DEVELOPMENT mode of intelligent system for discrete manufacturing

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Abstract. To solve various problems caused by the uncertainty in the development process of discrete manufacturing industry represented by aerospace of aerospace, an intelligent manufacturing architecture is proposed. Complementary to the system, the procedure for modeling the product variety and quantity uncertainty is described. Furthermore, the key support modes such as model driven parallel collaborative intelligent design, flexible intelligent production of multi system integration, experimental verification of model physical virtual reality fusion are discussed. The intelligent development mode and the logical relationship between the modules of the development system are expounded systematically, and the method to solve the uncertain problem in the development process is discussed from the perspective of operation mode. It has reference value for the subsequent construction of advanced manufacturing system and the realization of high-efficiency, high-quality and high-efficiency research and production of the products.

Keywords: uncertainty; discrete manufacturing; intelligent manufacturing; development mode

1 INTRODUCTION

The discrete manufacturing industry represented by aerospace industry generally has the characteristics of multi-variety and variable-batch [1-2], which emphasizes the uncertainty of processed objects in production, mainly including the uncertainty of product variety and product quantity [1-3]. Nevertheless, the problems, such as numerous design types and heavy workload, frequent production conversion and difficult to accurately implement the plan, difficult to ensure quality consistency and low production efficiency caused by the Uncertainty, can be solved effectively by intelligent manufacturing [4]. Accordingly, it is of great significance to improve the efficiency and quality of aerospace product development by conducting research on intelligent manufacturing and forming a development mode for intelligent manufacturing, which is also one of the key areas of national defense construction and military industry development.

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Many studies have been conducted on intelligent manufacturing. Around the theory and methods, the upgrading route analysis model of three basic paradigms of digital manufacturing, digital networked manufacturing and new generation intelligent manufacturing had been studied as well as the overall architecture of intelligent manufacturing, and the connotation, characteristics and technical system for new generation intelligent manufacturing had been emphatically discussed [5-7]. Around the system, the elements such as the architecture of discrete intelligent manufacturing, the hierarchical model of intelligent manufacturing system and the technical characteristics of each level and the reference model of socialized collaboration of alliance level intelligent manufacturing system were proposed [8-10]. In addition, the application framework, challenges, application direction [11, 12] and application system [13, 14] of the big data considered as the key supporting technology were elaborated. Around the application, the basic characteristics, framework and key technologies of intelligent factory were discussed [15], and the construction idea of new intelligent interconnected factory based on "industrial operating system industrial app" was put forward [16] as well as the main contents and key technologies to be overcome in the construction of intelligent factory [17]. Furthermore, the system structure and operation framework of intelligent workshop were studied [18] as well as the optimization and Simulation of large-scale ship welding intelligent workshop framework and workshop production line [19] by the background of the key supporting enterprises of ship power. In addition, with the background of the aviation intelligent production line, the technical framework, basic key technologies and construction ideas were put forward, and preliminary demonstration and application were carried out [20].

The intelligent manufacturing involves the whole product system, involving a wide range and complex process, and many problems still need to be discussed. In view of this, it is necessary to fully use the previous research results for reference to carry out the research on discrete intelligent development mode, which has reference value for the further development of intelligent manufacturing technology and the construction of advanced intelligent development system.

2 Architecture of discrete intelligent development system

The framework of discrete intelligent development system represented by aerospace includes base layer, integration layer, operation layer and application layer, as shown in Figure 1.

The basic layer includes industrial Internet, information security and management, intelligent equipment, Full lifecycle management, Full lifecycle data center, etc. It mainly provides interconnection environment, various hardware equipment, information management and data analysis means for intelligent research and production. The “Full lifecycle data center " collects and stores the full life cycle data such as design, process, production and test.

