Brief Analysis of Intelligent Manufacturing Reliability

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Abstract Against the backdrop of the deepening of the "Quality Power" strategy and the global industrial transformation, intelligent manufacturing has become the core path for the high-end, intelligent and green transformation of China's manufacturing industry. As the lifeline of the manufacturing industry, reliability is a key support for the effective implementation of intelligent manufacturing and the enhancement of industrial competitiveness. Combining typical practical cases, standard system construction and industry research in the fields of domestic intelligent manufacturing and reliability, this paper systematically sorts out the development status of China's intelligent manufacturing and reliability, deeply analyzes the problems in concepts, technologies, standards, talents and other aspects during the development process, and puts forward targeted solutions based on the practical experience and theoretical achievements in existing research, providing a theoretical reference for the integration of China's intelligent manufacturing and reliability and the promotion of the high-quality development of the manufacturing industry.

Keywords Intelligent Manufacturing; Reliability; Development Status; Existing Problems; Solutions

I. Introduction

At present, a new round of scientific and technological revolution and industrial transformation is accelerating, and the "dual carbon" goals and the "Made in China 2025" strategy are being thoroughly implemented. China's manufacturing industry is in a critical period of transformation from scale expansion to quality improvement. Relying on advanced technologies such as the industrial internet, artificial intelligence and big data, intelligent manufacturing realizes the digital and intelligent upgrading of the production process, greatly improving the production efficiency and precision of products. As the core characterization of product quality, reliability covers the whole life cycle of design, production, testing and service, and is directly related to the market competitiveness of enterprises, national industrial security and energy security.

In recent years, with the popularization of intelligent manufacturing, the integration trend of the two has become increasingly obvious, and a number of enterprises have made phased achievements in the fields of equipment manufacturing, industrial robots, hydrogen energy, aerospace and so on. However, compared with developed countries, the integrated development of China's intelligent manufacturing and reliability still faces many bottlenecks. Some enterprises have problems such as backward concepts, weak technologies and imperfect standards, which restrict the high-quality development of the manufacturing industry.

II. Development Status of China's Intelligent Manufacturing and Reliability

In recent years, China has made remarkable progress in the integrated development of intelligent manufacturing and reliability, showing a steady development trend in policy guidance, technological application, standard construction, enterprise practice and other dimensions.

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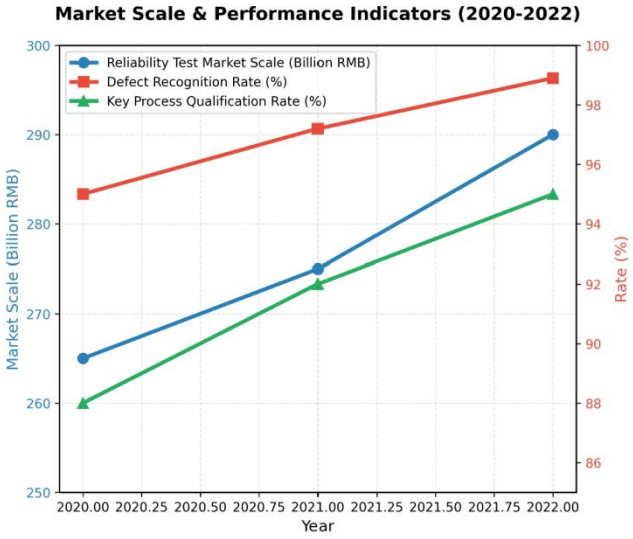


Fig. 1. Market Scale & Performance Indicators.

A. Optimized Policy Environment and Improved Top-level Design

The national government attaches great importance to the development of intelligent manufacturing and reliability, and has successively issued a series of policy documents such as the Outline for Building a Quality Power and the 14th Five-Year Plan for the Development of Intelligent Manufacturing, clearly identifying reliability improvement as an important part of intelligent manufacturing and promoting the in-depth integration of the two. At the same time, the state supports the research and development of reliability technologies in the fields of industrial robots and high-end equipment through key research and development program projects, providing a solid policy support for the development of the industry.

