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Development of Industrial Software for Building Materials Industry

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Abstract: The building materials industry is the foundation for the national economy. Intelligent reforms and digital transformations have deepened the application of new technologies and brought about more digital scenarios, which drives the development of industrial software for the building materials industry and facilitates its high-quality development. Industrial software is a link that connects industrial design and manufacturing processes with informatization, intelligence, and digitization. In this study, we categorize the industrial software for the building materials industry into the following four types based on industrial characteristics, technical processes, and core functions of the software: operation management; research, development, and design; production control; and service-guaranteed software. Subsequently, the development status of industrial software for the building materials industry in China and abroad is reviewed, and the gap between China and the advanced international level regarding industrial software development is analyzed. The key development directions are clarified from the perspectives of improving weak links, promoting replacement, and developing advantages. The research suggests that the industrial software for the building materials industry should be developed from the following technological perspectives: (1) breaking technical barriers in key areas, (2) ensuring the safety and control of key links, (3) promoting the application of information technology innovations, and (4) building an industry public service platform. Moreover, we propose the following development strategies: (1) optimizing the support policies, (2) improving the industrial software standards system, (3) encouraging industry–university–research–application collaboration to address key problems, (4) cultivating industrial software compound talents, and (5) establishing an appropriate software application ecology.

Keywords: building materials industry; industrial software; industrial bottlenecks; intelligent manufacturing

1 Introduction

The building materials industry is in a critical period of adjusting and transforming the structure of the industry. As a link between the industrial design manufacturing process and informatization, industrial software has a clear scale market advantage and domestic demand potential in the industry; it is of great significance for the building materials industry to transform its mode, adjust its structure, increase its power, and accelerate its high-quality development. Currently, the literature mainly focuses on the development of industrial software itself, including research on the overall development level, development difficulties, and development direction for industrial software [1–7]; it pays less attention to the application of industrial software in the industry. In the context of the rapid development of intelligent manufacturing and digital transformation in the building materials industry, the tasks that must be completed include clarifying the application of industrial software in the industry, resolving

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existing problems, and rectifying existing defects. Therefore, this study focuses on the research gaps in the field of industrial software in the building materials industry and conducts a series of investigations.

Based on the characteristics of the industry and technological process, this study defines the industrial software for the building materials industry into four categories according to the core functions of the industrial software, including research and development (R&D) and design, management and operation, production control, and service guarantee. Specifically, the industrial software for R&D and design in the building materials industry is mainly used to improve the efficiency of enterprise simulation and R&D and design, and to realize digital R&D. The production control industrial software for the building-materials industry is mainly used to improve the production efficiency, management and control level, and equipment efficiency of the manufacturing process. The service-support industrial software refers to the new industrial software for new business and new operation mode of building materials enterprises under the industrial Internet. Based on the classification of the industrial software, this study comprehensively analyzes the development status, gap, and trend of industrial software in the building materials industry. Simultaneously, it clarifies the key development directions for the four types of industrial software and proposes development suggestions that will guide the development of industrial software in the building materials industry.

2 Status analysis of industrial software in the building materials industry

2.1 Domestic and international development status

2.1.1 R&D and design

The commonly used R&D and design software in the building materials industry includes the following: molecular dynamic simulation software (Lammps), material simulation software (Materials Studio), glass-furnace simulation software (GFM), fluid simulation software (Ansys CFD), general structural mechanics simulation and analysis system (Ansys Mechanical), computer-aided design system (CAD), computer-aided engineering system (CAE), computer-aided manufacturing system (CAM), computer-aided process design system (CAPP), product data management system (PDM), and product lifecycle management system (PLM). In the application of industrial software in the building materials industry, the R&D design software is the weakest point. Although some building materials enterprises use domestic CAD and CAE software for process design, or use PDM and PLM to build building materials product-data relationship information platforms, they also use structural mechanics simulation software for new-material development simulation; in addition, some cement and concrete enterprises have established online laboratory management systems; however, foreign manufacturers have obvious technology and market advantages. The main manufacturers are Dassault Systemes, the United States Parametric Technology Corporation (PTC), Siemens AG, Autodesk, Bentley, and ANSYS, Inc [8,9]. Domestic CAD and CAE products currently lag behind the international advanced level in terms of integration, scale, coverage, and maturity. Domestic PLM is mostly based on the secondary development of foreign systems, with few self-researched underlying platforms. Material simulation software has always been a pain point for domestic R&D and design [10,11]. For a long time, firms in the building materials industry such as cement, glass, ceramics, design institutes, and universities in the field of new material research are mostly dependent on foreign manufacturers' simulation products, which not only has the problem of low matching, but also has certain security risks.

2.1.2 Management and operation

Management and operation industrial software mainly includes an enterprise resource management system (ERP), a customer relationship management system (CRM), a supply chain management system (SCM), a human resource management system (HRM), an enterprise asset management system (EAM), a warehouse management system (WMS), and an office automation system (OA). Compared with other types of industrial software, the management and operation software for the building materials industry is the most widely used and has the highest degree of localization. Building material enterprises basically realize the coverage of an ERP system, and integrate HRM, SCM, CRM, and EAM systems into the ERP system to achieve comprehensive control of enterprise resources to improve operational efficiency. The adaptability and customization level of management and operation software in foreign building materials enterprises is higher, while the domestic technology level is advanced, with a leading market share. With the advantages of cloud computing, ERP, CRM, and other operation and management software have realized software as a service (SaaS).

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2.1.3 Production control

Production control industrial software mainly includes a manufacturing execution system (MES), a data acquisition and monitoring control system (SCADA), a decentralized control system (DCS), a statistical process control system (SPC), a programmable logic controller (PLC), an advanced process control system (APC), and an online defect detection system. The trend in the integration of production control software in other countries is obvious; for example, the strength of automation system suppliers such as Siemens AG through the acquisition of MES companies or the development of MES software packages to capture the market. The large DCS companies basically belong to the fourth generation. China's domestic R&D forces in the field are strong, although the software is less independent and less controllable.

