Research on Intelligent Design Method and Technology of Grenade Driven by Digital Twin

Che Yi [1], Liwei Liu [2,*], Hao Bo [2], Wanjiong Wang [2], Yang Bin [2]

[1] Southwest Technology and Engineering Research Institute, Chongqing, China

[2] School of Mechanical Engineering and Automation, Northeastern University, Shenyang, China

* Corresponding Author Email: 2172253@stu.neu.edu.cn

Abstract. In order to change the design method of grenade based on hand drawing and traditional CAD numerical calculation, solve the problem of long design cycle caused by repeated design because the result of grenade design does not meet the tactical index, and promote the transformation of grenade design to the direction of intelligence, based on the concept and architecture of digital twin, a five-layer structure model of the intelligent design system of grenade driven by digital twin is established, and the relationship and connotation of each layer are analyzed: the preliminary realization scheme of applying digital twin technology and intelligent design technology to grenade design is discussed, which provides theoretical reference for subsequent practical application.

Keywords: Digital twin, Grenade, Intelligent design, Process twin.

1. Introduction

With the rapid development of science and technology, in the process of product design, digital twins can be used to build an intent model to improve the accuracy of the design and verify the actual performance of the product [1]. Digital twin is to establish a virtual physical entity model in a digital way, use big data to simulate the behavior of physical entities in the real environment, and use technical means such as virtual-real interactive response, data fusion analysis, decision iteration and optimization, and then add and expand new capabilities to physical entities; as a modern technology that takes full advantage of simulation, data, intelligence, and fusion of multi-disciplinary features, digital twin services are oriented to the entire production (life) cycle process of products, serving as a link between the information world and the physical world. It acts as a bridge and link between the world and provides more real-time, efficient and intelligent services [2]. Due to the complexity and high cost of digital twin, the technology is currently mainly used in some high-precision manufacturing fields such as aerospace, automobile manufacturing, process industry and smart factories [3].

The grenade is one of the most expensive, widely used and fast-modified ammunitions in the naval, land and air forces. It has the characteristics of many varieties, variable batches and mass production. In developed countries such as the United States and other developed countries, the development of grenade is very fast, and different warheads can be developed within two weeks according to the specific characteristics of the tactical target. In China, some research results have been achieved in the expert system of intelligent design of grenade [4] and the digital design and analysis platform of grenade [5], but the research results of applying digital twin technology to the intelligent design of grenade have not been reported.

This paper introduces the combination of digital twin technology and grenade intelligent design technology and applies it to grenade design work. Driven by the digital twin, the design process of the grenade is accurately mapped to the digital platform, and the fusion analysis of application flow, data flow and information flow is realized [6]. And according to the design result data of the grenade plan, simulate, evaluate and modify the design data of the grenade to realize the intelligence of the grenade design process.

2. Intelligent Design Method of Grenade Driven by Digital Twin

The intelligent design method of grenade driven by digital twin is based on data and model, and takes the data transmission and information feedback between physical space and virtual space as the way to construct digital twin, which realizes real-time monitoring, guidance, evaluation and modification of high explosive projectile intelligent design process. Its architecture is shown in Fig.1.

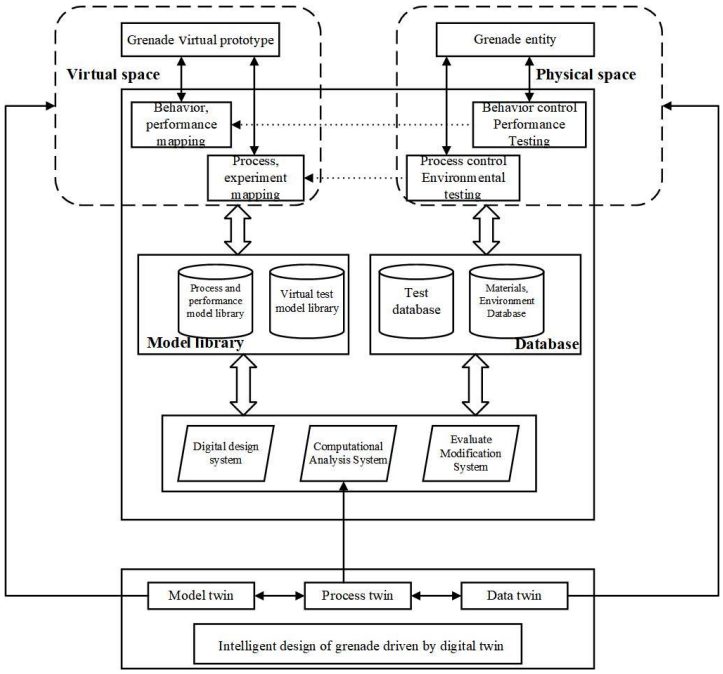


Figure 1. Architecture of intelligent design method of grenade driven by digital twin

