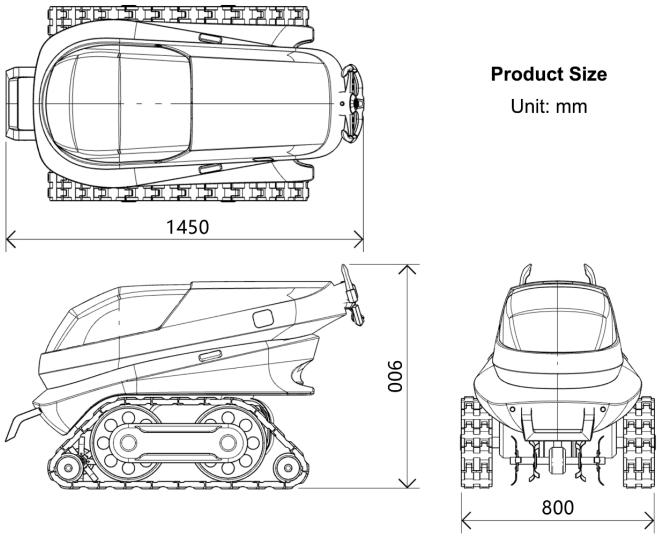


Figure 7. Dimensions

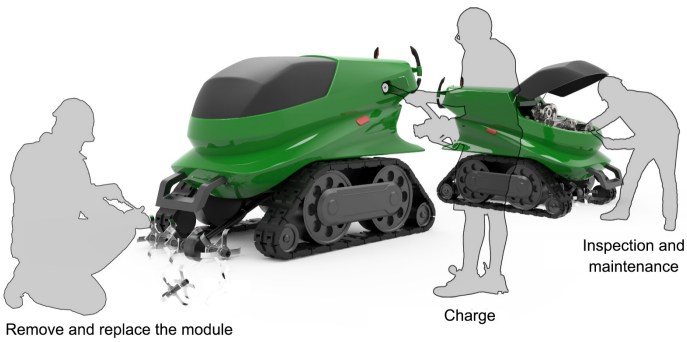


Figure 8. Usage scenarios

Conclusion

The development of agricultural mechanization in mountainous areas in China is relatively slow. Promoting the design and use of micro agricultural machinery in mountainous areas can effectively promote economic development. When designing, we should comprehensively consider relevant factors such as practicality, economy, ergonomics and local culture, so as to highlight the importance of one machine with multiple functions. In terms of modeling, break through the traditional mechanical modeling and promote the popularization of micro-agricultural machinery.

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