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Intelligent Manufacturing of Special Equipment Based on Intelligent Connection

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Abstract: Special equipment is important for the economic and societal development of a country. Implementing intelligent manufacturing in the special equipment field could facilitate the transformation and upgrade of the special equipment manufacturing industry in China, and it is also an essential component for the China Manufacturing 2025 plan. In this study, we first analyze the characteristics and current status of special equipment in China and summarize the demand for intelligent manufacturing of special equipment. Then we propose some measures and development ideas for promoting the special equipment manufacturing industry. We propose that the guiding ideology should be parallel development; the Industry 2.0, Industry 3.0, and Industry 4.0 should be promoted in parallel within the special equipment industry. The development of intelligent manufacturing of special equipment should focus on product traceability, intelligent quality management, and real-time monitoring of dynamic risks. Based on this, the intelligent connection is introduced as a technology path for developing intelligent manufacturing of special equipment, and the concept of intelligent connection is further analyzed. Furthermore, the key tasks for future development are building an intelligent connection network of special equipment and developing intelligent applications.
Keywords: special equipment; intelligent manufacturing; intelligent connection; parallel development

1 Introduction

China has become a significant manufacturing country, accounting for approximately 20% of the global manufacturing industry but is not yet regarded as a manufacturing power [1]. To further promote the manufacturing industry from big to strong, China proposes the Made in China 2025 initiative [2], with the deep integration of informatization and industrialization as the main line. In addition, the basic policy of “innovation driven, quality first, green development, structural optimization, and talent oriented,” is of great significance for China to cope with the new round of international competition brought about by the fourth scientific and technological revolution. Intelligent manufacturing is the main direction, command point and breakthrough of Made in China 2025, and is also the development direction of Industry 4.0 proposed by Germany and the industrial Internet proposed by the United States. At present, there is no exact definition of intelligent manufacturing in China. The common understanding is that it includes three main aspects: intelligent product/equipment, intelligent manufacturing processes, and new production mode/industrial mode. The three aspects are organically combined, mutually supported, and gradually promoted to form an intelligent manufacturing system [1–4]. At present, China’s intelligent manufacturing is still in an initial stage of continuous development in depth and breadth. Due to the lack of specific technical path guidance, the progress in most directions is slow [3].

Special equipment is an important infrastructure for national economic construction and people’s lives and plays an important role in economic and social development. Developing intelligent manufacturing in the field of

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special equipment and realizing the transformation and upgrade needs of the special equipment manufacturing industry are important components of Made in China 2025. In the field of special equipment, China actively promotes informatization and guides and promotes the development of Internet Plus Special Equipment. For example, in 2015, the general office of the State Council issued *Opinions on Accelerating the Construction of Traceability Systems for Important Products* that proposed to develop safety and quality traceability systems for cylinders and elevators. In 2016, The State Administration for Market Regulation put forward the Internet Plus Quality Inspection action plan. As far as the intelligent manufacturing of special equipment is concerned, China's current research in, for instance, theory, technology, regulations, and standards is still very basic. China needs to step up the research on the influencing factors, development approaches, solutions that transform traditional manufacturing to intelligent manufacturing, and business models, laws, and regulations for intelligent manufacturing, so as to support the high-quality development of intelligent manufacturing of special equipment. The most urgent one is to choose and determine a reasonable and feasible technical approach.

Recent studies [5–9] proposed that technologies such as big data, Internet of Things, and artificial intelligence (AI) should be fully applied in the special equipment industry to build the development idea of intelligent and connected special equipment, and analyze for instance, its technology and standardization requirements, and its inspection and supervision mode. Based on this, in this study we introduce the concept of the intelligent connection in the manufacturing of special equipment, as a technical way to realize the intelligent manufacturing of special equipment, and we discuss the specific development ideas, so as to provide guidance for the next step of promoting intelligent manufacturing in the field of special equipment.