2.1.4 Service guarantee

Service guarantee industrial software is a new driving force for the industrial Internet, and is also among the scenarios for the transformation and upgrading of building materials enterprises, including a product quality traceability system and Internet Plus service platforms. There are many overseas digital technology applications, while new scenarios have emerged; as an emerging trend, China's industrial software for service security has gained widespread attention and shows promising development. Several new platforms with new models and new scenarios have emerged, such as the "I find my car" intelligent logistics platform by Ningxia Building Materials Group Co., Ltd., Yidan.com's "cross-border e-commerce + overseas warehouse" foreign-trade e-commerce platform, and the "Huaxin Mall" e-commerce platform by Huaxin Cement Co., Ltd. Thus, the industry's innovation ability evidently continues to strengthen.

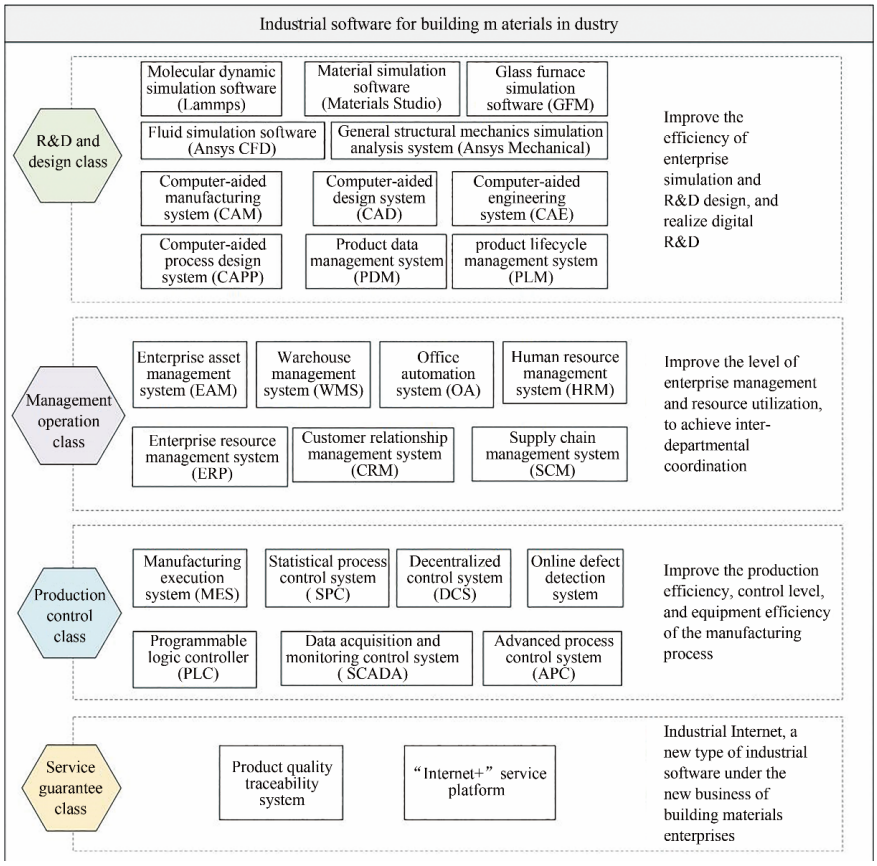

Fig. 1. Classification of industrial software for building materials industry.

2.2 Gap analysis

2.2.1 R&D and design: high-end industrial software is heavily dependent on imports, with a considerable lag behind the world's advanced level.

Although the overall scale of R&D and design software is small, its technical content is the highest. With the transformation, upgrading, and rapid development of China's building materials industry, the R&D design

software is growing more rapidly, while the degree of localization is gradually increasing, basically realizing domestic replacement at the two-dimensional (2D) level but still dominated by foreign products at the three-dimensional (3D) level. The high-end CAD, CAE, PLM, and other R&D industrial software market is especially dominated by SAP, Siemens AG, and Dassault. In particular, the market for high-end CAD, CAE, PLM, and other R&D industrial software is dominated by foreign vendors such as SAP, Siemens AG, Dassault Systèmes, PTC, and Autodesk [12], while foreign vendors dominate the simulation software as well as the digital twin and artificial intelligence R&D and design platforms [13,14].

2.2.2 Management and operation class: industry-specific and customized degree is low; energy security management must be improved.

Owing to the large differences in the main products, production processes, and service objects of each subdivision industry of building materials, the demand for industrial software is not consistent. All enterprises expect to have a set of management and operation systems or platforms that fit the industry and even the enterprises themselves. At present, most of the ERP systems independently developed in China are general-purpose software, lacking industry pertinence and low customization. With the proposed goals of carbon neutrality and carbon emission peak, an energy management system (EMS) has become an important part of the management and operation of building materials enterprises. Therefore, it is necessary to further improve the application of energy management information systems and promote the realization of the goals of energy saving and carbon reduction in the building materials industry.

2.2.3 Production control: fully independent and controllable; the level of technological innovation must be continuously enhanced.

In the field of production control software for building materials, Siemens AG, Dassault Systèmes, and other companies maintain leading positions in the industry, while there are many R&D manufacturers; however, it is difficult to acquire full, independent control over their products. In contrast, the level of integration and comprehensive performance of domestic software must be further enhanced. Production control software plays an extremely important role in the whole business process of building materials enterprises. However, after applying foreign MESs, many enterprises cannot integrate them with domestic management and operation software owing to data port problems, resulting in industrial data asymmetry, which brings certain difficulties to the overall construction of intelligent factories.

