Exploration and practice of intelligent manufacturing of electronic information equipment

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Abstract. At present, the global manufacturing industry is accelerating towards the era of digitalization, networking and intelligence. Aiming at the manufacturing characteristics of electronic information equipment, such as the integration of scientific research and production, multi variety and small batch, fast renewal, high coupling of multi disciplines, and huge supply chain, this paper studies and analyzes the technical hotspots of intelligent manufacturing of electronic information equipment, such as 3D printing of mechatronic system structures, design and manufacturing of microsystem, immersive virtual assembly and digital twin. At the same time, based on the guiding ideology of Model-Based Systems Engineering (MBSE), the exploration and practice of electronic information equipment design mode, production mode, support mode and management mode are carried out. The research shows that the application of new technology and mode of intelligent manufacturing effectively shortens the development cycle of electronic information equipment, greatly improves the production efficiency and comprehensive utilization of resources, and significantly reduces the operating cost and the rate of defective products.

1. Introduction
At present, with the rapid development of information technology innovation, the information tide characterized by digitalization, networking and intelligence is booming, which accelerates the integration innovation of information technology and various industries and fields of economic society, and creates conditions for the rise of intelligent manufacturing. Electronic information equipment is an important part of the electronic information industry, widely used in communication, detection, navigation, confrontation and other electronic systems, is the carrier of information detection, storage, processing and transmission, is the pillar of the information age [1]. Electronic information equipment manufacturing industry has also become the main battlefield to promote intelligent manufacturing.

Under this background, researchers gradually introduce the key technology of intelligent manufacturing into the whole life cycle of electronic information equipment. Li and others studied the concept/function and model of different forms of telecommunication virtual prototype according to different development stages, and put forward a co-operation simulation platform supporting conceptual/functional prototype and engineering prototype [2]. Hu and others put forward the implementation mode of structural digital prototype of electronic information equipment, established the standard system architecture of structural digital prototype, and established the integrated platform of structural digital prototype [3]. Ben put forward the architecture of intelligent manufacturing system for radar assembly, and studied and analyzed the key implementation technology of radar assembly system [4]. Wang and others designed the scheme of the integrated supply platform for electronic information equipment, and put forward the content of service station of integrated support [5].
On the basis of the above research, this paper further analyzes the current characteristics of electronic information equipment manufacturing and the demand for intelligent manufacturing, carries out the application exploration and practice of new technologies and modes of Intelligent Manufacturing in electronic information equipment manufacturing industry, and promotes the transformation and upgrading of electronic information equipment manufacturing industry.

2. Characteristics and requirements of electronic information equipment manufacturing

Electronic information equipment, which involves many different fields, is a complex of parts and subsystems in different fields such as machinery, control, electronics, hydraulic, pneumatic, software, etc. [6]. It is a typical complex product with five manufacturing features:

1) Most of the electronic information equipment enterprises adopt the integrated operation mode of "scientific research + production + service", which requires a model system that runs through the integration of demand analysis, scheme design, process trial production, test verification and maintenance support, and has the ability of information perception, analysis and control in the whole life cycle.

2) Electronic information equipment is a typical multi-variety, variable batch and customized production mode, which determines that flexible and transparent new manufacturing mode must be adopted to solve the problems of high production cost and difficult production process control.

3) Electronic information equipment has a faster update speed than its loading platform. It needs digital, network and intelligent technology to improve the development and production efficiency.

4) The research and development of electronic information equipment involves multi-disciplinary and cross professional deep coupling, which requires more advanced digital collaborative simulation means to improve the comprehensive design optimization ability of multi-disciplinary and cross professional.

5) The research and development of electronic information equipment involves a wide range of fields and many enterprises. It is a complex system engineering, which requires strong cross system and cross platform integration capabilities.

In essence, intelligent manufacturing of electronic information equipment aims at the characteristics and requirements of electronic equipment manufacturing, and deeply integrates the new generation of information technology and advanced manufacturing technology in the main activities of the whole life cycle, such as product design, production, support and management, so as to effectively shorten the development cycle of electronic information equipment, improve production efficiency and comprehensive utilization of resources, reduce operation cost and defective product rate.