In the architecture shown in Fig.1, the digital twin technology is a refined digital description of the product entity. Through the simulation experiment of the digital model, it can more truly reflect the characteristics, behavior, formation process and performance of the physical product, and manage the entire life of the product. The periodic related data has the ability to interact between virtual and real, so as to realize the correlation mapping of real-time collected data to the digital twin, so as to identify, track and monitor the product, and at the same time, through the digital twin to predict and analyze the behavior of the simulation object, fault diagnosis and Early warning, problem location and recording, and optimization control [7]; according to the category of objects to be processed, it can be divided into digital twin technology of grenade design data, digital twin technology of grenade design model and digital twin technology of grenade design process, as follows:

The purpose of the data twin is to comprehensively map the projectile structure, material, performance, technology and other information involved in the intelligent design of the grenade in the virtual space, which is the virtual and real consistency of the digital twin of the grenade at the data level. The realization of data twinning is the basis for realizing digital twin and intelligent design of grenade, including structural twin data, material twin data, performance twin data and technical twin data.

Model twin is an abstract description based on data twinning, which is a set of functions or equations that define relationships between data. grenade twin model is of shrapnel in the virtual space structure relations, the relations between performance and behavior, the internal and external environment, behavioral decision, such as part of the map, including used to describe the grenade structure and shape of the structure model, process model is used to describe a grenade process characteristics, is used to describe a grenade simulation model performance and behavior of disciplines, An organizational model for describing grenade design team members, an environmental model for describing different environmental characteristics and a design decision model for describing design knowledge. Models interact with each other through twinning data, and the evolution of models and the relationships between models in different fields are reflected through

process twinning. With the development of grenade 's whole life cycle, the model twinning changes from simple to complex, and finally forms a multi-level twinning model network with longitudinal depth and transverse complexity [8].

Process twin is a higher-level twinning based on data twin and model twin. Its purpose is to model and manage the dynamic evolution process of macro-tasks and the process of micro-design exploration in the grenade design process, forming the grenade design process in the virtual space. Mapping, creating a digital model of the grenade design process. Through the orderly management of the virtual process, the correct people can be controlled to correctly complete the predetermined design activities in the real world under reasonable time constraints. Through virtual-real iteration, the resource redundancy and conflict in the design process are eliminated, the design efficiency is improved, and finally the convergence and closed loop of the design process are realized.

The reasoning design process in the intelligent grenade design method is shown in Fig.2 [9]: (1) Establish tasks according to tactical indicators: select inference tasks according to the technical indicators required in the task book. (2) Determine the design characteristic parameters according to the technical requirements, and deduce the main structural characteristic parameters of the grenade scheme design. (3) Select a preliminary scheme from the knowledge base: According to the main structural characteristic parameters given by reasoning, select a design scheme from the knowledge base, and modify it to form a preliminary scheme. (4) The input driving parameters are inferred into a new scheme: the preliminary scheme formed is driven according to the given number of main structural features and the projectile design driving constraint condition memory to form a new scheme. (5) Calculate the structural characteristic parameters of the projectile. (6) Calculate the strength, stability and trajectory of the projectile: Calculate the strength, flight stability and trajectory of the projectile comprehensively according to equations and formulas. (7) Evaluation, that is, testing and evaluating various calculation results. If the assessment fails, go to (8). (8) Modify the design and create a new scheme: According to the design modification suggestion, modify the scheme again, establish a new scheme, and then return to (2). If the assessment passes, go to (9). (9) The design is completed and the data is stored.