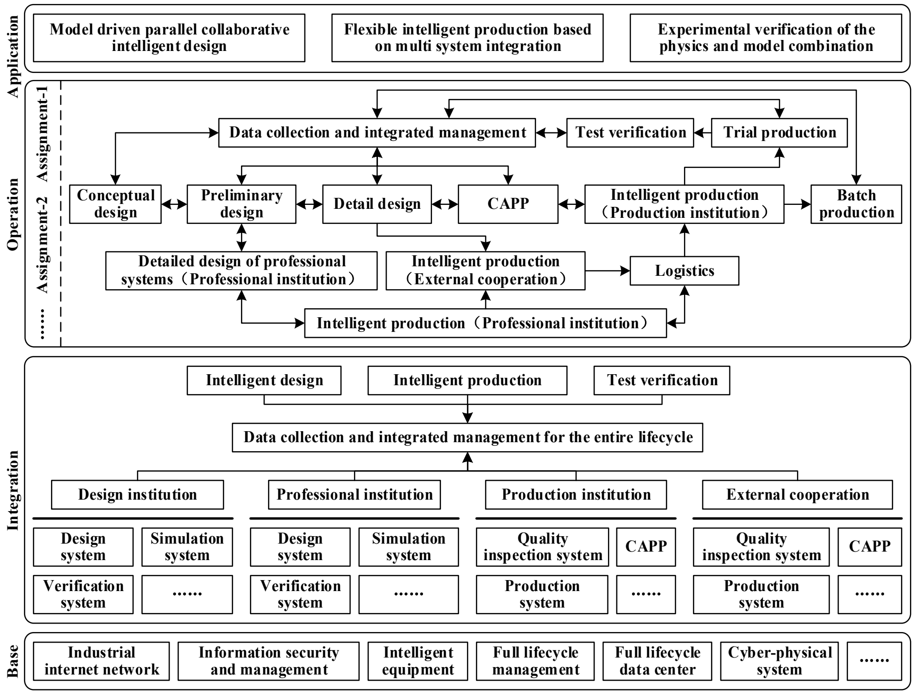

Fig. 1. Architecture of discrete intelligent development system

The integration layer mainly realizes intelligent design, intelligent production, test verification, data acquisition and integrated management through the cooperation and system integration of design institute, professional institute, production institutes and external cooperation. Among them, the design institute is responsible for demand analysis, conceptual design, overall design and detailed design, the professional institute is responsible for the development and production of key systems with strong professionalism, the production institute is responsible for the production of parts and components and product assembly, and the external cooperation is responsible for the production of outsourced parts, etc. "Data collection and integrated management for the entire lifecycle" realizes the data collection, storage and management of product development and production process, The hidden association relationship is obtained through data mining, which provides the basis for optimizing product design and production.

The main functions of the operation layer are product-oriented development and production tasks, completing tasks according to intelligent design, intelligent production, test and verification and other processes. Furthermore, the product development process data is collected, stored, mined, analyzed, decided and applied by “Data collection and integrated management for the entire lifecycle”. Furthermore, after completing the overall design, the subsystem development and production task will be sent to the professional institute for development and production. After the detailed design is completed, the parts to be outsourced and purchased will be sent to the external cooperation for production and purchase. All kinds of parts and components developed and produced by professional institute and external cooperation need to be delivered to the production institute for final assembly.

The application layer mainly includes model driven parallel collaborative intelligent design, flexible intelligent production based on multi system integration, and Experimental verification of the physics and model combination. The function is to quickly generate conceptual prototypes according to product tasks around the variety and quantity uncertainties in the product development and production process, and quickly organize and complete the overall design, detailed design, and trial production and test verification based on the conceptual prototypes under the concurrent design and manufacturing and virtual verification architecture. The production system can carry out production tasks according to multiple varieties, batches and different quantities quickly adjust the production system and complete production tasks.

3 Mode of discrete intelligent development system

As shown in Figure 2. Firstly, based on the customer demand such as task mission, application environment and function/performance indicators, the functions and behaviors representing the product task requirements are determined, and the relationship between task requirements and functions/behaviors is established through a model. Then, combined with the basic conditions and development capabilities of the product development institute, the Multi scheme conceptual models that meet the task requirements and functions/behaviors are quickly generated by the overall design department based on data analysis (such as case, neural network, big data mining) and knowledge reasoning (such as analogy, rules). Furthermore, the conceptual model is optimized by combining the virtual real fusion test and multi-objective comprehensive evaluation optimization model of the overall product in the use environment. Finally, the conceptual design scheme is preliminarily selected through multiple communications with the task demand institute, and the conceptual design scheme and model are determined on the basis of multiple iterative optimization.