3. Application of new technology in intelligent manufacturing

At present, there are many bright spots in the application of new technology in the intelligent manufacturing of electronic information equipment, among which the emerging manufacturing technology represented by 3D printing, micro nano manufacturing and the information communication technology represented by immersive virtual simulation and digital Twin are the representatives.

3.1. 3D printing of mechatronic system structures

3D printing technology is a technology that uses the method of material accumulation layer by layer to make solid parts through CAD design data. It does not need the traditional tools, fixtures and multiple processing procedures, and can produce structural parts of any complex shape, greatly saving material costs and shortening the processing cycle.

These technical characteristics of 3D printing make it particularly suitable for the development of single piece / small batch and multi-variety of electronic products, as well as the manufacturing of complex electronic components which are difficult to realize by traditional manufacturing methods, such as mechanical and electrical integration, structure and function integration.

Dragonfly 2020 3D printer, the world's first composite circuit board 3D printer, has attracted a lot of attention since it was released. It can quickly produce professional multi-layer circuit boards (as
shown in Figure 1) and three-dimensional circuit boards [7]. The multi-layer circuit boards made can weld electronic parts as well as traditional printed circuit boards. At present, 3D printing is a good way for the rapid manufacturing of single, small batch multilayer and three-dimensional circuit boards.

For the manufacturing of new complex electronic products with structure and function integration composed of multi-layer heterogeneous materials in millimetre thickness, such as fighter surface conformal antenna (Figure 2) [8], the traditional technology has become difficult to achieve, which has become a key factor restricting the development of miniaturization and integration of structure and function of electronic information equipment. At present, it is urgent to break through the technical difficulties of 3D printing materials, technology and equipment.

3.2. Design and manufacturing of microsystem
Microsystem, supported by micro nano scale theory and based on micro nano manufacturing and technology, is a comprehensive frontier technology integrating micro machinery, microelectronics, micro optics, micro energy, micro flow and other technologies, with micro sensing, micro processing, micro control, micro transmission, micro confrontation and other functions, and realizing single or multi-purpose through the integration of functional modules [9]. At present, some new micro system technologies have begun to enter the practical stage, such as micro radar, chip level atomic clock, chip satellite and other electronic information equipment (as shown in Figure 3 and Figure 4)[10, 11].

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**Figure 1.** Small circuit board made by 3D printing.

**Figure 2.** Schematic of composition of mechatronic structure inside conformal antenna.

**Figure 3.** Highly integrated mm-wave radar.

**Figure 4.** NanoEye satellite prototype and structural composition.
Micro and nano manufacturing technology is the basic means and foundation of microsystem. Micro nano manufacturing mainly studies the scientific issues of functional structure, device and system design and manufacturing of feature size in the range of micro and nano. The research content involves the design, processing, testing, packaging and equipment of micro nano devices and systems [12]. With the continuous development of micro nano manufacturing technology, at present, micro system products are developing from chip level and component level to system level with higher complexity. Microsystem technology is also having a subversive impact on the miniaturization, lightweight and intelligence of electronic information equipment.

3.3. immersive virtual assembly
With the rapid development of multimedia, sensor sensing, network communication and other technologies, virtual reality (VR) and augmented reality (AR) technologies have gradually penetrated into the industrial field, bringing profound changes to the R&D, production, sales and service of the manufacturing industry, further promoting the development of intelligent manufacturing. In the process of product R&D, industry leading enterprises begin to use virtual reality (VR) software and system to simulate the assembly process of electronic information equipment in virtual environment, and realize the simulation and optimization of assembly process (as shown in Figure 5) [13]. Virtual evaluation of products before manufacturing by VR technology can solve the problems of electronic information equipment in the early stage of manufacturing process, improve the efficiency of R&D and manufacturing, and reduce the labour cost.

The biggest difference between AR and VR lies in the difference of immersion level. VR is based on the complete simulation of the real world, while VR is the superposition of computer-generated images into the real world. In the future, AR/VR technology will be applied to typical application scenarios such as immersive design review, production operation guidance, product installation, and transportation service of electronic information equipment.