2.2.4 Service guarantee: the supply market is more fragmented and has not yet formed industry-segmented platforms.

The current industrial software for the building materials industry is mainly focused on R&D and design, operations and management, and production control software, while considerable room remains in the supply and application of service guarantee software. Overall, the attention to quality traceability and other services is insufficient. Individual users can hardly trace products' production information. In addition, the new generation of information technology in the building materials industry is not applied to a high degree, resulting in an overall lack of service security capacity. Most enterprises still rely on the traditional business model to achieve product import, export, and storage, and therefore the industry- and enterprise-innovation capacity must be improved.

3 Development trend for industrial software in the building materials industry

3.1 Application areas have gradually increased and have been refined; industry-specific areas have been enhanced.

With the gradual implementation of intelligent manufacturing policies and the acceleration of China's industrialization process, the application scope and depth for industrial software have been further expanded. If China's industrial software market continues to grow at a double-digit rate in the next five years, the market size is expected to exceed 430 billion CNY in 2026. As is well known, industrial software has always played an extremely important role in promoting the national strategies of "integration of informatization and industrialization," industrial transformation and upgrading, and new industrialization in the building-materials industry. From the perspective of the building-materials industry chain, with the technological progress, the application field for industrial software will continue to increase. Industrial software will be widely used in various links and elements, closely combined with the production process, building materials products, industrial equipment, etc., to fully support the R&D and design, production and manufacturing, management and operation,

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service guarantee, and other activities of building materials enterprises, and thus become the integration agent for industrialization and informatization. Meanwhile, industrial software will provide more suitable solutions for the cement, glass, ceramics, and other subdivisions of the building materials industry to enhance industry targeting.

3.2 Carbon neutrality targets drive energy management and industrial software helps green manufacturing

There have been problems of high energy consumption, high emissions, and overcapacity in the building materials industry. In the context of the national strategy to achieve the goals of carbon peaking and carbon neutrality, the building materials industry must urgently choose an effective emission-reduction path and strengthen energy management. At present, many building materials enterprises realize real-time supervision of energy consumption by applying EMSs and real-time supervision of the production process by applying MESs; however, an EMS and an MES mostly exist as independent operations, with no connection between these two systems. However, with the emergence of Industry 4.0, industrial Internet, intelligent manufacturing, and other platforms and systems, the conditions for the integration of the two are provided. Meanwhile, energy management is not only about equipment energy efficiency, energy consumption monitoring, and energy visualization, but also, more importantly, it is about energy consumption modeling; that is, the value utilization of energy data. With the rapid development of industrial software and the continuous upgrading of green manufacturing requirements, a deep integration of MES and EMS will become inevitable; that is, through energy planning, energy monitoring, energy statistics, energy consumption analysis, key energy-consumption equipment management, energy metering equipment management, and other means to help energy management and achieve green manufacturing.

3.3 Industrial software is developing toward miniaturization and the industrial application program (APP) will become common.

Industrial software presents the development trend for large platforms, small applications, cloud, knowledge, etc. [15]. Due to some deficiencies in architecture, function integration, development cost, and application maintenance, it has gradually become difficult to meet the development needs. Therefore, the industrial APP has become the product of a combination of “knowledge” and “software.” The world’s major developed countries are accelerating the deployment of industrial Internet platforms and vigorously deploying industrial APPs to empower industry to improve quality, efficiency, transformation, and upgrading by activating industrial data and knowledge resources. As the building materials industry and Internet integration have developed, the pace of the digitalization, networking, and intelligent transformation of the industry has accelerated, while the penetration rate of industrial APPs in the building materials industry has also significantly increased. In the future, the industrial APP will be oriented to the application scenarios of the building materials industry, and will be horizontally applied to multiple links such as R&D and design, manufacturing, operation and management, and operation maintenance services of building materials products. Simultaneously, the industrial APP will be vertically applied to multi-level and multi-industrial scenarios from products to industries, and will achieve convenient operations in the design and simulation of product production in building materials, equipment monitoring and management, remote operation and maintenance monitoring of workshops, enterprise resource allocation management, and industrial coordinated development. In short, the industrial APP will become a common form of smart factory for industrial enterprises. In the future, with the accumulation of industrial big data, the industrial APP will also be closely combined with big data to optimize the industrial process and improve industrial production efficiency based on the results of data analysis.

3.4 Artificial intelligence technology is becoming increasingly mature, promoting the intelligent development of industrial software.

With the development of artificial intelligence, industrial production behavior will be better understood and learned by machines, while industrial software will have certain thinking, judgment, and learning capabilities to achieve true intelligent production. Specifically, artificial intelligence, 5G, cloud computing, big data, industrial Internet, Internet of Things, mixed reality, quantum computing, blockchain, edge computing, and other new generation of information technologies support one another, enabling the whole production process of the building materials industry, creating an innovation chain, and building a business closed loop of “ubiquitous perception − real-time analysis − self-help decision − accurate execution − learning and improvement.” In addition, industrial software such as artificial-intelligence-enabled intelligent CAD, expert optimization system, unmanned inspection, fine ore blending scheduling and mining operation coordination, automobile intelligent loading and transportation

management system, safety behavior monitoring, production intelligent scheduling, intelligent data platform, energy management analysis, and so on can effectively improve the intelligent manufacturing level of building materials R&D, production, circulation, processing, service, and guarantee, and promote the intelligent development of industrial software.