While carrying out the conceptual optimization design, the preliminary overall design is carried out and the corresponding design model is formed. After determining the conceptual design model, the overall design is completed on the basis of the preliminary overall design model by the methods such as data mining, virtual simulation and multidisciplinary design optimization el, and the overall design digital model, calculation report and design report are formed. While carrying out the overall design, the general assembly and commissioning process design model is formed by the simulation tools and process design knowledge. As the overall design is completed, the overall design model and technical requirements will be sent to the structural design department, and the professional system overall design model and technical requirements will be sent to the professional research and production unit (Professional Institute).

While carrying out the overall design, the preliminary detailed design is carried out by the structural design department and professional institute, and the preliminary detailed design model is generated. As the overall design model determined, the design of components and parts, hydraulic/control system, test platform, tooling, strength calculation and verification are completed based on the preliminary detailed design model and various simulation analyses, data mining and numerical simulation tools, and the detailed design model and corresponding design report are also formed. While carrying out the detailed design, designers and technologists cooperate in process design. As the detailed design completed, the process design scheme of parts processing, parts assembly and general assembly are determined, and the parts, components and supporting equipment (such as process equipment and test platform) that need to be outsourced, the standard parts and technical requirement that need to be purchased are send to the external cooperation for production or material preparation as required.

While completing process design, production preparation is carried out. The flexible intelligent production units and production lines are formed by the resource integration and adjustment. Furthermore, the parts are processed according to process requirements, and the final product are assembled finally. In the trial production stage, the various tests of the product in stages, verifying whether the product's functions and performance meet the design requirements are completed by the combination of simulation and physical experiments, as well as the current defects and deficiencies of the product, and the data and basis for subsequent design optimization and production optimization adjustments are provided. As the trial production completed, the overall design and detailed design model are optimized and adjusted based on experimental data, and the process adjustments, production adjustments, and organizational reproduction are carried out. Finally, qualified products are delivered to the customer. Among them, professional institutes and external cooperation is responsible to complete the development and production of components as required, and the timely delivery of components is finished after production is completed. The data center achieves the collection, storage, analysis, mining, and prediction of development trends of full lifecycle data, obtaining valuable information and providing support for product development and production optimization. It should also be noted that since the product development and production are focused in the paper, the logistics system will not be discussed.

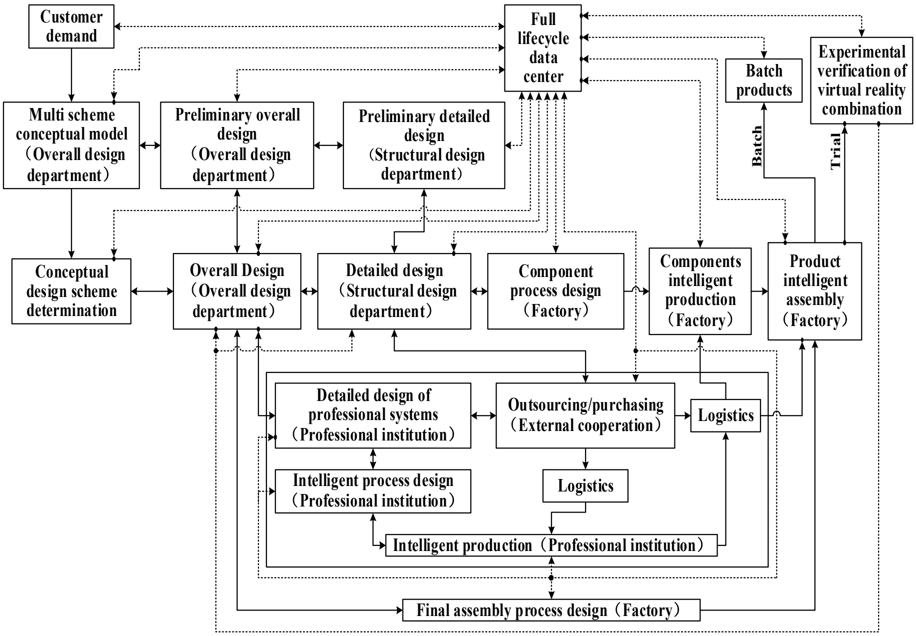

Fig. 2. Mode process of discrete intelligent manufacturing system

4 Key mode support of Intelligent System

4.1 Model driven parallel collaborative intelligent design

The process of model driven parallel collaborative intelligent design mode is shown in Figure 3. According to the characteristics of uncertain customer demands and varieties, the design, trial production, test and design finalization of products through knowledge base, data analysis and decision-making, parametric model, etc. can be quickly completed by the design institution, which mainly reflecting the mode characteristics of model driven, parallel collaboration and virtual verification.