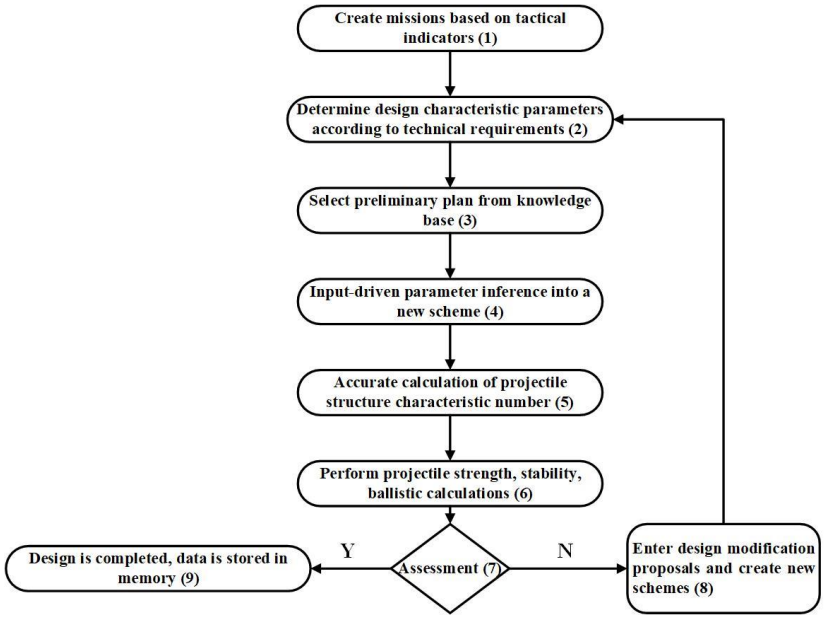


Figure 2. Reasoning design process

In the above definitions, data twin, model twin and process twin are interrelated and complementary, and together with the intelligent design technology of grenade, constitute the intelligent design of grenade driven by digital twin. Data is the underlying driving force in the intelligent design process of grenade driven by digital twin, which is used to store and characterize all the behaviors, phenomena and results of the grenade physical entity and virtual model, and facilitate the operation of the digital twin system; the model is the core engine of the intelligent design

of grenade driven by digital twin, which is driven by data, transforms the theory of ammunition design into application and implementation; the process is the backbone of the intelligent design of the grenade driven by the digital twin, controlling the correct and orderly implementation of the design tasks of the life cycle of the grenade; the intelligent design of the grenade is a digital The main body of the twin-driven grenade intelligent design, it mainly completes the automatic design of the overall scheme of the grenade and accelerates the design process of the grenade scheme.

3. Overall Framework of Intelligent Design of Grenade Driven by Digital Twin

The overall framework of intelligent design of grenade driven by digital twin in this paper is divided into five layers, namely the application layer, the function layer, the technology layer, the model layer and the data layer, as shown in Fig.3. The specific contents of each layer are as follows:

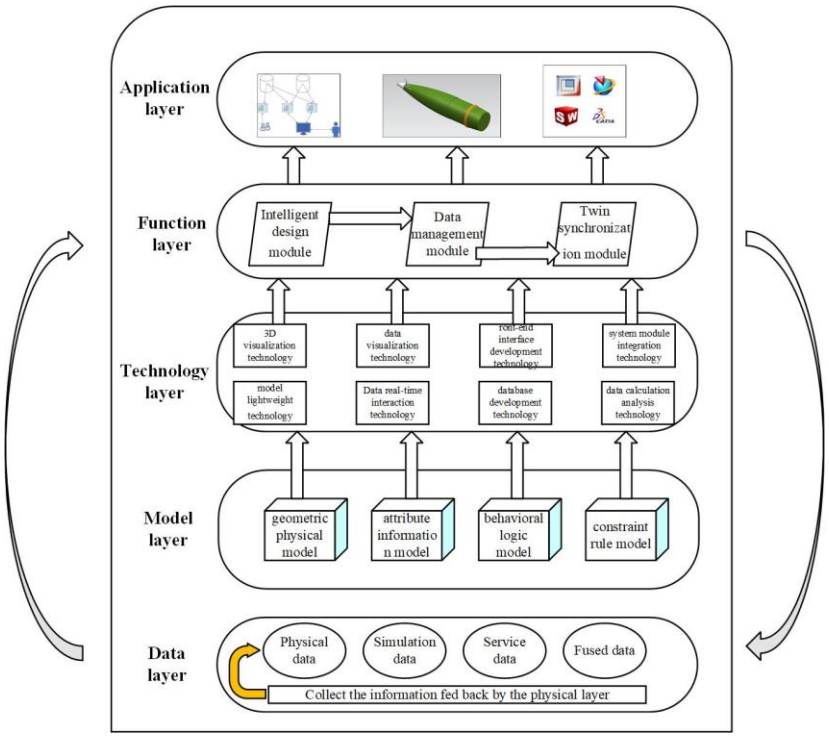


Figure 3. The overall framework of intelligent design of grenade driven by digital twin

(1) Application layer: Provide human-computer interaction interface display for each functional module; provide designers with an intuitive display of the actual design status.