3.5 High-end industrial software R&D breakthroughs enable digital transformation of building materials.

Industrial software is the weak link in the domestic intelligent building materials industry chain; high-end industrial software represented by the R&D and design software is the weak link of China's intelligent manufacturing. Specifically, it is unrealistic to catch up with and replace foreign, strong products in the short term; however, in the long run, it remains necessary to independently control industrial software. Breakthroughs in indigenous technology can change the structure of the technology block and gain a more advantageous position in the use and development of high-end industrial software. At present, industrial software is in the stage of accelerating the transformation and upgrading of the building materials industry, while the localization process continues to accelerate. Industrial software, as a bottleneck link, is bound to strengthen investment. Therefore, focusing on the key points regarding the urgent need for breakthroughs in intelligent manufacturing in the building materials industry, enhancing the supply capacity for high-end software, focusing on breakthroughs in several urgently needed, safe, and controllable intelligent equipment and industrial software, and encouraging key enterprises in the main building materials field to try first can effectively improve the intelligent manufacturing technology support capabilities.

4 Development focus of industrial software for R&D and design in the building materials industry

The development of R&D and design industrial software for the building materials industry mainly focuses on digital R&D for new materials, product design, material performance research, mechanical structure research, kiln simulation, strength testing, engineering design, and other common needs in R&D design scenarios.

4.1 Compensation for the lack of online R&D and design of new building materials

R&D design software in the building materials industry is weak for the R&D of new materials; therefore, the focus of future development is on the introduction of artificial intelligence in the development and design of building materials products, aided by data sharing and the rapid screening and prediction of the physical and chemical properties of materials to accelerate the synthesis of new building materials and shorten the R&D cycle.

4.2 Promoting the domestic alternative for R&D and design simulation software

CAD software: CAD software in the building materials industry applications has gradually increased, such as cement plant design simulation, process drawing design, and ceramic product design. In the future, we should focus on strengthening the overall coverage and maturity of CAD software independently developed in China.

Lammps software: Lammps is widely used in the research and design stage for new materials in the building materials industry. It is mainly used in the molecular dynamic simulation of glass microstructure and mechanical structure. However, it is mainly based on foreign products. Research on domestic-related simulation software will be the key development direction in the future.

Furnace simulation model software: GFM and fluid dynamics software (FLUENT) are widely used in the simulation of glass and ceramic furnaces, and provide a basis for the design optimization of these furnaces. However, GFM and FLUENT software are provided by foreign manufacturers, and domestic manufacturers must still fully explore the realization of independent control of furnace simulation software.

CFD software: CFD software can effectively simulate the glass forming process by simulating the flow of float glass, the forming process for tin trough glass strip, and the hemispherical pressing process. The most widely used CFD computational fluid dynamics software in China comes from foreign manufacturers. In the field of computational fluid dynamics simulation of building materials, it remains necessary to strengthen the development and application of domestic manufacturers.

Material mechanics structure research software: Material mechanics structure research software provides a scientific basis for the structural mechanics research of new materials in a building materials laboratory. At present, ANSYS Mechanical is the most common. In the research on building materials mechanics in China, it is necessary to strengthen the R&D of related software.

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Concrete specimen detection system: The system can complete the whole process of concrete specimen maintenance and compressive strength testing in a 24-hour unmanned test and upload data to achieve the whole task of intelligent control of concrete specimen testing machine maintenance. At present, the internal system is widely used in foreign control and identification systems as well as for components; China must strengthen R&D hereon.

PLM system: Although the PLM system has been gradually applied in the building materials industry, the domestic PLM system is mostly based on the secondary development of foreign systems, while there are few self-developed underlying platforms, and it is difficult to integrate with CAD, CAE, and other systems.

4.3 Consolidating the digital management advantages of the entire business chain of engineering procurement construction (EPC).

An Engineering digital-management platform is based on mature technology platform and software products to realize the digital management of the entire lifecycle of projects and has been applied in many domestic enterprises. With the digital twin factory model as the basic data, the platform builds a digital model for the management of the entire business chain of EPC, creates digital, refined, and platform solutions for the entire business chain covering digital design, procurement, logistics, construction, commissioning, and delivery; it brings together resources and creates a new mode for the digital transformation of the entire industry chain of engineering EPC.

5 Development focus of management and operation industrial software in the building materials industry

Focusing on management and operation scenarios such as video inspection, equipment operation and maintenance, cement loading and transportation, energy management, mine scheduling, storage management, supply chain management, marketing management, business analysis, carbon emission management, we actively find shortcomings and exploit existing advantages to promote the development of digital management and operation software for building materials.

5.1 Strengthening the weaknesses regarding safety inspection and intelligent equipment management

Safety intelligent video-inspection control system: In the future, we should combine the intelligent-vision algorithm developed based on deep learning technology and integrate the regional DCS monitoring data, vibration-temperature collection data of the main and auxiliary equipment, and video monitoring system. We should also adopt the high-frequency remote video inspection method to conduct intelligent real-time analysis of the four types of targets in the video image, such as personnel, vehicles, equipment/items, and environment, in order to realize the automatic identification of hidden dangers, timely perception of environmental risks, safety monitoring of equipment operation, and automatic video inspection.

The intelligent supervision system for mobile equipment in a mine’s mining area: To strengthen the management of mobile equipment and improve the digital, refined, and intelligent management of a mine’s level, the focus must be on the following: optimizing the real-time monitoring and optimal scheduling of mobile equipment; monitoring the speed of transportation vehicles; storing the track information for operation equipment; early warning of anti-collision and idle work; automatically recording weighing information and counting production data, etc.

Intelligent diagnosis and early warning system for critical equipment: In the future, the system will focus on the establishment of intelligent diagnosis and early warning systems for critical equipment by increasing the construction and learning of equipment-fault knowledge maps, knowledge description and generation, and knowledge discovery and decision-making; it will integrate them with integrated and efficient intelligent inspection systems, automatic lubrication systems, online diagnosis systems for main and auxiliary equipment, and oil online monitoring systems to achieve intelligent operation and maintenance of production line equipment. A large screen of the construction inspection and maintenance task in a machine repair workshop can be used to cooperate with a mobile APP to realize task distribution and push.

