Proceedings of the 2023 International Conference on Mechatronics and Smart Systems
DOI: 10.54254/2755-2721/9/20230107

Research on digital production of agricultural machinery based on mathematical modeling

Bohao Liang

Shanghai Dianji University, Shanghai, 201306, China

L2235608940@outlook.com

Abstract. Agricultural production is a basic industry that can make a country thrive, and agricultural machinery can guarantee the efficiency and development of agricultural production. However, at present, agricultural mechanization production in many countries is still facing various problems, so reasonable measures should be taken to improve the current situation. With the rapid development of digital technology today, digitization of agricultural machinery can well solve some existing problems. In order to meet the needs of agriculture, this study uses mathematical modeling technology to discuss the digital production of agricultural machinery. The results show that the optimization of production through mathematical modeling technology can significantly improve the quality of equipment, reduce manufacturing costs, enhance production efficiency, and promote agricultural development.

Keywords: mathematical modeling, digitization, manufacturing technology, agricultural machinery.

1. Introduction

With the progress of science and technology, agricultural machinery is becoming more and more popular, and agricultural production is gradually moving towards digitalization. The perfect combination of machinery manufacturing and digital information plays an important role in agricultural development. However, in the production process of agricultural machinery, there are many irregular and complex parts. The requirement for precision is very strict, which has brought great challenges to the production process. At present, mathematical modeling is closely related to the development of modern agriculture. Mathematical modeling has the characteristics of digitization and intelligentization, which can provide information resources and more accurate data for agricultural mechanization production. This paper summarizes the characteristics of agricultural machinery, introduces the concept and classification of digital design and manufacturing technology, and analyzes the application of digital modeling technology in agricultural machinery production. This paper can help readers understand the latest progress and research trends in the field of digital production of agricultural machinery.

2. Characteristics of agricultural machinery

Since the users of agricultural machinery are mostly farmers who did not receive higher education, the complexity of agricultural machinery is generally at a low level and the product structure is relatively simple. It is mainly composed of a transmission system, crankshaft, machine parts, and other basic

DOI: 10.54254/2755-2721/9/20230107

structures. Although the application and performance of different agricultural machinery are different, the basic structure is similar [1].

However, there is still a large amount of agricultural machinery with relatively complex structures, bringing many difficulties to farmers' daily use. The digital template design is concise, which is conducive to the development of agricultural machinery digital technology. In the field of agricultural production, all mechanical equipment is designed to be suitable for some specific agricultural work after a series of upgrades and improvements based on agricultural technology. In this process, the combination with advanced agricultural technology is the core. Common planters, coolers, and irrigators are all products of a combination of technologies. Agricultural machinery production is a more complex process, involving a number of professional fields. By integrating some advanced high-end science and technology to improve and innovate, agricultural machinery production can be more accurate and efficient, further promoting the development of agriculture [2].

From the simplest mechanical structure in the early years to the one that combines with advanced technology now, not only the production efficiency, but also the production conditions have been improved, and the production level has reached a new height. In a word, agricultural machinery production not only keeps up with the pace of the changing times, but also conforms to the development of productivity levels.

3. Digital design and manufacturing technology

3.1. The concept of digital design and manufacturing technology

Digital design and manufacturing technology refers to the overall and comprehensive fitting of relevant product analysis, design, assembly, and production steps through computer software and network environment. It can provide accurate and reliable data information for the actual production process. In the design and production process of agricultural machinery, adopting digital design and manufacturing technology can help improve the quality of agricultural machinery and equipment, shorten the research and development cycle of products, and reduce the research and development cost of agricultural machinery, thus better realizing the design purpose. From an economic point of view, it can improve the market competitiveness of agricultural machinery manufacturing-related enterprises, and bring more considerable economic benefits.

3.2. Classification of digital design and manufacturing technology

Up to now, digital design and manufacturing technology mainly includes modeling technology, finite element analysis technology, simulation technology, and virtual reality technology. Digital modeling technology is divided into two parts: product modeling and process modeling. Product modeling refers to the design of parameters based on the characteristics of agricultural machinery. The specific design content is the three-dimensional construction and virtual assembly of each part. Process modeling refers to the modeling work of optimizing the processing process of each part of agricultural machinery. It can significantly improve the precision and progress of processing. Finite element analysis technology can analyze the stress distribution by imposing loads on the completed production of agricultural machinery parts, thereby avoiding the stress concentration caused by deformation, failure, and other problems, extending the service life of the parts, and optimizing the agricultural machinery products. Digital simulation technology combines simulation analysis software and finite element analysis to study the mechanical performance of agricultural machinery and equipment transmission systems and check whether the design structure is defective, so as to optimize and further improve the quality of products. Virtual reality technology can simulate the assembly of agricultural machinery parts and the subsequent operation, so as to verify the dynamic characteristics of agricultural machinery more conveniently [3].