B. In-depth Technological Application and Remarkable Results of Typical Practices

With the popularization of intelligent manufacturing technologies, Chinese enterprises have gradually integrated artificial intelligence, big data, industrial internet and other technologies into the whole life cycle reliability management and control of products, forming a number of replicable and promotable practical cases. In the field of equipment manufacturing, a company has innovatively proposed a "Smart Manufacturing Chain Core" dual-drive model, with intelligent manufacturing and chain leader collaboration as the core, to build a product full life cycle reliability guarantee system. Through the application of digital design, intelligent manufacturing, digital testing and other technologies, the missed detection rate of harmful defects in welds has been reduced to 0, the defect recognition rate has reached 98.9%, and the one-time qualification rate of key processes has been increased to more than 95%. In the field of industrial robots, China has become the world's largest industrial robot market, with an installed capacity accounting for 36% of the global total. Enterprises have gradually applied testing equipment such as high and low temperature chambers, vibration tables and electromagnetic shielding rooms to improve the environmental reliability of robots. In high-end fields such as hydrogen energy and aerospace, the fuel cell system reliability verification technology developed by Shanghai Jie Hydrogen Technology Co., Ltd. has realized 100% localization of key testing equipment, reducing costs by more than 50%. The comprehensive testing system for aerospace batteries established by the Shanghai Institute of Space Power Sources has supported the fault-free operation of more than 200 satellites in orbit for 24 million days, demonstrating China's technological strength in the integration of intelligent manufacturing and reliability.

C. Initially Established Standard System and Improved Testing Capabilities

China has gradually built an intelligent manufacturing and reliability standard system covering basic standards, product standards and method standards. In the field of reliability management, China has formulated a series of national standards such as GB/T 37079–2018 Equipment reliability - Reliability assessment methods and GB/T 7826–2012 System reliability analysis techniques - Procedures for failure mode and effects analysis (FMEA), providing a basis for enterprise reliability management. At the same time, China has established institutions such as the National Robot Testing and Evaluation Center and the National Robot Public Service Platform, equipped with complete reliability testing equipment, and the testing capabilities have been continuously improved.

D. Enhanced Subject Awareness of Enterprises and Sustained Increase in Investment

With the intensification of market competition and the improvement of quality awareness, Chinese enterprises have paid increasing attention to intelligent manufacturing and reliability, with continuous investment growth. According to statistics, the market scale of environmental testing and reliability testing in China reached 29 billion yuan in 2022, a year-on-year increase of 5.45%, reflecting the increasingly urgent demand of enterprises for reliability improvement. Leading manufacturing enterprises have taken the lead in establishing special reliability management mechanisms and integrating reliability into the quality management system; some enterprises have improved employees' reliability technical level by setting up special reliability departments and carrying out full-staff quality training.

III. Main Problems in the Development of China's Intelligent Manufacturing and Reliability

Despite the remarkable achievements made in the development of China's intelligent manufacturing and reliabil-

ity, compared with developed countries, there are still prominent problems in concepts, technologies, standards, talents, industrial chain collaboration and other aspects, which restrict the further development of the two.

A. Backward Management Concepts and Insufficient Integration Awareness

Some enterprises have insufficient understanding of the integration of intelligent manufacturing and reliability, and have conceptual misunderstandings such as "valuing technology over quality" and "valuing production over reliability". They simply equate intelligent manufacturing with automation, ignoring the core role of reliability in the whole product life cycle. Most small and medium-sized enterprises are still in the primary stage of reliability management, lacking systematic reliability planning, and failing to embed reliability requirements into all links such as product design, production, testing and service, resulting in a high product failure rate. At the same time, some enterprises lack a customer-oriented reliability management concept and fail to optimize product reliability design in a timely manner according to customer needs.