5.2 Creating the advantages of domestic management and operation industrial software

Intelligent cement-shipping management system: through an intelligent, integrated, quick response (QR) code, self-service card issuing, factory queuing, empty car weighing, remote loading, heavy car weighing, self-service card receiving and leaving the factory, automatic lane management, point package counting, spray code system

docking, automatic loading based on laser radar, artificial intelligence cement-loading safety monitoring, and other technologies, the system realizes automatic, unmanned cement shipping. In the future, through continuous system optimization, the system will be promoted to have more applications in cement enterprises.

EMS system: Fully integrated with energy-management data, it realizes the query and analysis functions of indicators such as process power consumption cost, process power, process monthly actual power consumption, daily energy consumption, peak- and valley-level power consumption analysis, etc. to help enterprises in organizing production. Simultaneously, it rationally plans and utilizes energy to reduce energy consumption and CO_2 emissions per unit of product. In the future, we will strengthen energy-warning management and system integration to achieve the goals of "carbon peaking and carbon neutrality."

5G intelligent mine dispatching system: Based on data acquisition and vehicle-control transformation through 5G real-time communication between vehicles and vehicles as well as between vehicles and dispatching centers; based on 3D modeling and real-time road test data, edge-computing capabilities, and unmanned dispatching-system algorithms in the mining area, tasks such as path planning, correct parking, automatic loading and unloading, parking shelter, and remote operation are realized. In future, the focus will be on popularizing the system in small- and medium-sized mines.

WMS system: Through a bar code, a handheld terminal, and other technical means to guide and standardize the operation and process in a warehouse, the system automatically collects and records relevant data, reduces the cost of warehouse management, and increases the utilization rate for warehouse space to improve enterprises' productivity and logistics efficiency. In the future, based on the characteristics of the products of building materials, the system will improve the adaptability of the storage scene for bulk products of building materials.

ERP system: China's self-developed ERP system has been gradually strengthened in terms of industry version, software-function improvement and implementation ability, and has been continuously upgraded in terms of function improvement, application universality, and software maturity. It has been widely used in the building-materials industry. Future development should focus on accelerating the pace of the iterative upgrading of the domestic ERP system, strengthen the link between the system and business needs, and promote the expansion of domestic ERP system applications.

SCM system: The system connects upstream, midstream, and downstream enterprises in the building-materials industry; it is customer-centered, order-based, and covers all aspects of the order execution process, realizing the synchronization of logistics and capital, information, and task flows, thus improving the efficiency of logistics operation, reducing costs, and controlling risks. The interconnection of the system should be optimized to derive customer value in the future.

Carbon-emission digital-assessment system: Through the independently developed building information modeling system (BIM) assignment software, the BIM model information is clouded to assess the carbon emissions from an entire factory's life cycle; in the future, the focus will be on combining national norms and data from the building materials industry to assess the carbon emission level at each stage, providing accurate, efficient, and traceable digital tools for enterprises to conduct carbon inventories and powerful support for building zero-carbon park factories and other kinds of carbon-neutral projects.

Digital marketing system: The system covers the whole scenario of the front and back chain of marketing by establishing a customer database, connecting customer-flow and sales data, and docking multi-channel customers. In the future, it should be combined with the characteristics of the building materials industry, especially the existence of a sales radius for products such as cement, to realize personalized and precise marketing by building data-driven, marketing, closed-loop, algorithm-driven user portraits.

Business-intelligence software: This software can classify, organize, analyze and display data, tap the value of data, meet various complex analysis needs in enterprise production and operation, assist enterprise managers in making decisions, achieve more intelligent data insight, and become an indispensable tool for the command and management of production and operation of building materials enterprises. In the future, it will be combined with artificial intelligence algorithms to extract enterprises' data value.

6 Development focus of production control industrial software in the building materials industry

Based on the production control scenarios for cement, glass, ceramics, glass fiber, and other building materials products, we focus on promoting the development of industrial software that meets industry attributes, solves

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development difficulties and pain points, and can reduce costs and increase efficiency for enterprises in production control.

6.1 Supplementing key subsector production management software defects

Cement quality control intelligent laboratory system: Based on automation and information technology, it focuses on the construction of a new generation of cement production process products from automatic sampling, preparation, and detection to intelligent analysis of quality components and intelligent, unmanned inspection; additionally, through the integration of MLD advanced X-ray fluorescence detection and factory cement intelligent sample storage system and other key technologies, it achieves automatic sampling and reduces labor intensity. Simultaneously, the sampling frequency should be controlled. If the sampling frequency is high, the discontinuous and uncontrollable problems of the original sampling will be solved; if the sampling is uniform and the sampling and sample preparation analysis are not affected, the system has a fast processing speed and high efficiency. Therefore, the data will be automatically transmitted to guide in-time production.

Intelligent sawing system for high-efficiency plates: In the future, it should integrate real-time, network, and two-way energy-feeding control technology based on 5G network; it should build an intelligent control system based on the multi-objective optimization of sawing process technology library and data fusion, thus developing a distributed intelligent control system that supports fieldbus communication function and interoperability with a process technology library.

Glass fiber electronic fabric defect detection and classification system software: The existing manual inspection method suffers from the problems of slow detection speed and low detection rate, while longtime inspection affects employees' visual health. Therefore, an electronic fabric detection method with long-term stable operation, high accuracy, and fast speed is urgently needed. In the future, we will focus on the gray level co-occurrence matrix feature extraction of the detected defect images to realize the intelligent classification of defects.

The automatic detection system for refractory bricks: the quality detection for refractory bricks will be realized by connecting with the automatic mechanical equipment. Refractory bricks are automatically detected by electronic eye to detect whether there are cracks, missing angles, and missing edges and cracks, and the optical instruments are then used to detect whether there are leakage defects. The density, size, distortion, wedge degree, and compressive strength of each brick are measured by ultrasonic scanning, laser electronic instrument, and weight sensor device, and the deformation modulus is detected, if necessary.