2 Development status and demand analysis of special equipment

2.1 Characteristics and development status of special equipment

2.1.1 Technical and management characteristics of special equipment

According to the *Special Equipment Safety Law of the People's Republic of China*, eight categories of equipment comprising boilers, pressure vessels (such as gas cylinders), pressure pipes, elevators, lifting machinery, passenger ropeways, large amusement facilities, and special motor vehicles in the field (factory) shall be managed as special equipment, and each category is divided into several varieties, some of which are further subdivided into multiple levels of sub-categories. Once the special equipment fails, it can pose a risk to personal and property safety. Therefore, the state has set up specific government departments to implement classified and whole process safety supervision and management on the production, operation, and use of special equipment. All kinds of special equipment are characterized by high technical complexity, many design elements, a complex production process, many use links, high operational requirements, difficult operation and maintenance, and a long service cycle. How to effectively guarantee the quality and safety of special equipment products and avoid accidents is a difficult task and also a system engineering challenge. Therefore, it needs the participation of, for instance, producers, operators and users, government, and third-party technical institutions to strengthen the continuous investment in science and technology, management, talent, the economy, and other aspects in the whole lifecycle of the design, manufacture, use, and scrap of special equipment. Currently, China has established a set of special equipment quality and safety assurance systems and corresponding laws and standards systems based on traditional technology. This system is open and can continuously absorb scientific and technological innovation achievements for optimization and adjustment. However, special equipment products are still mainly mechanized and semi-automatic, and many links are still manually operated; all links must be subject to the mandatory supervision of the government. These links include that the design needs to pass the audit and appraisal of a third-party organization, the manufacturing process needs to be evaluated and recognized, the product quality inspection needs to be subject to the supervision of a third party, and the safety inspection needs to be carried out regularly by a third-party organization in the process of use. For reliability re-evaluation, relevant organizations and personnel involved in the re-evaluation must obtain corresponding qualifications and certifications.

2.1.2 Development trend of special equipment

The development of special equipment and of the special equipment industry, are influenced and promoted by science and technology, the economy, and society. Over the past 40 years of reform and opening up, with the economic development and social progress that has been achieved, the variety of special equipment items has gradually increased, and the number continues to grow rapidly. By the end of 2019, the total number of special equipment items had reached 1.525×10^7 sets, with an annual growth rate of more than 11%. Furthermore, there are

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approximately 1.64×10^8 gas cylinders and 5.613×10^5 km of pressure pipelines [4]. In addition, to meet the needs of industrial development and people's livelihood, the structure of special equipment is becoming more complex, the medium, working conditions and the environment are becoming more and more harsh, the design load, pressure, size, speed, and other parameters are constantly improving, and some of them are close to extremes. At the same time, the operation, maintenance, inspection, and service cycles are becoming longer, which leads to more diversified and coupled factors affecting quality and safety. There are more elements for safety risk prevention and control of special equipment, and the risk is increasing.

2.1.3 Challenges faced by the development of special equipment

The existing special equipment quality and safety assurance system plays an important role in improving the quality and safety level of special equipment products and reducing the accident rate. However, there are also common problems such as low technology content, too many elements, complex processes, rigid mechanisms, and low efficiencies. that make the special equipment development bottleneck problem increasingly prominent. This is especially true of product quality stability, safety assurance reliability, and the effectiveness of safety supervision all of which urgently need to be improved further. Today's world is at the threshold of the fourth scientific and technological revolution: a new round of international competition is becoming increasingly fierce; scientific and technological innovation is intensive and active; and rapid development, and industrial and social standards are changing with each passing day. It is imperative to promote the transformation and upgrading of the special equipment industry and improve the quality and safety level based on technological innovation.