![Figure 5. Immersed type virtual simulation environment of some phased array radar.](image)

![Figure 6. Model network of radar Digital twin.](image)

3.4. Digital twin in the whole life cycle
Digital twin makes full use of physical model, sensor update, operation history and other data, integrates multi-disciplinary, multi physical quantity, multi-scale, multi probability simulation process, completes mapping in virtual space, so as to reflect the whole life cycle process of corresponding physical equipment [14]. The model network of digital twin in the whole radar life cycle is shown in Figure 6.

The application of digital twin technology in electronic information equipment runs through different stages of product life cycle, including digital twin in design stage, digital twin in production stage and digital twin in service stage. In the stage of product design, using digital twin can improve the accuracy of electronic information equipment design. Through digital model design, simulation...
and simulation, verify its performance in the real environment. In the manufacturing stage, the quality of electronic information equipment design is improved, production cost is reduced and delivery speed is improved through production line digitization, production process simulation, key index monitoring and process capability evaluation. In the service phase of digital twin, a large number of sensors are used to collect the environment and working status of electronic information equipment in the operation phase, to carry out remote monitoring, predictive maintenance, and to optimize the production indicators of customers and improve the user experience. Digital twin technology has been constantly evolving rapidly, which has a huge role in promoting product design, production and service.

4. Exploration of new mode of intelligent manufacturing

With the application of new intelligent manufacturing technology, electronic information equipment, guided by model-based systems engineering (MBSE), carries out the exploration and practice of R&D mode, production mode, support mode and management mode.

4.1. New mode of intelligent R&D

MBSE method is to establish and use a series of models to control the principle, process and practice of system engineering. By establishing the model driven working mode of system, continuity, integration, synthesis and covering the whole cycle, we can help people better use the principle of system engineering, greatly reduce the complexity of management, and improve the robustness and accuracy of system engineering. It regards the whole system engineering as a technical system and method rather than a series of events [15]. At present, MBSE method has been widely used in the field of aerospace, and is being promoted in the field of electronic information equipment [16].

![Figure 7. The network of digital twin model in the full life cycle of radar.](image)

In order to meet the requirements of the improvement and upgrading, technology research and development, and original design of electronic information equipment, a forward R&D innovation system of electronic information equipment is established under the guidance of MBSE method (as shown in Figure 7). A new R&D mode characterized by "demand traction, model penetration, virtual reality verification, positive collaboration, process specification and parallel work" is constructed. It has formed R&D capabilities, including the whole process tracking and traceability of requirements, integrated sales management of project planning process, model-based system engineering, collaborative design and management of digital prototype, and multi-disciplinary collaborative
simulation. The product positive design process has been opened up, which improves the product innovation ability and market competitiveness of the enterprise, greatly shortens the product R&D cycle and improves the product quality. The integration of MBSE methodology and intelligent manufacturing technology is promoting the transformation of electronic information equipment R&D mode from traditional reverse engineering to positive R&D.

4.2. New mode of intelligent production

Intelligent production refers to the use of advanced manufacturing tools and network information technology to carry out intelligent transformation of production process, realize cross system flow, collection, analysis and optimization of data, and complete intelligent production methods such as equipment performance perception, process optimization and intelligent production scheduling [17]. The multi variety and small batch production mode of electronic information equipment has given birth to the demand for flexible production. Flexible production needs to be realized through intelligent production carriers. Intelligent production line, intelligent workshop and intelligent factory are the main carriers of flexible production.

4.2.1. Intelligent production line. In the process of production and assembly, the intelligent production line can automatically collect data through sensors or radio frequency identification (RFID), and display real-time production status through electronic kanban. It can detect the quality through machine vision and a variety of sensors, automatically eliminate the unqualified products, and analyze the collected quality data by statistical process control (SPC), to find out the causes of quality problems. It can also support mixed line production and assembly of many similar products, flexibly adjust the process, and adapt to the production mode of small batch and multiple varieties. Figure 8 shows the intelligent production line supporting the mixed production line of micro system products.

![Figure 8. Micro-system intelligent production line.](image)

4.2.2. Intelligent workshop. Based on the intelligent production line, the intelligent workshop further deploys manufacturing execution system (MES). It collects and analyzes the production status, production quality, material consumption, process parameters, equipment status, energy consumption and other information in real time, conducts efficient production scheduling and reasonable scheduling, significantly improves the overall equipment efficiency (OEE) and product quality, and realizes the traceability of production process.