6.2 Ensuring that production control software is secure and controllable the soonest possible

Cement efficient non-catalytic denitrification control system: To achieve the carbon peak and neutrality targets, cement-industry denitrification control system R&D is imminent. Therefore, in this field, it is necessary to establish the core technical parameters and software package for the denitrification process with completely independent property rights the soonest possible in the future as well as independently design a denitrification reactor and reducing-agent addition-control system to realize a wide application of the cement denitrification project.

Digital glaze spraying process system: The digital glaze spraying process system can complete the production of anhydrous glaze line, realize multi-channel, superimposed, inkjet printing, and fundamentally improve the dark plate color difference and solve many other problems to ensure that the color is richer, with more texture. Therefore, many foreign color-glaze enterprises have widely used digital spray-glaze in ceramic enterprises. In the future, the proportion of the digital spray-glaze system applied by domestic ceramic enterprises should be increased, and an independent and controllable digital spray-glaze system should be promoted.

DCS system: China's DCS system is developing rapidly; however, an obvious lag behind the international advanced level remains. Many domestic building materials enterprises adopt foreign enterprises' DCS systems. In the future, we should accelerate R&D on DCS, enhance the overall strength of software, and expand the market share of domestic DCS.

MES system: Automatically and in real time, it collects various data from a production site through intelligent monitoring, generates quality data-analysis reports, and analyzes the data for key items of key processes to facilitate the discovery of hidden quality problems in a workshop production and perform the function of finding and dealing with problems the soonest possible as well as improving production efficiency. Domestic manufacturers should focus on the development of fully independent and controllable MES products to strengthen their market shares.

SCADA system: By establishing a flexible and efficient database, it provides a stable foundation for data access and function application, and fully extracts data value. It can realize the digital, visual, and intelligent monitoring and management of building materials production equipment, as well as the intelligent prediction, analysis, and diagnosis of production links and the related decision-making. At present, SCADA has not yet achieved full localization; domestic technology-development enterprises should increase investment to ensure the safety of controllable industrial data.

6.3 Creating the advantages of key control software for key industry segments

The future development of the cement-batching dynamic optimization system focuses on the following: combining with artificial intelligence technology; establishing mathematical models; advance prediction guidance; dynamic optimization of batching components; realizing control of the instantaneous flow of each input material according to the set ratio and flow rate; controlling the quality and output of cement; for the software processing in the slow-down stage, especially the air fall processing, hopper vibration, and overshoot, establishing a self-correcting, predictive, control algorithm model, ensuring both dynamic accuracy and speed.

The development of the kiln intelligent real-time optimization control system focuses on the following: based on the current actual situation of a kiln, with global optimization and a self-learning function, the system comprehensively considers the actual working conditions; it automatically calculates and sets the optimized control target; it accurately monitors the kiln flame temperature, shape, and material temperature, and reduces the decomposition furnace-outlet temperature; it stabilizes and improves the secondary air temperature, increases the energy recovery of the grate cooler, reduces excess air and clinker over-burning; and it realizes the real sense of closed-loop automatic control.

The development focus for the intelligent real-time optimization control system for a cement mill is as follows: Based on the production-process data and internal and external variables, through the mechanism model, the real-time optimization of the grinding system is realized, and the control objectives for controlled variables such as the system's feeding amount, the mill's filling rate, the rotation speeds of the system fan, separator, and circulating fan, the material ratio and particle gradation are set independently. In the case of low power and low material (clinker) consumption, high unit output and stable cement quality are realized.

The development focus for the glass hot-end control system is as follows: Based on a systematic analysis and optimization of the hot-end technology, a mathematical model of the key structure of a large-scale furnace and tin bath is established. Through the development of multiple software, the design and engineering application technology for a large-scale hot end of float-glass production is developed, and automatic control of the furnace's reversing, temperature, combustion system, pressure, important forming area, and annealing temperature is effectively achieved.

The development of the whole line-control system for the glass cold end focuses on the following: developing a networked, all-digital control system; coordinating slitting, cross-cutting, stacking, defect-detection control systems, etc.; collecting and centrally redistributing the data for each subsystem; tracking the glass-data information in real time for the entire line; realizing the optimized cutting of the board; running off tracking; accelerating separation; automatic breaking and breaking of the edge; automatic falling of the board; and automatic steering and tracking of the annealing kiln speed. The system can also improve the accuracy of the automatic control system at the cold end by automatically tracking the speed of the annealing kiln and steering.

The development of the glass online defect-detection system focuses on the following: based on the machine-vision detection model, the system increases the accuracy of the judgment of the full glass defect-detection system through the system's control to achieve image acquisition and processing, intelligent control, mechanical execution, etc.; this achieves high single-image output, millisecond processing speed, high detection accuracy, fast output of detection results, high processing efficiency, and other goals.

The development of the glass optimization cutting system focuses on the following: automatic slitting and cross-cutting control systems and the optimization system. The cutting system is responsible for completing the cutting tasks issued by the optimization system, while the cutting and optimization systems must be equipped with a cutting management-interface system to coordinate the cutting equipment to complete the cutting tasks issued by the optimization system.

The intelligent control system for glass coating mainly realizes the automatic production of glass vacuum coating, realizes the glass transmission control, production-process distribution system control, vacuum-pumping system control, cooling circulating-water system control, etc. The intelligent control system for glass coating

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improves the working efficiency of the coating production line while ensuring the thickness and quality of the coating.

The automatic production system for expandable polystyrene board (EPS) has the characteristics of intelligent scheduling, production-process system, equipment interconnection, production-resource control, quality process control, and decision support. China has independently developed and implemented the first EPS board automatic intelligent production line, which fills a gap in the industry. It is a typical automated production line and an MES system that meets the industry 4.0 standard and will continue to optimize and promote the application of the system.

