Manufacturing Resource Management and Control for Production Site of Complex Products

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Abstract: In response to the complex composition, scattered data storage, and differences in management levels of manufacturing resources in the production site of complex products, the research and application of digital technology for perception and control of manufacturing resources in the production site of complex products are of great significance for accelerating the digital transformation and upgrading of complex product manufacturing enterprises. Firstly, focusing on the problems of single element of local management, high cost of heterogeneous integration of multiple data sources, and the difficulty in cleaning up the global status of manufacturing resources in the production site of complex products, basic requirements and core requirements of enterprises for global management and control of manufacturing resources in the production site are deeply analyzed. Secondly, the indicators and data sources of different manufacturing resources that managers at different levels are concerned about are analyzed, providing guidance for refined management. Thirdly, a reference architecture of the manufacturing resource management and control platform for the production site of complex products is proposed, supporting access, integration, and global unified management of manufacturing resource information through the access strategy, data, basic component, and APP layers. Finally, the feasibility, effectiveness, and practicality of the architecture are verified through practical cases, aiming to provide a reference for the manufacturing resource management of complex product manufacturing enterprises.

Key words: complex product; manufacturing resource; management; control; platform; reference architecture

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0 Introduction

Complex products, such as aircraft, ships, satellites, and trains, etc., are a series of complex software and hardware products assembled according to a certain process flow. They have the characteristics of complex product composition, long development cycles, multiple manufacturing resources, and high-quality requirements[1-5]. On one hand, with the diversification and personalized development of usage requirements, higher requirements are put forward for quality, cost, and cycle of complex products. On the other hand, with the integration of informatization and industrialization[6], the construction of digital infrastructure, such as industrial communication networks, digital resources, and digital knowledge, is effectively promoted, which also drives manufacturing enterprises to accelerate digital transformation and upgrading.

In the process of digital transformation practice, complex product manufacturing enterprises focus on the product itself and use digital theories, methods, or tools to improve research and development efficiency, such as digital twin equipment[7], digital twin satellite[8], and digital construction of space equipment digital construction[9]. In addition, the digital technology is introduced to improve the efficiency of research and development process management[10-12], such as the digital twin shop-floor

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manufacturing operation management platform[13], aircraft assembly line digital twin system[14], intelligent workshop[15], and visualization management and control methods of production cell[16].

The management objects in the production site of complex products are complex during the manufacturing stage, and the efficient management of manufacturing resources in the production site will directly affect manufacturing efficiency. In aiming for on-time delivery, most complex product manufacturing enterprises mainly rely on "extensive" ledger manufacturing resource management in the production site, such as manual maintenance of ledger forms, paper records of maintenance information, etc. Feedback on the availability and operation status of manufacturing resources lags, and the production managers of enterprises cannot promptly obtain accurate information on manufacturing resources, which brings difficulties to management decision-making. With the implementation of policies and national standards related to intelligent manufacturing, more and more enterprises are introducing digital means to manage manufacturing resources in production site. Zhao et al.[17] proposed an optimization method of equipment resource cloud service combination in a cloud manufacturing environment, which achieves fast and effective matching between resource demanders and resource providers. Ma et al.[18] proposed a dynamic scheduling method of machine tools to facilitate multi-task collaboration and ensure efficient and stable operation. Zhao et al.[19] grouped manufacturing resources based on manufacturability characteristics and established a manufacturing resource information model, successfully reducing processing equipment's search space and time. Li et al.[20] established a framework for the manufacturing-resource recommendation for digital twin shop-floor, achieving rapid resource recommendation. Yuan[21] proposed a Holon-based dynamic management method for fast manufacturing resource configuration, achieving rapid optimization of manufacturing resource configuration. Li et al.[22] proposed a metadata based manufacturing resource ontology modeling method, which solves the ontology's consistency description problem in cloud manufacturing systems. Wang et al.[23] proposed a manufacturing resource selection strategy based on an improved distributed genetic algorithm, which enhances the efficiency of manufacturing resource combination optimization in cloud manufacturing. Yu et al.[24] conducted research on the trading mechanism of cloud manufacturing resources. Nie et al.[25] achieved control of production resources by building digital twin enterprises. Li et al.[26] proposed a blockchain-based digital twin sharing platform to simplify heterogeneous manufacturing resource integration in decentralized and distributed environments. Li et al.[27] utilized the digital management capability maturity to evaluate the digital management capability of production equipment. Zhang et al.[28] constructed an on-site abnormal monitoring and analysis platform for aircraft assembly, supporting the rapid perception of personnel and equipment abnormal problems in production sites. However, this platform mainly relies on perceiving and disposing of abnormal problems in the production site through manual feedback and has limited control capabilities over manufacturing resources.