B. Inadequate Technological Integration and Prominent Core Shortcomings

The integration of China's intelligent manufacturing and reliability technologies is still in the primary stage. On the one hand, the application of intelligent manufacturing technologies in some enterprises is limited to the production link, without integration into reliability design, testing, maintenance and other links; on the other hand, the investment in reliability technology research and development is insufficient, and core technologies and high-end equipment still rely on imports, with shortcomings in the fields of complex product reliability design, prognostics and health management, and intelligent testing. Taking the industrial robot segment as an example, although China's industrial robot market is leading in scale, there is a significant gap in core reliability indicators compared with the international advanced level. The mean time between failures (MTBF) of domestic industrial robots is about 8,000-10,000 hours, while that of international well-known brands can reach 15,000-20,000 hours, showing a huge gap. At the core component level, the reliability of key components such as servo motors and reducers of domestic robots is insufficient, prone to problems such as operation jams and precision drift, and there is a lack of effective intelligent fault early warning mechanisms. Most enterprises still rely on manual patrol inspection to troubleshoot faults, which not only increases operation and maintenance costs, but also affects production continuity. At the testing technology level, some high-end reliability testing equipment in the industrial robot field still rely on imports, and domestic testing technology is difficult to meet the extreme environmental reliability requirements of high-end robots, such as insufficient reliability testing capabilities under complex working conditions such as high temperature, high humidity and strong electromagnetic interference. The reliability verification technology of some high-end equipment still has the limitation of "static testing", failing to realize multi-working condition dynamic simulation verification, which is difficult to fully reflect the reliability level of robots in actual operation.

C. Imperfect Standard System and Insufficient Adaptability and Timeliness

China's intelligent manufacturing and reliability standard system still has many shortcomings: first, there is a lack of coordination between standards, intelligent manufacturing standards and reliability standards are independent of each other, and some standards have overlapping and conflicting phenomena, which hinder the integrated development of the two; second, the coverage of standards is not comprehensive, and there is a lack of reliability standards for emerging fields such as high-end equipment, new energy and artificial intelligence; third, the update speed of standards is lagging behind, difficult to match the rapidly developing technological changes and market demands, and the content of some standards lacks specific and quantitative indicators and evaluation methods, with poor operability; fourth, the connection with international standards is insufficient, and there is a gap between China's reliability standards and international advanced standards, which is not conducive to the internationalization of China's intelligent manufacturing products.

D. Shortage of Talent Supply and Need for Capacity Improvement

The integrated development of intelligent manufacturing and reliability requires compound talents who master both intelligent manufacturing technologies and reliability engineering, and the current supply of such talents in China is seriously insufficient, becoming a key bottleneck restricting the development of the industry. On the one hand, universities have not generally set up relevant majors in intelligent manufacturing and reliability, the coverage of relevant courses is limited, and the talent training system is imperfect; on the other hand, the investment in internal talent training of enterprises is limited, and existing employees lack systematic reliability technology training, especially the insufficient reliability awareness of front-line technical personnel and managers.

E. Inadequate Industrial Chain Collaboration and Unformed Quality Co-governance Pattern

The reliability collaboration capacity of upstream and downstream enterprises in China's intelligent manufacturing industrial chain is insufficient. Leading enterprises have not given full play to their leading role and cannot effectively drive upstream and downstream suppliers to jointly improve reliability levels, resulting in unstable product quality and unqualified reliability of some suppliers, which affects the product reliability of the entire

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industrial chain; at the same time, there is no information sharing between various subjects of the industrial chain, making it difficult to guarantee product reliability. In addition, China has insufficient practical experience in the field of reliability verification, and the reliability technologies in some emerging fields lack industry exchange and promotion, making it difficult to form a large-scale application effect.

IV. Solutions for the Collaborative Development of China's Intelligent Manufacturing and Reliability

A. Strengthen Conceptual Guidance and Establish Awareness of Collaborative Development

Popularize the concept of integrated development of intelligent manufacturing and reliability through policy interpretation, promotion of typical cases and industry forums. Conduct regular customer satisfaction surveys and collect product usage feedback to deeply understand customer needs and integrate customer expectations into the whole life cycle reliability management and control of products. Give play to the demonstration and leading role of leading enterprises, summarize and promote typical reliability practical experience in the industry, guide small and medium-sized enterprises to learn from it, and gradually establish a systematic reliability management system.

B. Deepen Technological Integration and Break Through Core Technical Shortcomings

Promote the in-depth integration of intelligent manufacturing technologies and reliability technologies, build a full life cycle reliability management and control system, and integrate digital design, intelligent manufacturing, digital testing, intelligent operation and maintenance and other technologies into all links of product design, production, testing and service. Increase investment in core technology research and development, support the collaborative research of enterprises, universities and research institutes, focus on core shortcomings such as complex product reliability design, prognostics and health management, and intelligent testing equipment, break through key technologies, realize the localization of high-end testing equipment, and reduce dependence on imported equipment. Promote the application of advanced reliability technologies and tools, such as Failure Mode and Effects Analysis (FMEA), Fault Tree Analysis (FTA) and Lean Six Sigma, to improve the scientific level of enterprise reliability management.