2.2 Demand analysis of intelligent manufacturing for special equipment

2.2.1 New requirements of special equipment development

With the continuous emergence of new trends in global industry, science, and technology, and with economic and social development coupled with the emergence of new trends in the development of special equipment, a series of new requirements have been proposed for special equipment that fall into the following categories. (1) It is necessary to eliminate serious accidents. In 2015, the central government proposed the requirement to "resolutely curb the occurrence of major safety accidents." Recently, serious accidents involving special equipment are still reported to occur frequently, which seriously affects economic development and social stability. (2) The overall safety level needs to be further improved. The overall safety level of special equipment in China still lags behind that of developed countries, and the mortality rate of some equipment is still 2–3 times that in developed countries. There is still a big gap between the safety status of special equipment and the requirements of the country and the people. (3) The quality and safety performance of products needs to be improved further. The competitiveness of China's special equipment products is still weak; many high-end products still rely on imports, and most of the export products are low-tech, low value-added products, and are mainly exported to less developed countries and regions; this is a long way from the development goal of building China into a quality power. (4) We need to improve the efficiency of safety supervision. The man–machine contradiction between the shortage of special equipment safety supervision personnel and the rapid growth in the number of special equipment items in China is prominent. This has not been effectively addressed, and the safety supervision business is under pressure and at high risk. (5) We need to build a new business model in all aspects. The development of the digital economy has brought about changes in social production relations. The existing government supervision and third-party technical service business models and service methods can no longer meet market needs.

2.2.2 Development demand of intelligent manufacturing of special equipment

The fourth scientific and technological revolution is represented by the Internet of Things, advanced sensing, AI, big data, cloud computing, and other modern information technologies. An effective way to solve the current application problems and development bottlenecks in the field of special equipment is to seize the development opportunity of the fourth scientific and technological revolution, make full use of modern information technology, and vigorously develop intelligent manufacturing.

To enhance the competitiveness of special equipment products, intelligent manufacturing needs to be developed and intelligent special equipment products need to be created. Possible developments include intelligent elevators, intelligent amusement facilities, intelligent gas cylinders, personalized design, online health monitoring, real-time state diagnosis, accurate defect detection, advanced perception and early warning, remote prevention and maintenance, independent state adjustment, and timely and efficient emergency response. Intelligence can be built into many aspects of the chain such as product design, safety state identification, regular inspection, early warning and prediction of danger, state control and adjustment, and accident emergency response. Product design can be optimized, product functions upgraded, and product quality and safety performance improved.

The development of intelligent manufacturing and the realization of digital and intelligent production of special equipment products are the requirements to ensure the quality, safety, and stable performance of special equipment products. In the manufacturing and processing links, the development of digital workshops and intelligent factories, and adoption of intelligent process equipment and less humanized or even unmanned, continuous, automated, intelligent production lines are needed. In addition the adoption of accurate product testing, quality inspection, and analysis technology to improve process stability, controllability, adjustability, and reliability of parameter accuracy, and ensuring the efficiency of quality inspection and the accuracy of defect detection, will effectively avoid the delivery of unqualified products.

To improve the service efficiency of special equipment and realize accurate risk prevention and control intelligent manufacturing needs to be developed and an intelligent service mode of special equipment needs to be constructed. For third-party technical services, government supervision, and other businesses, we should create an intelligent mode, with data as the driving force, risk as the criterion, informatization, networking, automation and standardization as the basis, and big data representing the whole lifecycle and the whole chain, as the platform. This will enable us to realize the functions of self-awareness, learning, analysis, information sharing, rapid response, and accurate policy implementation, and improve the service quality energy efficiency, and ease the contradiction between man and machine. Through the development of intelligent manufacturing, we will ultimately achieve accurate prevention and control of safety risks, effectively avoid accidents, and improve the overall safety level of special equipment. In addition, through the networking interaction among equipment, people, the environment and institutions, the system risk of equipment will be effectively reduced, and the occurrence of major accidents will be avoided.