(1) Model driven. The digital model runs through the whole process. Firstly, According to the product task/mission, function/performance, using environment and other requirements proposed by customers, a function/performance model representing customer demands is established based on existing knowledge and models to form a quantitative relationship between customer demands and product behavior, that is, customer demands and product behavior can be mutually corresponding and parametrically adjusted. Then, according to the product behavior index, a multi scheme conceptual design model is formed to represent the realization principle of product sizes, shape layout, function/performance and other behaviors. After expert evaluation and decision-making, customer confirmation, the conceptual design model is selected and further determined through multiple reviews and optimization. Next, the overall design model is formed on the basis of conceptual design, mainly including Component classification/connection method, functional components selection and fixation, ma-

chine/electric/hydraulic/control/thermal function/performance parameterization, multi parameter optimization and integrated design, etc., and the overall design model is determined through reviews and optimization. Finally, based on the overall design model, the detailed design model is determined through several reviews and optimization. In addition, the general assembly process is generated based on the overall design model, and the parts manufacturing process is generated based on the detailed design model. In the product design process, the inheritance and association among customer requirements, conceptual design, overall design, detailed design, process design, and even processing process inspection models are realized through digital models. Furthermore, each model can be analyzed, judged, and automatically adjusted according to the adjustment of other models.

(2) Parallel collaboration. The design process reflects the collaboration between conceptual design, overall design, detailed design, and process design. Firstly, while conducting the multiple conceptual designs, the preliminary overall design models for each conceptual design model are completed. Furthermore, the preliminary overall design model is modified synchronously with the optimization of the conceptual design model after the evaluation and selection of the multi scheme conceptual design model and used as input for the overall design. Then, while conducting the overall design, the preliminary detailed design and assembly process design are completed. Similarly, the preliminary detailed design model is modified as the overall design model is optimized and used as input for detailed design. Finally, while conducting detailed design, a component process model is generated, and the production and assembly process models of the components are modified with the optimization of the detailed model. Through the collaboration of conceptual design and overall design, overall design and detailed design, as well as the collaboration of assembly process, detailed design and process design, the parallel collaborative design based on a unique data source is achieved, which meets the requirements of model based mutual inspection and verification, model correlation and adaptive adjustment, efficient and fast optimization design, and can detect potential design problems in advance and make timely modifications.

(3) Virtual authentication. The integration of knowledge, simulation, and physical objects reflects the digitization and intelligence of design. On the one hand, the independent analysis, evaluation and optimization based on design requirements are realized through the sorting and refining of design knowledge and the application of big data technology, and the design scheme is automatically generated to achieve intelligent design. For example, demand models are automatically generated based on customer needs and supported by knowledge and big data, and the conceptual design model is automatically generated based on the requirements model and the capabilities of the development institution. On the other hand, the functional performances, working state, manufacturability, etc. of the product in the usage environment are verified by simulation to verify whether the design parameters and indicators meet the design and process requirements. In the conceptual design phase, the working condition of the product is simulated in use using by a high simulation model to verify whether the appearance and layout meet customer needs, in the overall design stage, whether each subsystem operates efficiently is verified through multi parameter de-

sign and optimization simulation, and in the detailed design stage, whether each part can achieve machining is simulated by simulation methods. Finally, the few physical experiments are used to further verify and confirm the key links of the design. Furthermore, through the data mining and design knowledge support, the current problems and defects were identified, and optimization plans were proposed.