In the above research results, they mainly conduct studies on manufacturing resource modeling, optimization combination, and capability evaluation and achieves good results. However, there are still some shortcomings in the research on the perception and control of basic information and the status of manufacturing resources, such as:

(1) Focus on managing a single manufacturing resource. In the manufacturing operation, the low-level managers will focus on the core production business and establish a ledger for specific equipment, fixtures, tools, cutting tools, etc., from the perspectives of convenience and practicality for management. The management object is relatively single, and if adjusted, a new solution will be implemented.

(2) The characteristics of personalized customization are becoming increasingly prominent. With the digital transformation of equipment and the purchase of digital equipment, complex product manufacturing enterprises have an increasing variety and quantity of manufacturing resources. Taking CNC

(Computer numerical control) machining equipment as an example, mainstream CNC systems and their supported communication protocols are diverse. To achieve data acquisition of CNC machining equipment, customized development based on the system and communication protocols is required, resulting in high labor and time costs.

(3) Enterprises have to work hard to clean up the global status of manufacturing resources. Low-level managers focus on local management and personalized customization of manufacturing resource control, making it difficult for high-level managers to clean up the status and quantity of manufacturing resources. In addition, data from different departments are scattered, and the status clean-up cycle is long, affecting the efficiency of enterprise management decision-making.

(4) The digitalization level of information supporting cross-departmental coordination is low. For digital equipment, digital fixtures, digital tools, etc., relevant information could be obtained through digital collection methods, with a high degree of digitization of information. However, information, such as personnel location, wearing of safety helmets, and product location, is often collected through post feedback, resulting in insufficient accuracy and real-time performance. Due to the large amount of data being manually recorded by operators, the digitization level of information is limited, leading to low efficiency in business coordination between different departments.

Based on the shortcomings mentioned above, the basic requirements for manufacturing resource management and control for the production site of complex products are gradually changing.

(1) Transitioning from extensive management to refined management

The composition of manufacturing resources in production site is complex, including different types of manufacturing resources, such as personnel, equipment, and materials. There are differences in the focus of management for different types of manufacturing resources, such as personnel being more concerned about the validity period of qualifications, equipment being more concerned about the available status, and materials being more concerned about inventory information. Therefore, it is necessary to classify and refine management elements for different manufacturing resources to achieve refined management.

(2) Transitioning from local management to global management

Low-level managers pay more attention to manufacturing resource information related to their business, resulting in inconsistent manufacturing resource information across different workshops and departments of the enterprise, which makes it difficult to integrate and compile the required information. From the perspective of the overall development of the enterprise, high-level managers pay more attention to the comprehensive distribution and utilization of manufacturing resources. Therefore, manufacturing resource management for the production site should be more inclined towards building a unified management model to achieve global management of enterprise manufacturing resources.

(3) Transitioning from personalized customization to universal services

The management elements and data sources of different manufacturing resources are complex, and personalized customization development of integrated interfaces increases enterprise investment costs, making it difficult to manage them uniformly. In the digital age, enterprises should start from a global management perspective, plan and coordinate different types of manufacturing resources, unify and standardize typical application system integration interfaces, equipment data acquisition interfaces, image recognition interfaces, etc., and form unified services to support the application needs of managers at different levels.