(2) Functional layer: It is mainly composed of three functional modules, the first is the intelligent design module, which is mainly responsible for grenade scheme design, drawing, digital modeling, structural parameter optimization design, strength finite element analysis, ballistic calculation, power calculation, launch process simulation, grenade simulation assembly, comprehensive performance evaluation; the data management module is the basis for the realization of other functional modules. The function of importing the data of the grenade instance file; the last is the twin synchronization module. The feedback data collection function is the basis of the twin synchronization module. In this module, the twin synchronization movement is driven based on real-time feedback data.

(3) Technical layer: The technical layer provides technical support for the realization of its functions. The main technologies involved in the system development process include model lightweight technology, 3D visualization technology, real-time data interaction technology, data visualization technology, database development technology, Front-end interface development technology, data calculation and analysis technology and system module integration technology, etc. [10].

(4) Model layer: The model layer is the core of the entire intelligent design system of grenade driven by digital twin. According to the models established in the design process of grenade

(constraint rule model, behavioral logic model, geometric physical model and attribute information model), it provides the basis for various application implementations of the functional layer.

(5) Data layer: The data layer includes physical data collected by the physical layer, simulation data generated during system operation, business data generated by calculation and analysis in system applications, and fusion data generated by the fusion of the three.

4. Intelligent Design System of Grenade Driven by Digital Twin

The intelligent design system of grenade driven by digital twin mainly completes the data twin, model twin and process twin of the intelligent design process, and on this basis completes the grenade scheme design, modification suggestion, evaluation and other work, its operating mechanism and the relationship between each part is shown in Fig.4:

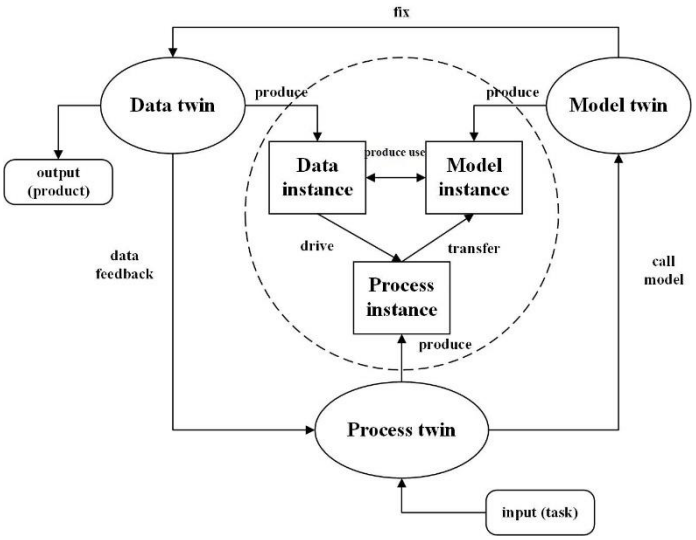


Figure 4. Operation mechanism of intelligent design system of grenade driven by digital twin

The process twin part is shown in Fig.5, which reflects the twinning and operation of the intelligent design process of grenade. This part mainly completes the modeling, control, supervision and operation in the design process of grenade. After the designer receives the input grenade's design task (tactical index), it is input into the digitizing design simulation platform. According to the task requirements, the platform can automatically establish a model of the intelligent design process of grenade; after the modeling is completed, start the design task, and the system will generate a design process instance on the grenade's digital twin, which will complete the control and supervision of the task; at the same time, other designers complete the design work in the instance, and transmit their own instructions to the virtual prototype and physical prototype for parameter modification. At this time, the platform will receive the modified grenade performance feedback, and decide whether to proceed with the next design work according to the feedback results.

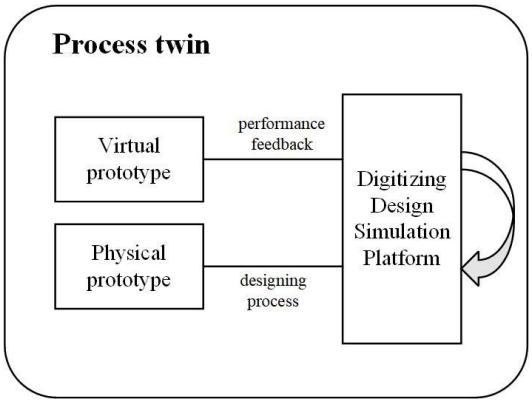


Figure 5. Process twin

The model twin part is shown in Fig.6. Based on the process twin part, according to the purpose of the design task, the system selects the appropriate model from the known model instance library to complete the grenade design and simulation. This part also generates the corresponding model instance on the digital twin, and through calculation and simulation, the characteristic data (performance, function) of the generating grenade will be stored in the database of the data twin.