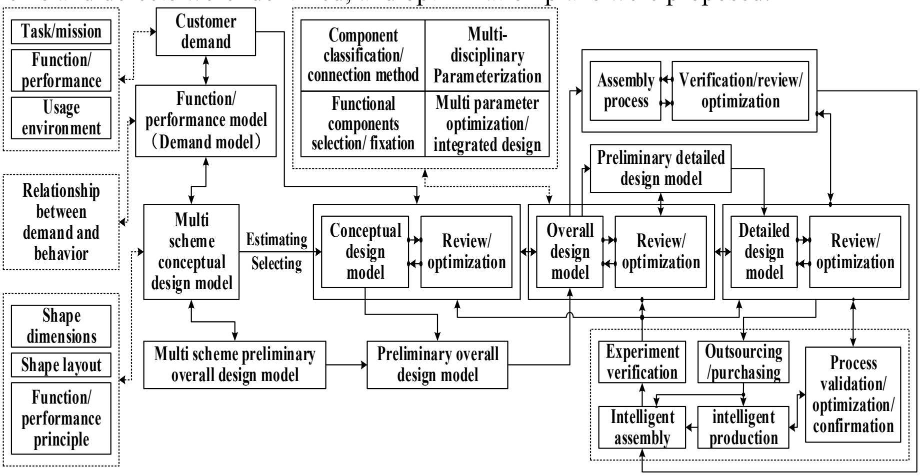

Fig. 3. Intelligent design mode process of discrete intelligent manufacturing system

4.2 Flexible intelligent production based on multi system integration

Focusing on the production characteristics of uncertain varieties and quantities, according to the production task, production process and bill of materials, the company formulates production plans, adjusts manufacturing resources and reconstructs the production line, completes material preparation, inspection preparation, tooling/fixture preparation, and then completes production according to the production plan and production process, as shown in Figure 4, reflecting the mode characteristics of system integration, flexible reconfiguration and intelligent production.

(1) System integration. The intelligent production system is integrated by multiple systems with different functions, mainly including production intelligent control, material management, production line, detection and quality management, manufacturing resource management and other systems. The intelligent control system formulates the schedule of production line reconstruction, warehouse material preparation, etc. according to the production plan, and by which the intelligent production scheduling is also executed, and the material distribution instructions are send to realize distribution. Furthermore, the information such as the execution of production scheduling plan, production status, material preparation and distribution, and production line operation is collected by the system to realize the analysis and optimal control of the production process. The material management system includes the management of warehouse materials, material procurement, material warehousing, material distribution, etc., to ensure the timely and accurate distribution of materials to the workshop during the production process. The production line system is composed of multiple

stations, which include intelligent production equipment, flexible process equipment, automatic detection system, etc. The timely and accurate distribution from the workshop to the production line is realized by the intelligent distribution system, and the control and optimization adjustment of the implementation for the production line is executed by the intelligent control system. The detection and quality management system detects the key quality points in the production process according to the process specification based on the three-dimensional detection model, further realizes the management and analysis of the collected data, and excavates the potential quality problems and realizes the traceability of quality problems. The manufacturing resource management system mainly manages and allocates the manufacturing resources of the whole workshop to ensure that the production line and supporting equipment and facilities meet the production requirements.

(2) Flexible reconfiguration. The construction and production preparation of intelligent production line are quickly completed according to production requirements. Firstly, the type and quantity of parts to be produced (including parts or component to be assembled) and key production nodes are obtained according to the production task and plan. Further, the intelligent production line is designed and planned on the basis of considering the current production status of the workshop, future production arrangements and workshop manufacturing resources, which is optimized by the simulation system. Then, the planning and construction of the production line are carried out, including the flexible physical reconstruction, logical reconstruction and the integration of physical and logical reconstruction of the production line. In addition, the flexible logical reconstruction is defined as the physical position of the mechanical production line equipment is unchanged, and the processing is carried out in accordance with the logical sequence of the process specification, and physical reconstruction is defined as the assembly line uses flexible process equipment, automatic detection equipment and manual operation to produce, and readjusts the physical position of each equipment according to the process specification.