C. Improve the Standard System and Enhance the Adaptability and Timeliness of Standards

Build a coordinated and unified standard system, integrate relevant standards of intelligent manufacturing and reliability, eliminate overlapping and conflicting phenomena of standards, and adapt to the needs of the integrated development of the two. Improve the coverage of standards, accelerate the formulation of reliability standards for emerging fields such as high-end equipment, new energy, artificial intelligence and hydrogen energy, and fill the standard gaps; refine standard content according to the needs of industries such as industrial robots and high-end equipment, add specific and quantitative indicators and evaluation methods, and improve the operability of standards. Accelerate the update speed of standards, establish a dynamic standard update mechanism, timely connect with international advanced standards, learn from the advanced experience of international standards such as ASME and DIN, revise and improve China's relevant standards, promote the alignment of China's standards with international ones, and enhance the international competitiveness of China's intelligent manufacturing products. Establish a standard implementation effect evaluation mechanism to promote enterprises to carry out production and operation activities in strict accordance with standards and ensure the effective implementation of standards.

D. Strengthen Talent Training and Build a Compound Talent Team

Improve the talent training system, promote universities to optimize professional settings, set up relevant majors for the integration of intelligent manufacturing and reliability, add core courses such as reliability engineering, intelligent testing and fault diagnosis, and cultivate compound professional talents; strengthen the construction of vocational colleges, carry out skilled talent training, and improve the reliability operation capabilities of front-line technical personnel. Increase investment in enterprise internal talent training, establish a sound training system, regularly carry out relevant training on reliability technology and intelligent manufacturing technology, and batch cultivate high-skilled talents through the model of "technological research and development + skill research + talent training" combined with platforms such as master studios and QC groups; establish an incentive mechanism, set up a special reward fund, encourage employees to participate in reliability improvement activities, and enhance employees' enthusiasm and initiative. Introduce international high-end reliability talents and leading talents, carry out inter-industry and international talent exchange and cooperation, and improve the overall level of China's reliability talent team.

E. Promote Industrial Chain Collaboration and Build a Quality Co-governance Pattern

Give play to the leading role of chain master enterprises, drive upstream and downstream suppliers to jointly improve reliability levels through standard output, joint innovation, hierarchical evaluation and other methods, establish a supplier access and hierarchical evaluation system, and promote the collaborative quality improvement of the industrial chain. Build an industrial chain in-

formation sharing platform to realize the interconnection of reliability data, technological achievements, standard specifications and other information, break information silos, and promote all subjects of the industrial chain to carry out reliability design, production, testing and service in a coordinated manner, forming a quality co-governance pattern. Strengthen industry coordination and exchange, hold activities such as reliability verification competitions and industry forums, promote advanced technologies and practical experience, and fill the gap in reliability verification practice; promote the collaborative cooperation of enterprises, universities and research institutes, establish an industry-university-research-application integrated innovation system, and accelerate the transformation and application of reliability technology achievements.

V. Conclusions and Prospects

The integrated development of intelligent manufacturing and reliability is the core path to promote the high-quality development of China's manufacturing industry and realize the "Quality Power" strategy. At present, China has made remarkable achievements in the development of intelligent manufacturing and reliability, with an optimized policy environment, in-depth technological application, an initially established standard system and enhanced subject awareness of enterprises. However, it also faces prominent problems such as backward management concepts, inadequate technological integration, an imperfect standard system, talent shortage and inadequate industrial chain collaboration.

In the future, it is necessary to promote the in-depth integration of intelligent manufacturing and reliability and build a full life cycle reliability guarantee system through a series of measures such as strengthening conceptual guidance, deepening technological integration, improving the standard system, strengthening talent training, promoting industrial chain collaboration and increasing policy support. With the continuous development of digital technology and the deepening of industrial chain collaboration, China's intelligent manufacturing and reliability levels will be gradually improved, expected to break through core technical shortcomings, improve the standard system, build a compound talent team, and form a development pattern of "advanced technology, improved standards, sufficient talents and efficient collaboration". This will drive the transformation of China's manufacturing industry from "Made in China" to "Intelligently Made in China" and "Quality Made in China", and provide Chinese solutions and experience for the high-quality development of the global manufacturing industry.

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