DOI: 10.54254/2755-2721/9/20230107

4. Digital modeling technology and agricultural machinery production

4.1. Requirements of digital modeling technology for modern agricultural machinery production

Digital modeling technology plays a core role in the design and optimization process of agricultural machinery. With the continuous development and progress of modern agriculture, the requirements for the digital production of agricultural machinery for modeling technology are also increased. The modern agricultural machinery design process and mathematical modeling are inseparable. Establishing a scientific and reasonable mathematical model during the design process will be a good solution to the problem in the traditional design scheme. The requirements of mathematical modeling for modern agricultural machinery design are as follows: 1) it should be consistent with the level of computer software at the present stage. 2) It can still ensure accuracy under different constraints. 3) The model design objectives, process, and results should be clearly indicated to reduce the difficulty of subsequent processing work.

4.2. Application of digital modeling technology in agricultural machinery production

In the current agricultural machinery design, the application of mathematical modeling is very extensive. So far, theoretical analysis is the main mathematical modeling method used in agricultural machinery design. The theoretical analysis method is to further analyze the causality and correlation of agricultural machinery facilities according to their own attributes, and then use mathematical tools to elaborate its quantitative characteristics under ideal assumptions, so as to achieve the purpose of constructing the model scientifically and reasonably. The essence of the application of mathematical modeling to agricultural machinery design is to establish the optimization of mechanical design into a specific mathematical model. Through computer software, the model can be transformed into mathematical problems for analysis. Compared with the numerical solution, the analytical solution is usually difficult to get, so in the process of solving, a variety of advanced computing equipment is essential, such as computer software and network technology. At the same time, it is necessary to use some mathematical solution methods, such as numerical analysis, numerical optimization, linear and nonlinear programming, numerical solution of differential equations, and probability theory.

4.2.1. Optimization of design scheme. With the rapid development of the manufacturing industry, the design and production of agricultural machinery are gradually moving towards informatization and integration. The rational use of digital technology can significantly improve the quality and efficiency of agricultural machinery production [4]. Taking the processing of irregular parts in agricultural machinery and equipment as an example, in order to ensure that the dimensional accuracy of parts can meet the requirements of processing and production and avoid conflicts between various processes, the processing of parts can be optimized based on mathematical modeling technology, thus improving production efficiency. In the process of parts processing, the time required by parts mainly includes processing time and transmission time. At this point, assuming that $t_{i,1}$ is the processing time of the ith part and $t_{i,2}$ is the transportation time of the ith part, so the time required for processing n parts is $T = \Sigma(t_{i,1} + t_{i,2}) = At$, where $t_{i,2} = \Sigma t_{i,1} (1 < i \leq n)$, $i = 1$, $A = (n, n-1, \ldots, 2, 1)$, and $t = (t_{i,1}, t_{i,2}, \ldots t_{n-1,1}, t_{n,1})$.

In order to meet the individual processing parts consumption, the shortest time $(T) = \text{total } \min T/n$ at this time, and $t_{i,1} \leq t_{i+1,1}$ should be guaranteed [5]. In addition, the bubble method can be used to process working procedure time to plan to quickly get the process steps. However, if it is found that there is a limit to the end time of agricultural machinery processing when obtaining the process information, each process time is supposed to be made brief within the limit. Suppose that the time required for the completion of a part is P_i, and its processing steps can be characterized as $y = (y_1, y_2, \ldots y_{n-1}, y_n)$, with the constraints at the beginning of the process, the processing time for parts is $t_{i,1} = (t_{1,1}, t_{2,1}, \ldots t_{n-1,1}, t_{n,1})$, and n is the maximum number of parts processed under the condition of ensuring completion. In the process of machining parts, the machining selection mode can be expressed as follows:

DOI: 10.54254/2755-2721/9/20230107

$$y_1 = t_{1,1}X_{1,1} + t_{2,1}X_{1,2}+\ldots+t_{n,1}X_{1,n} \quad (1)$$

$$y_2 = t_{1,1}X_{2,1} + t_{2,1}X_{2,2}+\ldots+t_{n,1}X_{2,n} \quad (2)$$

$$y_{n-1} = t_{1,1}X_{n-1,1} + t_{2,1}X_{n-1,2}+\ldots+t_{n,1}X_{n-1,n} \quad (3)$$

$$y_n = t_{1,1}X_{n,1} + t_{2,1}X_{n,2}+\ldots+t_{n,1}X_{n,n} \quad (4)$$

When the ith part is j, then Xi and j in the original formula $y_i = t_{i,n}X_{i,1} + t_{i,n-1}X_{i,2}+\ldots+t_{i,1}X_{1,n})$ can be 1, and the rest can be 0. At this time, the constraint conditions of the objective function $(T) = \text{total min}T/n$ and $T = \Sigma(t_{i,1} + t_{i,2}) = At$ include: $\sum i = 1Xi, j \le 1$; $\sum j = 1Xi, j \le 1$; $\sum i = 1ti, 1Yi \le pj$, where $1 \le i, j \le n$. The part is labeled according to whether it has finished machining or not, and it is denoted as matrix Y. If the part i has been machined, it is denoted as Yi=1. Otherwise Yi=0 [6].