China has developed a coarse aggregate gradation particle-shape online monitoring system based on artificial intelligence. Specifically, the system includes online particle-size monitoring equipment, a coarse aggregate particle-size distribution analyzer, and online automatic feeding and particle-size distribution monitoring integrated equipment. It can accurately and timely detect the change of aggregate particle size caused by the crusher cavity type, analyze coarse aggregate gradation and the content of needle and flake particles, and generate a particle-size curve for coarse-aggregate production. It is suggested that sand and stone mining enterprises apply the system to improve the production quality and process.

5G+ intelligent mine-management system is based on various sensors and network, automation, and management information technologies to realize automation of data processing in the process of extraction production and management. Using 3D, virtual reality, and other technologies, the system integrates the whole of a real mine and related phenomena and expresses them in digital form to realize a 3D geological visualization of above-ground and underground information. In the future, through the use of remote sensing and remote control and other technologies, remote control and automated mining will further realize intelligent mining, unmanned mining, and unattended mineral-processing plants.

The 5G+Fine Yarn Visual Quality Inspection System, supported by the 5G network, quickly obtains data collected by industrial cameras, conducts a 24-hour, real-time, full-width inspection of textiles, and produces inspection reports with pictures of defective points, coordinates, and other information for decision making. It controls machine stop/running by issuing instructions through a 5G network while synchronizing the information to be processed to notify staff-handheld devices and workshop-visualization devices. The system's inspection information and inspection reports can be docked with enterprise ERP, MES, and other systems to meet the batch-inspection management requirements. In the future, we will focus on promoting the application of the system in small- and medium-sized enterprises.

The kiln waste-heat utilization system uses the tail-gas waste heat of a kiln before desulfurization and dedusting with a temperature of up to 150 ℃ to generate electricity for cooling, and introduces domestic, advanced, waste-heat cooling, non-electric, central air conditioning equipment to supply cooling for the workshop office, special equipment, etc., which reduces the processing pressure of the desulfurization and dedusting tower while reducing the electricity used for conventional air conditioning; it can also use the heat energy in the hot air produced by the kiln for drying the billets and molds produced by the kiln; thus, waste heat is effectively used to save energy and improve the production output of the kiln. In the context of green manufacturing, the application of this system in building materials enterprises should be promoted.

7 Development focus of service guarantee industrial software in the building materials industry

For the purpose of a "service guarantee" through the establishment of a digital service-guarantee platform, a service extension for the building materials industry is performed. Through the development of an industrial Internet digital-service platform for the building materials industry, the real-time, anti-counterfeiting, traceability system for ceramics is popularized and applied to improve the building-materials industry's digital service ability.

7.1 Acceleration of industrial Internet digital-platform development

The development of the industrial Internet digital-service platform for the building materials industry focuses on establishing a new model of "manufacturing + service" that provides flexible customization and shared manufacturing core services for enterprises in the building materials industry and the industry's chain radiation users, as well as extended services such as R&D design, inspection and testing, engineering safety monitoring and early warning, and technical consulting. This improves the entire chain of the supply-chain collaborative-service

system, from R&D design and manufacturing to after-sales service, and encourages the building materials and modern service industries to blend, grow together, couple, and coexist.

7.2 Application of the ceramic real-time anti-counterfeiting traceability system

The development of the real-time, anti-counterfeit, traceability system for ceramics focuses on establishing a quality traceability system for the whole process of ceramic products from production of raw materials to product circulation. It adopts the method of brick-one-code and laser coding in and out of the warehouse, identifying product information and sales-area information and displaying on-site, remote reading and memory storage through sorting data. Customers can scan the code to view ceramic product production process information to enhance the objectivity, accuracy, and reliability of traceability.

8 Suggestions on the development of industrial software in the building materials industry

8.1 Technical suggestions

8.1.1 Addressing the technical bottlenecks of key areas

Currently, most of China's industrial software has not yet been able to achieve independent control, which is the weakness of industrial upgrading. The building materials industry has many subdivided industries, and each sub-industry has its own characteristics in R&D and design, operation and management, production and manufacturing, and service guarantee. Therefore, it is necessary to focus on breakthroughs of the key software in the following fields: new material R&D design software; a safety intelligent video-inspection and control system; an intelligent supervision system for mobile equipment in the mining area; an intelligent diagnosis and early-warning system for key equipment; an intelligent laboratory system for cement-quality control; an intelligent sawing system for high-efficiency plate; software for the electronic-fabric defect-detection and classification system; automatic detection system for refractory brick; and a digital service platform for the building materials industry Internet. The aim is to improve the intelligent level of building materials industry from point to surface.

8.1.2 Ensuring the security and controllability of key links

For enterprises' core business processes, especially the manufacturing and automatic control links of building materials enterprises, focusing on the automation of key processes, substitution of industrial robots for key positions, intelligent optimization control of production processes, and intelligent management of supply chain, we must develop professional software with independent intellectual property rights and efficient and practical field automation equipment and control systems to provide support. We must also increase the application of original technologies, especially for the second generation of dry process cement, high generation glass, etc., and develop a software system suitable for the actual development of China's building materials industry. We must attach great importance to data arrangement and privacy protection in the cloud-computing environment, clarify the security boundaries and security standards for different levels of software, and avoid system security risks.