In response to the shortcomings and basic requirements above, an in-depth analysis is conducted on the core requirements for enterprises to manage and control manufacturing resources in the production site of complex products. Then, the indicators and data sources of different manufacturing resources that managers at different levels are concerned about are analyzed to achieve refined management of manufacturing resources in the production site. Next, A reference architecture of the manufacturing resource management and control platform for the production site of complex products is proposed, which supports the status perception and control of different manufacturing resources through the access strategy layer, aggregates manufacturing resource information through the data layer, solidifies the global common management elements through the basic component layer, and realizes on-demand management through the APP layer. Finally, the feasibility, effectiveness, and practicality of the architecture are verified through practical cases, providing a reference for the digital management of manufacturing resources of complex product manufacturing enterprises.

1 Requirement Analysis

1.1 Scope description

The composition of resources in the production site of complex products is complex, generally including six related objects: man (i.e., personnel), machine, material, method (i.e., process), environment, and measurement, namely 5M1E[29]. To provide constraints for in-depth analysis of the management and control requirements and access strategies of different manufacturing resources, the scope of manufacturing resources in the production site is clarified below.

(1) Personnel

This term mainly refers to personnel in the production site, such as operators, managers, inspectors, logistics personnel, and inspection personnel.

(2) Machine

This term mainly refers to equipment and its supporting components in the production site, such as processing equipment, testing equipment, measuring equipment, logistics equipment, and supporting fixtures, tools, and cutting tools, etc.

(3) Material

This term mainly refers to materials in the production site, such as blanks, raw materials, auxiliary materials, semi-finished products, finished products, and unqualified products.

(4) Process

This term mainly refers to operation methods in the production site, such as production process instructions, process cards, process procedures, and standard operating procedures.

(5) Environment

This term mainly refers to the environmental conditions in the production site, including the parameter requirements for the production environment, such as temperature, humidity, dust, 6S (Seiri, seiton, seiso, seiketsu, shitsuke, security) requirements, and safety warnings.

(6) Measurement

This term mainly refers to inspection and measurement methods, personnel qualifications, and procedures in the production site.

1.2 Core requirements

In response to the current shortcomings and changes in basic requirements of manufacturing resource management and control for the production site of complex products, and combination with the practical needs of refined and globally unified management, the core requirements are sorted out by low-level and high-level managers to achieve digital management and control of manufacturing resources in the production site of complex products.

(1) An indicator system for manufacturing resource management and control needs to be constructed. The composition of manufacturing resources in the production site of complex products is complex, and different manufacturing resources have different management and control focuses. Therefore, it is necessary to subdivide further the indicator system for management and control based on the type of manufacturing resources and clarify the data source.

(2) Multi-source heterogeneous data access strategies need to be constructed. The basic information, status, and other manufacturing resource data in the production site of complex products are scattered in different systems, databases, or paper media. Access strategies must be formulated based on the generation or storage location of manufacturing resource source data to achieve rapid perception and

control of manufacturing resources.

(3) The basic components of manufacturing resource management and control need to be built. A solution for manufacturing resource management and control for the production site of complex products is formed by analyzing core requirements and data access strategies. Basic management and control components can be constructed for different manufacturing resources, providing basic control functions to improve solutions' rapid promotion and flexible configurability.

(4) Support for low-level managers in configuring personalized APPs needs to be provided. Low-level managers of enterprises have different goals for manufacturing resource management and control based on different production businesses, product compositions, etc. They should be able to use manufacturing resources' basic management and control components to configure personalized APPs to support low-level management decision-making.

(5) Support for high-level managers in coordinating manufacturing resources needs to be provided. A unified management and control indicator system, access policies, and basic components support high-level managers in cleaning up the status of manufacturing resources and enhancing the enterprise's global management and control ability over manufacturing resources.