4.2.3. Intelligent factory. The intelligent factory is composed of one or more intelligent workshops. The production plan of multiple workshops needs to be made through enterprise resource planning (ERP). MES system makes detailed production scheduling according to the production plan of each workshop. Intelligent factory should not only realize automation, transparency, visualization and lean
in the production process, but also realize closed-loop integration of product detection, quality inspection and analysis, and production logistics with the production process [18]. Information integration and sharing, on-time delivery of materials and cooperation of operation plan should be realized among all workshops in the intelligent factory.

4.2.4. Network collaborative manufacturing. Network collaborative manufacturing refers to the development of new models such as collaborative R&D, crowdsourcing design and supply chain collaboration among enterprises by virtue of industrial Internet, big data and industrial cloud platform, which can effectively improve the efficiency of resource utilization, reduce the cost of resource utilization and broaden the scope of resource utilization. Network collaborative manufacturing is especially suitable for large-scale equipment products with complex product structure, long design cycle and many manufacturing links. Taking the medium-sized meteorological equipment as an example (as shown in Figure 9), it is a highly integrated complex electronic information equipment, with tens of thousands of parts and components and millions of components and components. The research and development of such an equipment must carry out collaborative design, collaborative production, supply chain coordination and other social cooperation.

![Figure 9. Composition of a weather radar.](image)

By using network collaborative manufacturing technology, the value chain of electronic information equipment manufacturing enterprises extends from a single manufacturing link to the upstream design and development link, and to the downstream production and manufacturing control link, forming a network collaborative manufacturing system integrating engineering design, production and manufacturing, supply chain and enterprise management.

4.3. New mode of intelligent support

Intelligent support refers to the realization of product networking and operation data collection through the Internet of things and sensor technology, and the use of big data analysis to provide a variety of intelligent services. Intelligent support realizes the expansion from selling products to selling services, from the manufacturing link of the industrial chain to both ends of the smile curve, and expands the profit space. The equipment status monitoring, predictive maintenance and remote maintenance of electronic information equipment are of great significance to ensure the safe operation of electronic information equipment, reduce the operation cost, and promote the leapfrog development of equipment service industry.

The intelligent service and support platform of radar products based on big data shown in Figure 10 can monitor and analyze the operation status, health level and performance change trend of the equipment through remote interconnection, and achieve predictive maintenance. In addition, through the analysis and mining of big data, it can provide feedback for equipment optimization design and continuously improve equipment performance. The traditional "turnkey project" has been transformed into full life intelligent support, realizing "one generation platform, multi generation electronics".
4.4. New mode of intelligent management

In the process of operation, the enterprise has produced a large number of core data from various business departments and business systems, real-time production data collected at the production site, big data of equipment operation, big data of quality, big data of product operation, big data of marketing brought by e-commerce, and big data related to the company from social networks. Business intelligence (BI) is a complete solution, which is used to effectively integrate the existing data in the enterprise, quickly and accurately provide reports and decision-making basis, and help the enterprise to make intelligent business management decisions.

Electronic information equipment enterprises have achieved the acquisition, analysis and early warning of data in the management fields of economic operation, scientific and technological innovation, marketing, etc. by building a decision support system based on big data (as shown in Figure 11). It realizes the management and control of the whole process, the whole field and the whole dimension, the early warning and prediction of major risks, the scientific decision driven by data, and effectively improves the decision-making efficiency and the management and control level of the electronic information equipment enterprises.

5. Conclusions

The application of new intelligent manufacturing technology promotes the transformation, upgrading and innovation of research and development mode, production mode, service mode and management mode of electronic information equipment, effectively shortens the development cycle of electronic
information equipment, greatly improves the production efficiency and comprehensive utilization rate of resources, and significantly reduces the operating cost and the rate of defective products. In the future, in the accelerated development of intelligent manufacturing of electronic information equipment, it will face many challenges, such as standards, talents, security, ecology, etc. It is believed that with the continuous maturity of information communication technology and advanced manufacturing technology such as blockchain, artificial intelligence (AI) and robot process automation (RPA), and the continuous deepening of exploration by all parties, the development of intelligent manufacturing of electronic information equipment will usher in a new chapter.

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