Due to the relatively large amount of calculation of this mathematical model, in the actual processing and production process of parts, the method of computer programming can be applied to complete the integration and layout of the working process, and then the processing process optimization can be done to reduce the time required for processing and transportation as much as possible and improve the overall work efficiency [7].

4.2.2. Optimization examples. Upland gap plant protection machine plays a very important role in paddy field operation. In order to ensure that it can adapt to different paddy field environments, its design can be optimized to improve the efficiency of rice production [8]. The outline of the paper-wrapped chicken fillet should be determined first. Its overall shaft length is set as L, width as B, and ground clearance as H. Generally speaking, the larger the site wheel pitch of the plant protection machine, the better the maneuverability. But because the mass will also increase, the amount of tire subsidence will also increase, thus reducing maneuverability and bringing safety risks. Therefore, the coordination among H\B\L should be optimized. Let B=kL (k is a constant, ranging from 0.55 to 0,64) [9]. Considering the actual factors of vegetation conditions and production steps, the preliminary wheel pitch is set as 1300~1800mm, the shaft length as 1800~2200mm, and the ground clearance as 1200~1400mm. In order to obtain the best equipment parameters, the mechanical properties can be further explored by constructing a mathematical model, applying digital technology, and being combined with stress-strain analysis and finite element analysis. Integrated B is 1400~1600mm; L takes 1800mm; H takes 1266~1487mm as the optimal parameter value. In the production process, the above parameters can be adjusted and optimized according to the actual situation to further improve work efficiency. Through the introduction of digital agricultural machinery design production, and based on the mathematical modeling of the way to optimize the production process, the costs can be reduced while the efficiency can be improved, thereby enhancing competitiveness and driving economic development [10].

5. Conclusion

In short, the integration of digital technology and mechanical manufacturing technology can better realize design optimization and efficient production, which can well promote agricultural development and thus promote economic prosperity. At the same time, in the digital production of agricultural machinery, mathematical modeling plays a vital role. Its core lies in the introduction of mathematical knowledge, so that the problem can be more clear and the solution can be more flexible. The digitalization of agricultural machinery has become a trend in the changing times, and the application of mathematical modeling techniques to agricultural machinery also conforms to the trend of science and technology. In the future, each manufacturer should conform to the tide of science and technology so that product research and development can be developed in the direction of digitization, intelligence, and automation.

References

[1] An, H. F. (2018). Development and design of remote monitoring system for agricultural

DOI: 10.54254/2755-2721/9/20230107

machinery Operation [J]. Agricultural Science and Technology and Assembly (1), 47-49.
[2] Li, Y. (2018). Problems existing in the application of remote monitoring system for deep Loose operation of agricultural machinery and suggestions for improvement [J]. Agricultural Machinery Operation and Maintenance (8), 95.
[3] Zhao, P. Y. (2020). Research on digital design of agricultural machinery based on mathematical modeling [J]. Journal of Agricultural Mechanization Research 42(10), 243-246.
[4] Li, Y. Q. (2019). Research on the application of dynamic optimization method in agricultural machinery design [J]. Journal of Shandong University of Agricultural Engineering 36(6), 13-14.
[5] Ma, C. (2020). Application analysis of modern digital design and manufacturing technology in agricultural machinery design and manufacturing [J]. Internal Combustion Engine and Accessories (2), 232-233.
[6] Luo, Z. J. (2018). Application of virtual prototype technology in agricultural machinery design [J]. Southern Agricultural Machinery 49(24), 76+78.
[7] Shen, C. J., Kong, X. J. and Gao, S. H. (2006). Application of modern design technology in agricultural machinery engineering design [J]. Agricultural Mechanization Research (6), 189-191.
[8] Gao, G. Z. and Ma, M. Y. (2020). Discussion on application of bionic design in agricultural machinery design [J]. Guangxi Agricultural Mechanization (3), 25-26.
[9] Wang, H., Jin, J. and Zhang, X. Y., et al. (2022). Development and design of agricultural machinery operation monitoring system [J]. Agricultural Development & Assembly (3), 50-52.
[10] Yuan, Y., Li, S. W. and Wang, W. W., et al. (2007). Application of software platform in remote monitoring system of orchard ecological environment [J]. Transactions of the Chinese Society of Agricultural Engineering (6), 186-188.