3 Strategy for developing intelligent manufacturing of special equipment

3.1 Strategies for developing intelligent manufacturing of special equipment

At present, the levels of manufacturing of different types of special equipment are very uneven among different enterprises in China. Some have been promoting intelligent manufacturing and have achieved some success, such as in the elevator and large amusement facilities industries. There are some that have only just started, such as organizations in the pipeline and gas cylinder industries, and there are some who have not yet started. Therefore, the strategy for promoting intelligent manufacturing with special equipment can be summarized in the following way: follow a parallel development path of Industry 2.0 make-up, Industry 3.0 popularization, and Industry 4.0 demonstration [10], and promote the parallel development of Industries 2.0, 3.0, and 4.0. Many enterprises are still essentially in the Industry 1.0 era, including those manufacturing pressure vessels, industrial boilers, and other pressure-bearing special equipment. In these organizations, most of the manufacturing work still needs to be completed by manual means or using simple machinery, such as welding, nondestructive testing, and macro inspection systems. In such organizations the simultaneous development of automation, informatization, and networking needs to be promoted. Some enterprises manufacturing electromechanical special equipment such as elevators, large-scale amusement equipment, and lifting machinery have started using automation. The automation and informatization of some of these manufacturing enterprises have developed sufficiently to be able to focus on promoting the development of intelligent manufacturing.

Special equipment is often highly dangerous, so ensuring the safety of its use should rank highly in the list of priorities. The intellectualization of special equipment cannot be at the expense of safety, and the further promotion of safety should be regarded as a fundamental goal. The development of intelligent manufacturing of special equipment must consider the information security and functional safety of the information technology used. Specifically, information security includes two connotations: on one hand, all tangible items such as communication, computer equipment, and related facilities in the network system must be protected (physical security); on the other hand, information has integrity, confidentiality, and availability attributes that need to be protected (logical security). Both physical and logical security are indispensable [11]. Functional safety also includes two aspects: on one hand, there needs to be sufficient safety functionality to ensure that there are sufficient safety protection measures in place to counteract all possible dangers; on the other hand, every safety function needs to be implemented reliably under all conditions including in the presence of faults [12].

3.2 Development points of intelligent manufacturing of special equipment

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3.2.1 Product traceability

An important aspect of the intelligent manufacture of special equipment products is to establish the traceability of special equipment products by making full use of modern information technology. This can enable the traceability, positioning, and management of special equipment products and their quality and safety. The traceability system collects and records information about the product production, circulation, consumption, and other links, so that the source and destination can be traced and responsibility can be investigated. It is an effective measure to strengthen the whole quality, safety management, and risk control process. It plays a significant role in improving the quality and safety management of special equipment, promoting the innovation of supervision methods, and ensuring the safe use of the products. There are many aspects of special equipment manufacture that can affect the quality and safety of special equipment products, including the design, fabrication process, quality measurement, fault detection, and installation. In addition, the quality and safety can be affected by the operation, inspection, and maintenance during use. Due to the difficulties of recording quality and safety information traceability, we should make full use of coding technology, advanced sensors, Internet of Things, cloud computing, modern databases, and big data to build an intelligent equipment traceability system for special equipment. This can enable the whole process quality, safety tracking, and traceability of products, and comprehensively improve the speed, convenience, accuracy, comprehensiveness, and durability of information collection and recording.

3.2.2 Intelligent quality management

Quality management is an important part of special equipment manufacturing activities. In addition, it is a necessary guarantee of the quality and safety of special equipment. China’s special equipment quality management has formed a “legal person management, enterprise self-inspection, third-party supervision, and government supervision” system mode. However, this traditional mode has some problems that are difficult to overcome: on one hand, whether it is enterprise self-inspection, third-party supervision, or government supervision, the main form of work is to randomly select a small number of products, parts, and some links for detection, inspection, and testing. This cannot achieve the full coverage of quality management in time and space; on the other hand, it relies too much on the role and influence of people, and people have randomness and different ways of doing things, as well as subjective perceptions. When the relevant personnel have a weak sense of responsibility or are in an unstable psychological state, the results of testing and inspection can be affected, which in turn affects the quality and safety performance of the products.