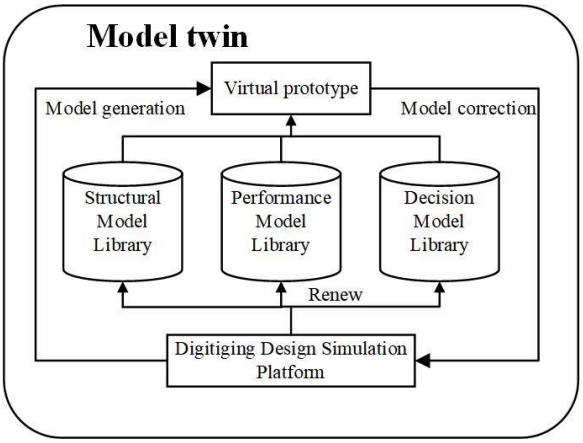


Figure 6. Model twin

The data twin part is shown in Fig.7. This part is mainly responsible for managing the data generated in the grenade's design process. The data of the process twin part and the model twin part will be transmitted here. In the process of intelligent design of the grenade driven by digital twin, this part will generate some data for forming the digital twin of the grenade. These data are generated by model simulation calculation and acquired by sensors in physical space, and their applications are to drive the orderly operation of the intelligent design process of the grenade, to drive the generation and modification of the digital model of the grenade, and to drive the process of manufacturing the grenade.

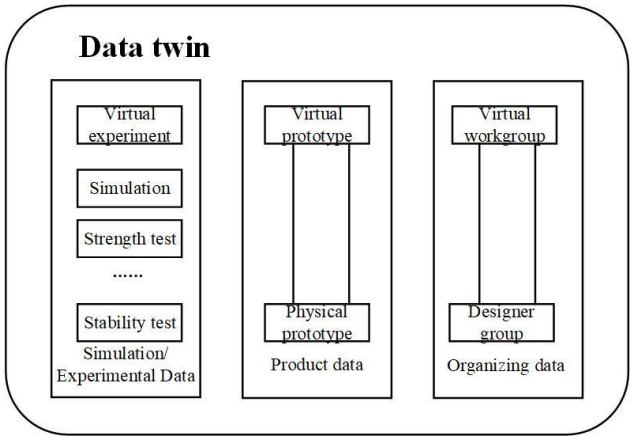


Figure 7. Data twin

The intelligent design system of grenade driven by digital twin can intelligently design, simulate and evaluate by inputting design tasks (tactical performance indicators: range, power, and accuracy), and modify recommendations to obtain grenade products that meet tactical indicators. Due to the limited space, this paper only takes the input design task as an example to demonstrate the intelligent design system of grenade driven by digital twin.

The initial input tactical performance index of the system is the range, so the system carries out the intelligent design of the grenade by increasing the range. Through the digital twin drive and the reasoning design process that is shown in Figure 2, the relevant parameters of the grenade product obtained by the system are shown in Fig.8.