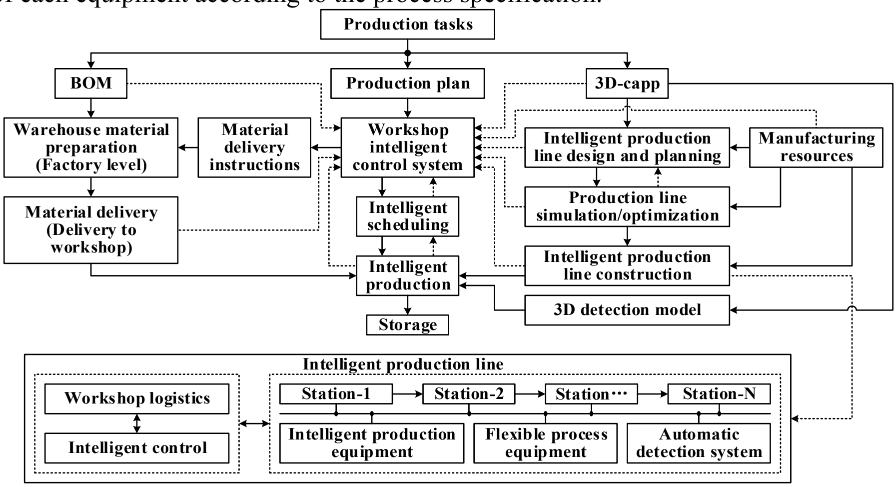

Fig. 4. Intelligent production mode process of discrete intelligent manufacturing system

(3) Intelligent production. The production is completed by the intelligent production system including the equipment level, line level, workshop level and factory level. Equipment level intelligent production is mainly reflected in the operation of intelligent production equipment, process equipment and logistics equipment. The intelligent equipment completes the adaptive production process including data acquisition, analysis, decision-making and optimization adjustment. According to different sizes and shapes of parts, the flexible process equipment can make independent judgment and decision of clamping parameters, so as to realize the automation of production process and flexible and accurate adaptive clamping. The intelligent distribution device completes the optimization of the distribution route, the automatic judgment and real-time decision-making adjustment of the distribution process. Intelligent production at the line level reflects the intelligent control of the line. In addition, the automatic detection system completes the automatic collection of key node data in the production process. The intelligent control system completes data analysis and mining, production process decision-making and independently generates optimization and adjustment instructions of the production line according to the working conditions of the production line and production demand instructions. The intelligent distribution system distributes according to the requirements formed by the intelligent control system. Workshop level intelligent production mainly reflects the allocation and control of workshop resources. The control system at the workshop level is responsible for the analysis, decision-making and unified optimal allocation of the production status, resource use and production plan execution of the entire workshop, so as to ensure the optimal allocation of workshop resources, efficient/high-quality production of products and the timely completion of production plans. Factory level intelligent production is mainly reflected in the macro-control of factory production tasks. It realizes the analysis, judgment, optimization and adjustment of product development and production related businesses such as the implementation of the plan and future evolution rules, resource utilization, material preparation and logistics, testing, etc., and forms a mode of online collection and analysis of factory business, real-time analysis of operation status, optimization and adjustment decision-making and accurate and rapid implementation, so as to realize the intelligence of management and control level.

4.3 Experimental verification of the physics and model combination

The simulation technology is applied to product development to analyze and predict the product development process and application effect in advance, so as to find out the possible problems and adjust them. On this account, the numbers of physical tests are effectively reduced as well as the development efficiency improved, the development cost reduced and the development cycle shortened, which reflects the mode characteristics of virtual reality fusion and multi-level simulation as shown in Figure 5.

(1) Virtual and real fusion. credibility of virtual models has always been a challenge in analyzing and optimizing product development and production processes through simulation methods, and establishing high simulation model is an important

part of intelligent development system. It is an important means to improve the accuracy and accuracy of the model simulation that used the rule obtained through few physical experiments, the laws obtained from the original experience knowledge, classic cases and data mining as the basis for credibility evaluation, and further modification of the simulation model. The basic process of experimental verification of virtual reality fusion is as follows: firstly, the function and behavior of physical entities are analyzed, and the functional principle, use environment, boundary conditions, parameters and influencing factors of the model are determined. Then, the initial simulation model is built based on the existing knowledge, and the behavior of the physical entity is simulated. Next, based on the existing knowledge and the analysis results of the initial simulation model, few physical test schemes and data acquisition methods are determined, according to which the tests are carried out and the test data are obtained. what's more, combined with the existing knowledge, the test data are analyzed, and the initial simulation model is modified and used as the basis for credibility evaluation. Further, based on the information and methods above, the credibility of the modified simulation model is evaluated until the simulation model meets the requirements. Finally, based on the modified simulation model, a large number of functions and behaviors of physical entities are simulated to obtain effective data, which provides the basis for product design optimization, production adjustment, design finalization and acceptance appraisal.