The development of modern information technology has laid a solid foundation for the transformation and upgrading of the traditional quality management mode for special equipment. We can make full use of advanced sensing, AI, Internet of Things, big data, and other technologies to build an intelligent quality management system. (1) In terms of the quality management of special equipment design, the traditional design process mainly relies on manual or stand-alone design software to complete certain tasks such as risk assessments, design calculations, and output of design documents. The quality management of design includes the qualified examination of designers outputs (design, audit, approval), the compliance examination of the design basis, and the random inspection of design output documents. These processes require highly skilled labor and qualified quality management personnel, and it is impossible to fully verify the quality of the design results. Intelligent manufacturing embraces the whole lifecycle of products. It has a rich design knowledge base, and an intelligent design system supported by simulation technology. It can work in parallel and cooperatively in the network environment, consider the failure mode comprehensively and empirically, and simulate the real situation. It can ensure the design quality, and also realize the comprehensive verification of the design results more easily. (2) In terms of materials and parts, the control elements of traditional special equipment quality management include supplier qualification examination, quality certification document confirmation, and quality spot checks and re-inspections; under the intelligent manufacturing mode, an online interactive platform between purchasers and suppliers can be built. Through the platform, purchasers can fully grasp the quality of purchased materials and parts and the supplier needs to cooperate to complete the manufacturing process, which keeps the quality of raw materials under control throughout the lifecycle. (3) In terms of technology, the implementation of traditional special equipment manufacturing process discipline relies on manual sampling; in the intelligent manufacturing mode, we can use computer vision, big data analysis, and other technologies to develop intelligent construction quality monitoring systems to comprehensively monitor, warn and correct the implementation of process discipline. In addition, in terms of inspection and testing, the development of intelligent detection systems can greatly improve the detection efficiency and accuracy.

3.2.3 Real-time monitoring of dynamic risks

To develop intelligent manufacturing of special equipment, we should make full use of modern information technology to realize real-time monitoring and intelligent prevention and control of equipment dynamic risk. Taking mobile pressure equipment as an example, previous studies [5] have proposed the idea of building a whole lifecycle and whole chain big data platform to gather information on elements such as equipment quality, use, operation, inspection, failure, and damage. The big data platform can achieve real-time monitoring of all kinds of risks by building corresponding models for data mining. It can not only monitor the failure risk of single items of equipment, but also monitor in real time the macro security risk of different time scales (cycles, time periods, etc.), different spatial ranges (regions, units, industries, etc.), and different application fields (government supervision, technical inspection, etc.) The results of risk analysis are provided to government regulatory departments, and technical inspection institutions to guide the corresponding business effort. When the risk reaches a certain level when dangerous situations may occur, early warnings can be given, and corresponding indicators designed according to specific needs. In short, big data platforms based on the whole lifecycle and the whole supply chain can conduct real-time or regular early warning analysis. It can detect ongoing and emerging problems in quality and safety providing prompt and timely warnings to the relevant units. Once an equipment incident occurs, rapid emergency response can be initiated, tracing of historical information about for instance, equipment identity and quality, safety, and management to provide guidance for the next step of emergency disposal and investigation. By installing intelligent terminals on the equipment, the data about incident characteristic parameters can be collected automatically and uploaded to the incident emergency module of the big data platform. Through analysis calculations and expert-aided decision-making systems, the emergency plan can be automatically generated to guide personnel evacuation, and start emergency measures such as safety protection.

4 Intelligent manufacturing of special equipment based on intelligent network

4.1 Connotation of intelligent and networking

The concept of “intelligence and networking” was first applied in the automobile industry [13], which is a recognized technical way to realize intelligent vehicles and transportation. This study introduces the technical concept of intelligent connection into the special equipment industry [4] and combines the characteristics of special equipment to further elaborate the connotation of intelligent connection, including the two aspects of intelligence and networking.

4.1.1 Intelligence

The original meaning of intelligence is to describe the wisdom and ability of human beings. As a high-level animal, human beings have sensory organs (eyes, ears, skin, nose, tongue), senses (vision, hearing, touch, smell, and taste), nerves, brains, hands, feet, muscles, etc. After feeling the external light, sound, heat and other signals through sensory organs, the signals are transmitted to the brain through nerves, the brain analyzes and evaluates the signals, sends out feedback signals, and finally commands the hands, feet, and muscles to respond accordingly. The intellectualization of machinery and equipment refers to the above abilities that are similar to human beings, including intelligent perception and recognition, intelligent analysis and decision-making, intelligent control and execution, and intelligent memory and learning.