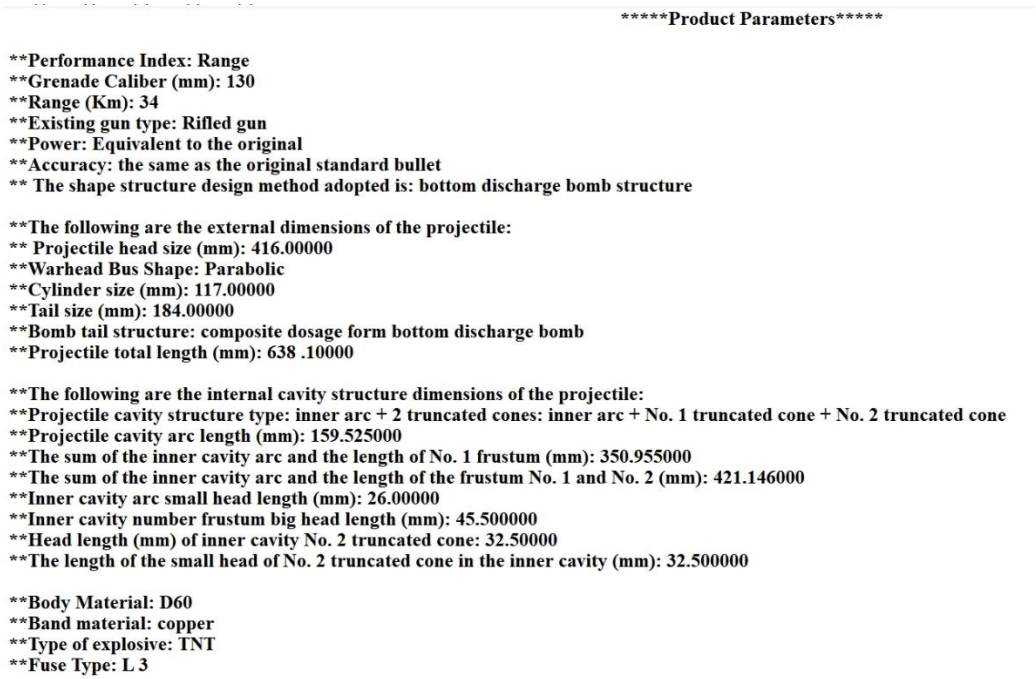


Figure 8. Grenade product parameters

5. Conclusion

The emergence and development of digital twin provides a new way of thinking for the realization of cyber-physical systems, especially the design and development of complex production machinery products involving multidisciplinary knowledge such as mechanical engineering and automatic engineering [11]. The emergence and development of digital twin technology has greatly promoted the intelligence of the product manufacturing process and the product itself. By establishing an intelligent design method of grenade driven by digital twin technology, the design process and state of the grenade can be reflected in the virtual space in real time and accurately. At the same time, the optimized decision-making information formed based on the simulation is fed back to the grenade design process and test site through the digital link, realizing the bidirectional flow of information, making it possible to accurately predict and control the performance and behavior of the grenade design, which is helpful for the realization of the grenade design process and design optimization.

Acknowledgments

This work was financially supported by National Defense Key Fund.

References

[1] Wu Yiting. How does digital twin technology change traditional industries? [N]. Shanghai Science and Technology News, 2021-09-17(003).

[2] Tao Fei, Liu Weiran, Liu Jianhua, Liu Xiaojun, Liu Qiang, Qu Ting, Hu Tianliang, Zhang Zhinan, Xiang Feng, Xu Wenjun, Wang Junqiang, Zhang Yingfeng, Liu Zhenyu, Li Hao, Cheng Jiangfeng, Qi Qinglin, Zhang Meng, Zhang He, Sui Fangyuan, He Lirong, Yi Wangmin, Cheng Hui. Digital twin and its potential application exploration [J]. Computer Integrated Manufacturing System, 2018, 24(01): 1-18.

[3] Wu Yan, Wang Xiaojun, He Yong, Huang Xinwei, Xiao Lijun, Guo Lixin.Review on the technology and application of digital twin in manufacturing industry [J]. Modern Manufacturing Engineering, 2021(09): 137-145.

[4] Yuan Zhihua, Guo Meifang, Hao Bo. Study on High-explosive Projectile Expert system Design [J]. Journal of Ordnance Engineering, 2006(01): 170-174.

[5] Liu Songjian. Development of Digital Design and Analysis Platform for HE [D]. North Central University, 2019.

[6] Wang Hao, He Qianyun, He Ziyang, Zhang Wenyu, Sun Xiaoteng, Lu Xu. Construction and application of automatic operation and maintenance system of "four lines and one warehouse" based on digital twin technology [J]. Industrial Metrology, 2021, 31(06): 51 -55.

[7] Nie Rongmei, Zhou Xiaoya, Xiao Jin, Zhao Bo. Analysis and Perspective on Digital Twin Technology [J]. Aerospace General Technology, 2022, 6(01): 1-6.

[8] Xiao Fei, Zhang Weihua, Wang Donghui, Peng Ke, Qian Fengchen. System architecture and application for overall design of solid rocket motor based on digital twin [J]. Computer Integrated Manufacturing Systems, 2019, 25(06): 1405-1418.

[9] Yuan Zhihua, Hao Bo. A HE intelligent design system and design method [P]. Liaoning Province: CN1315085C, 2007-05-09.

[10] Liu Huanlian. Digital Twin-drive research and development of virtual simulation system for Flexible Manufacturing Line [D]. Southeast University, 2020.

[11] Li Linli, Li Hao, Gu Fu, Ding Ning, Gu Xinjian, Luo Guofu. Multidisciplinary collaborative design and modeling technologies for complex mechanical products based on digital twin [J]. Computer Integrated Manufacturing Systems, 2019, 25(06): 1307-1319.