8.1.3 Enabling information technology innovation

We should adhere to the main direction of intelligent manufacturing in the building materials industry, appreciate the major international development trends in artificial intelligence, big data, and blockchain, undertake thematic research on data-driven, industrial collaboration, and industrial Internet construction specifications, and promote great strides toward information technology-enabled industrial software. We should introduce the advantages of 5G technology into the design and development of industrial software and applications, so that the industrial software in the 5G era will be more powerful, will perform better and faster, have a larger capacity, utilize more supported devices, and be more convenient to control. We must promote the combination of artificial intelligence and industrial software, develop an artificial intelligence expert-optimization system, intelligent decision-making and mining, machine vision detection, etc., and improve the logical reasoning and decision-making ability of industrial software. We should use big data technology to obtain all-round data from upstream and downstream enterprises in the building materials industry, establish a large industrial database for the building materials industry, and undertake data classification and application projects for industry data collection, governance, storage, calculation, use, management, power, and security. We must rely on cloud computing and other means to improve the reliability of the built-in decision-making system of industrial software and strengthen the research on the search for excellence in decision-making operations.

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8.1.4 Building an industry public-service platform

The focus should be on establishing an industry public-service platform, attracting excellent solution providers, gathering industrial software products in the building materials industry, establishing a resource pool of mainstream industrial software in the building materials industry, displaying industry-specific industrial software, increasing product exposure for industrial software enterprises, providing business expansion and supply-demand matching channels, and saving the cost of expanding the market. We must integrate service providers' resources, provide consulting services for enterprises in need and customized services for building materials enterprises to ensure that they find and match the right service providers and solutions according to their needs, and complete digital transformation with lower costs and higher efficiency. Through the platform, we provide industry communication channels and communication opportunities between enterprises and solve problems encountered by enterprises in the process of developing and applying industrial software.

8.2 Management suggestions

8.2.1 Optimizing software industry support policies

Concerning the lack of R&D funds, backward R&D equipment, and other issues, the state, local government, and even the building materials industry can coordinate science and technology funds to increase investment in industrial software R&D, while managers can encourage advanced enterprises, associations, etc. to establish special funds for industrial software research, borrowing social power to provide financial protection for industrial software R&D work. Guiding policies should be formulated to emphasize the strategic significance of industrial software for the development of the industry, and a major special program should be established to improve the application of industrial software planning for the cement, glass, ceramics, and other subdivided industries, to lead the community's scientific research power, financial strength, and entrepreneurial power to industrial software gathering. In view of the high cost of software application and the disconnection between production and application caused by large investment, appropriate fiscal policies should be introduced, such as the establishment of relevant subsidies, tax relief for enterprises, etc. to popularize domestic software in the building materials industry.

8.2.2 Improving the industrial software standards system

We should establish an interface standards system based on the requirements of each segment of the building materials industry for software compatibility and customization, develop and define unified and common interface standards for design, simulation, manufacturing, operation and maintenance, services, and other aspects to achieve a full range of docking. This will help solve the problem of the market's long dependence on international mainstream industrial software and improve the ability to replace foreign products. Additionally, it is necessary to accelerate the development of an industrial software application standards system for the building materials industry through a study of the industry's industrial software application needs and the establishment of key aspects of industrial software application-level assessment specifications; we should strengthen the standards for the intelligent development of the industry's planning and macro guidance. Furthermore, we should develop and promote industrial software cost metrics and value assessment standards, establish a reasonable pricing mechanism, and unify software pricing guidelines and norms.

8.2.3 Encouraging industry–academia–research–application joint research

We should comprehensively promote the industry–university–research–application multi-party cooperation mode, integrate domestic scientific research institutes, universities, industrial enterprises, industry alliances, and other advantages, jointly tackle key technologies, and provide strong technical support for the digital transformation of the building materials industry. Led by the government, we must build national and regional industrial software development bases, with an R&D team as the core and industrial enterprises as the main linkage mechanism. We should establish a key technology research team and an industrial software alliance comprising industrial enterprises and scientific research institutions; we should aim for software development and achievement transformation, build an industry–university–research–application integrated innovation ecosystem, and jointly address the building materials industry's pain points and difficulties. We should establish a scientific and technological achievements evaluation mechanism and optimize the transformation process for industrial software research results. Focusing on the key "neck" technologies and major application bottlenecks in the building materials industry, such a mechanism will establish major research projects to closely integrate key

technology breakthroughs, the commercial scale of building materials products, and ecological cultivation in the building materials industry.

8.2.4. Cultivating industrial-software composite talents

It is necessary to explore the path for training software talents with Chinese characteristics of industry-education integration, and establish a new model with exemplary, high-quality, software talents' training. We should strengthen the joint construction of schools and enterprises and docking and coupling of technological innovation upstream, midstream, and downstream, increase the opportunities for school students to practice in enterprises, and avoid the disconnection between teaching and production so that schools can give full play to their own talent and professional and resource advantages, while enterprises can give full play to their market and industrial advantages. Thus, the integration of industry and learning can be achieved. Moreover, we must cultivate composite talents who understand both information technology and operation technology, algorithms and programming, as well as building materials processing and process manufacturing; we should focus more on talents who are definitely needed by enterprises and have actual results and practical utility in the talent-identification criteria. It is necessary to encourage large building materials enterprises and solution providers to establish special bonuses and appropriately improve relevant talents' livelihood security and wages. We should promote industrial software to empower the building materials industry and encourage universities, research institutions, and industry associations to hold industrial software design and development competitions in the building materials industry.

8.2.5. Establishing a good software application ecology

We should encourage new achievements and technologies for industrial software to actively apply for intellectual property rights, encourage building materials enterprises, universities, and scientific research institutions to promote awareness of paying for intellectual property rights and genuine protection, resolutely resist pirated software, and build a firm foundation for benign industrial development. We should encourage large building materials enterprises to take the lead in applying domestic industrial software and then gradually promote it to small enterprises. We should increase after-sales service and improve the performance of software, optimize performance and interface, enrich functions in the process of use, and enhance the applicability of software to the building materials industry. Furthermore, we should enrich the application scenarios for the whole lifecycle activities for cement, glass, ceramics, glass fiber, and other products, and develop and apply suitable industrial software on the service side to help improve the service capability of the building materials industry.

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