Intelligent perception and recognition refers to the ability to sense and recognize one’s own state and environmental impact. It uses sensor monitoring technology such as pressure, temperature, level, and flow, as well as image recognition, voice recognition, and other AI technology. In addition, it uses other monitoring technologies including the loT, Internet information, and social network information monitoring technology, and is configured with reliable manual regular inspections. It will collect, search, analyze, and upload public opinion information about equipment working parameters, operational status, environmental conditions, and usage in real time to support further intelligent analysis and decision-making. For special equipment, it should focus on the perception and identification of safety state parameters related to fault, damage, failure, and risk.

Intelligent analysis and decision-making refer to the ability to self-analyze, make judgments, and make decisions based on perceptual information. The content of intelligent analysis includes the analysis of the quality level, safety status, use, and management of a single piece of equipment, as well as the analysis of the overall quality, management, and safety status of enterprises, institutions, regions, and industries. According to the analysis results, we can make combinations of decisions such as to shut down, maintain, inspect, supervise or scrap. Analysis and decision-making rely on rich model algorithms and powerful knowledge bases to establish an

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analysis and decision-making system based on big data. By collecting the whole lifecycle and the whole supply chain big data, different analysis, diagnosis, evaluation, prediction and early warning models can be constructed, and then use big data mining, cloud computing, modern statistics, and other tools to analyze and make appropriate decisions.

Intelligent control and execution refers to the ability to automatically respond to decision-making instructions. Based on the safety requirements, after monitoring the equipment fault, damage, failure, accident, illegal operation, or other abnormal situation, corresponding measures need to be taken to deal with them promptly. Therefore, automatic control systems need to be developed that can be used to adjust the process parameters, and correct the illegal operation behavior timeously. In case of dangerous situations in the external environment, safety protection needs to be initiated, and emergency disposal or evacuation completed in time, so as to avoid an accident or to reduce the consequences of an accident as far as possible.

Intelligent memory and learning refers to the ability to accumulate experience and learn to grow. Full use needs to be made of cloud storage, modern databases, and other technologies to build a big data platform, conduct data mining and analysis, and use the accumulated data to guide the completion of the corresponding business and service work. At the same time, new experience data in the business and service work needs to be continuously accumulated, and fed back into the database, so as to keep a virtuous circle. In this way, the quantity and quality of the collected data will continue to improve, and the data knowledge base is constantly enriched to realize self-learning and growth.

4.1.2 Intelligent connection

The intelligent connection is used to connect entities such as the related equipment, personnel, institutions, and the environment to form a network. As shown in Fig. 1, the equipment, personnel, institutions, and environment are the information nodes in the intelligent network. The intelligent network can interact with each node; the equipment can upload information to the intelligent network, and the intelligent network can also distribute information to the equipment. Intelligent connections are realized through modern information technologies such as the Internet of Things, mobile internet, and local area networks. The intelligent network collects multi-dimensional big data relating to special equipment based on time and space, and develops various applications through model construction, big data mining, and other technologies. Eventually, the equipment in the whole network will have the functions of perception and identification, analysis and decision-making, control and execution, memory, and learning, and then realize the goal of networked intelligence. Compared with the intelligent system with a single device as the object, the information perceived through the intelligent network will be more comprehensive and perfect. It can not only detect information from a certain device, but also from all other devices related to that device, as well as information about personnel, institutions, the environment, and management. In a word, the analysis and decision making based on the whole network data will be more reliable and scientific, the resulting control and execution will be timelier and in place, and the memory and learning will be more in-depth and efficient.