(2) Multi level simulation. For the product development process, multi-stage and multi-level virtual simulation verification is carried out combined with physical tests. In the conceptual design, the simulation model is established to simulate, analyze and optimize the function, performance and use environment proposed by customers, and the existing knowledge is used as the basis for simulation model modification and reliability evaluation. Finally, a high-precision simulation model representing the product function and performance behavior is established to realize the optimal design of the conceptual model. In the overall design, based on the existing knowledge, the general assembly process simulation and optimization model, multidisciplinary integration and multi parameter optimization calculation model are established respectively, and the actual assembly process and product test results are used as the basis for simulation model modification and reliability evaluation. In addition, the simulation model of reliability calculation is established, and few equivalent physical tests are used as the basis for simulation model modification and reliability evaluation. In the detailed design, the simulation models of electromechanical hydraulic control and testing, assembly and parts manufacturing are established respectively, and the corresponding high-precision models are established based on few physical tests, actual components assembly process and few parts manufacturing tests as the basis of simulation model correction and reliability evaluation. In the trial production, the simulation model under the product use environment is established, and the high-precision simulation model under the use environment is established based on few tests as the basis of simulation model correction and reliability evaluation.

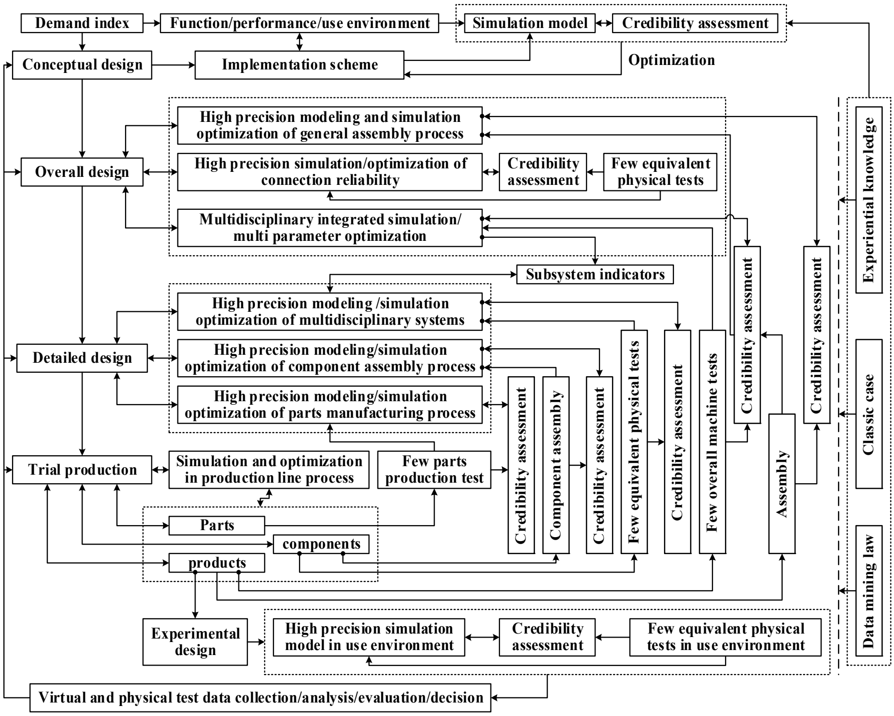

Fig. 5. Test verification mode process of discrete intelligent manufacturing system

5 Conclusions

Intelligent manufacturing is an effective way to solve the uncertainty of manufacturing process. Based on the background of aerospace product development and production, the architecture of discrete intelligent development system, mode flow, and the functions and relationships of each layer in the system are discussed around the process of design, production and test in the development. Furthermore, the operation modes such as model driven parallel collaborative intelligent design, flexible intelligent production of multi system integration, Experimental verification of the physics and model combination are put forward. Based on the above research on the discrete intelligent development system and process, the basic methods to solve the uncertain problems in the development process are put forward, and the logical relationship and operation mechanism between the modules of the intelligent development system are preliminarily expounded. It has certain reference value for enriching the theory and method of intelligent manufacturing, promoting the development and application of intelligent manufacturing technology. In the following study, the basic technologies, decision-making methods and model algorithms involved in the application of intelligent manufacturing will be focused to build an advanced manufacturing system and solve various problems caused by the uncertainty of aerospace products, which can achieve high-efficiency, high-quality and high-efficiency research and production.

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