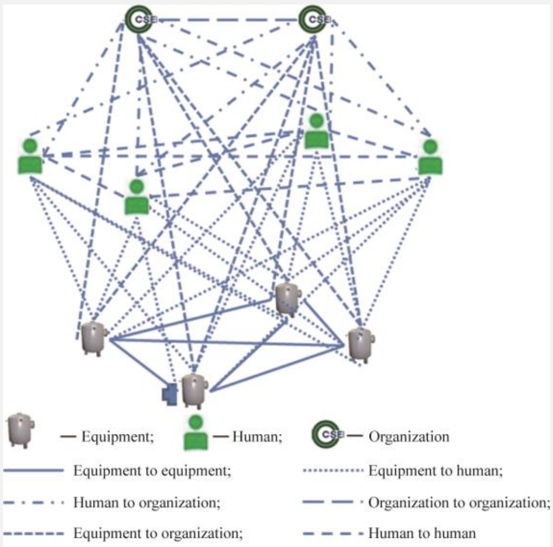

Fig. 1. Schematic diagram of intelligent network.

4.2 Key tasks of intelligent manufacturing of special equipment based on intelligent connection

To develop intelligent manufacturing of special equipment, the first thing is to determine the technical approach. It is technically, and economically feasible to use intelligent connections as a technical solution to promote intelligent manufacturing of special equipment. The key tasks involved are as follows.

4.2.1 Construction of special equipment intelligent network

The construction of an intelligent network is the premise to realize the intelligent connection of special equipment. We can take the strategy of gradual promotion, first build an intelligent network for different types and varieties of equipment, and then further interconnect various kinds of equipment in the intelligent network, and finally form a whole network of special equipment. The key points of special equipment intelligent network construction are described below.

(1) Configuration of intelligent monitoring system

For each item of equipment included in the intelligent network, it is necessary to configure a set of systems to monitor the operation, use, management, and other aspects of the equipment, and then execute the instructions of analysis and decision making. There needs to be a focus on monitoring the safety state parameters of equipment failure, damage, accident and other aspects, and to automatically conduct corresponding control measures such as early warning and prediction, safety protection, and emergency disposal. Different types of equipment have different structures, principles, use environments, and operation modes, so different monitoring systems need to be configured. 1) Specifically, the monitoring indicators of the intelligent monitoring system can be determined based on the principles of science, type of system, practicability, effectiveness, and feasibility. Through the identification of safety risk and its influencing factors, combined with the requirements of regulations and standards, the targeted and practical index system can be screened and refined. 2) The monitoring technology should make full use of technologies such as fiber grating, vibration, corrosion probe, acoustic emission, pulsed eddy current, and magnetic memory. It should also use radar, ultrasonic and other remote sensing technologies, as well as voice and image recognition and other AI technologies. Furthermore, further special research and development should be carried out depending on the specific reliability requirements. 3) The communication module is a necessary part of the special equipment connected to the intelligent network. The architecture design of the communication module should be based on the systematic analysis of the operational characteristics of the equipment paying attention to aspects such as the power supply, power consumption, equipment mobility, data stability, number of network nodes, and data flow. 4) The control execution system can either adopt the automatic control system or conduct reliable interventions using manual technology or through operations management. In addition, the monitoring system should consider the problem of functional security to ensure that the monitored data is real and available, the data storage and transmission should be confidential and reliable, and the control execution system should be able to start in time according to the design requirements in case of abnormal conditions.

(2) Construction of networked data platform

The special equipment of intelligent networks needs to be supported by data to build a network data platform. The data collected by the platform should be as comprehensive as possible to avoid data blind areas. Network access equipment, first of all, should be based on the whole lifecycle and all links of the chain. In addition, the equipment should be based on laws and standards, able to systematically distinguish the data source and distribution, and clarify the data flow direction and the overall data architecture. Finally, a data directory system and data classification system need to be established.

The construction of a network connected data platform needs to considered: 1) The overall architecture design of the platform should meet the needs of data collection convenience, dynamic updates, mass storage and so on. 2) The data collected by the platform should be standardized, develop standards of data elements, data formats, information classification, and coding. Unified specifications for the database architecture need to be developed, as well as for data processing, storage, conversion, retrieval, export, and access. The data should be usable, and a series of processing such as cleaning, integration, conversion, specification, screening, fusion, standardization, integration, and loading must be carried out before being stored to improve the quality of data and better adapt to the next step of the data mining processing. 3) In addition to real-time collection through the monitoring system, data collection can also use manual input, computer importing, and other methods. 4) With full consideration for information security, the information on data platforms and the devices connected to the platforms is connected to the network. The data can be accessed by the outside world anytime and anywhere, and may be stolen, intercepted or modified. Therefore, the basic requirement of data and information security is that information cannot be

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accessed by the outside world.

4.2.2 Intelligent application development

After the establishment of a special equipment intelligent network, we can develop all kinds of intelligent applications according to the actual need, realize the intellectualization of related management and service, improve work efficiency, and work quality. Specifically, the above-mentioned intelligent traceability systems and intelligent quality management systems can be developed, and the following intelligent applications can be developed based on the need to further improve the safety level of special equipment.

(1) Intelligent diagnosis and analysis

Diagnostic analysis refers to the prediction, analysis, and judgment of the faults in or damage to the equipment. By developing and embedding the intelligent diagnosis and analysis model based on the networked data platform, the real-time diagnosis and analysis of the equipment can be achieved, the real-time automatic identification of the equipment fault and damage can be carried out, and the location, nature, category, degree, and cause of the equipment problem can be determined. The trend and consequences of the occurrence and development of the fault and damage are clarified, and the adjustment, maintenance, and treatment measures to control and eliminate the fault and damage are determined.

(2) Dynamic risk assessment

How to determine the current risk status (dynamic risk) of equipment in real time and accurately is a hot issue in the field of equipment security assurance that needs to be solved urgently. Based on the network data, we can develop a dynamic risk assessment model and embed it into the intelligent network to conduct real-time and dynamic assessment of equipment risks, analyze and calculate the possibility and consequences of failure caused by each kind of failure and damage, and propose corresponding prevention and control measures, so as to realize the automatic identification, prevention, control, and governance of equipment risks.

(3) Intelligent early warning and forecasting

Early warning refers to sending emergency signals to the relevant units and reporting the dangerous situation before the occurrence of unacceptable risks or events. This avoids the occurrence taking place without prior knowledge or sufficient time for preparation, and in that way enables the loss caused by the occurrence to be minimized. The traditional early-warning technology provides early warning based on the previous law summary or possible precursors obtained from observations. However, based on the networked data platform, we can build an intelligent early warning technology system, determine the threshold of early warning index, and establish the early warning system and the corresponding early warning working mechanism. We can also develop the corresponding model, such as developing the early warning and forecasting module on the basis of the networked data platform, so that the real-time automatic early warning and forecasting can be realized.

(4) Intelligent emergency response

On the basis of networked data platforms, the intelligent emergency module is developed, which can realize rapid emergency response in case of equipment malfunction. It can quickly trace the historical information of equipment identity, quality, safety, and management, and provide guidance for the next step in terms of emergency disposal and incident investigation. According to the different types of equipment incident, the corresponding intelligent emergency disposal module is constructed to automatically detect the characteristic parameters of the incident, and provide data support for the timely generation of targeted emergency plans, which are suited to handling incidents and reducing incident consequences.

5 Conclusion

Currently, special equipment has encountered development bottlenecks in terms of quality and safety, which urgently needs to transform and upgrade. The fourth scientific and technological revolution has brought new development opportunities for special equipment that are of great significance to integration and the application of new generation information technologies such as the Internet of Things, big data, and AI, and to develop intelligent manufacturing of special equipment. This paper studies and analyzes the characteristics of special equipment, development status, and the demand of developing intelligent manufacturing. It introduces the intelligent connection as the technical path to follow for the development of intelligent manufacturing of special equipment. Furthermore, it analyzes its connotation, and defines the strategy and key points for the development of intelligent manufacturing of special equipment, as well as the key tasks based on the intelligent connection. In the future, we can carry out in-depth demonstrations and explore practices based on this, and better promote scientific and technological research and application in the field of special equipment.

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