1.3 Indicators and data sources

As described in section 1.1, the composition of resources in the production site of complex products is complex, and the data sources of different types of manufacturing resources have obvious multi-source heterogeneity characteristics. In response to the core requirements of manufacturing resource management and control for the production site of complex products, it is first necessary to clarify the indicators and data sources of different manufacturing resources to develop reasonable data access strategies, providing a foundation for refined management and supporting enterprises to develop reasonable data access strategies to achieve global unified management. The data sources of manufacturing resource management and control indicators are further analyzed, as shown in Table 1, using the dimensions of category, attention level (H/L, high-level/low-level), indicator classification, indicator description, and data source.

Table 1 Indicators and data sources

Category	Attention level	Indicator classification		Indicator description	Data source
Personnel	H, L	Master data		Basic information. Further statistics can be constructed on educational background, skill level composition, etc.	MDMS (Master data management system)
	L	Location		Location and update time	Sensor or on-site anomaly management system
	L	Profile		Personal management evaluation parameter set	Personnel profile system, HR (Human resources system), or Excel
	L	Qualification		Qualification acquisition time, validity period	HR
Machine	H, L	Equipment	Master data	Basic information. Further statistics can be constructed on manufacturers, system types, digitalization levels, etc.	MDMS
	H, L	Equipment	Operation efficiency	Equipment online rate, critical task execution rate, OEE(Overall equipment effectiveness), etc.	SCADA(Supervisory control and data acquisition), EMS (Equipment management system), MES (Manufacturing execution system), or Excel

to be continued

Category	Attention level	Indicator classification		Indicator description	Data source
	L	Equipment	Operation status	Status and duration of standby, running, abnormal, etc.	SCADA, MES, or Excel
	L	Equipment	Usage restrictions	Processing objects and their dimensions, materials, etc.	EMS or Excel
	L	Equipment	Maintenance	Daily maintenance, weekly maintenance time, cycle, records, etc., as well as MTBF (Mean time between failure)	EMS or Excel
	H, L	F-T-CT (Fixtures, tools, and cutting tools)	Master data	Basic information. Further statistics can be constructed on quantity, task proportion, etc.	MDMS
	L	F-T-CT	Usage status	F-T-CT in good condition, faulty, medium usage state, and its duration	FTCTMS (F-T-CT management system), MES or Excel
	L	F-T-CT	Usage restrictions	Service objects and their dimensions, materials, etc.	FTCTMS or Excel
	L	F-T-CT	Maintenance	Daily maintenance, weekly maintenance time, cycle, records, etc., as well as MTBF	FTCTMS or Excel
	L	F-T-CT	Borrowing and return	Borrowed object, time, location, return time and status	FTCTMS or Excel
	L	F-T-CT	Location	Current location	FTCTMS, sensor, VMS (Video monitoring system), or excel
Material	H, L	Master data		Basic information. Further statistics can be constructed on the proportion of critical and important components, etc.	MDMS
	H, L	Inventory		Warehouse, inventory level, entry time, exit time, storage cycle, return time, etc.	WMS (Warehouse management system)
	H, L	Processing status		Current process, manufacturing unit, start time, end time, inspection time, etc.	MES
	H, L	Processing progress		Current location, update time, cycle, etc.	MES, sensor, or VMS
	L	Matching situation		Suppliers, quantity of missing parts, matching cycle, etc.	WMS or MES
Process	H, L	Master data		Basic information	MDMS
	L	Process guidance		Process instructions, process cards, process procedures, standard operating procedures, etc.	CAPP (Computer aided process planning), MES, or Word
	L	Process conformity		Process compliance verification and warning	MES
	L	Process parameters		Process parameter set, process parameter optimization values	MES or NC (Numerical control) program management system
Environment	H, L	Master data		Basic information, i.e. specification of parameter description	MDMS
	L	Environmental parameters		Temperature, humidity, dust, smoke, etc.	Sensor
	L	Redundancy		Type, size, location, etc. of redundancies	VMS
	H, L	Safety helmet		Name, time, location, etc. of personnel who did not wear safety helmets	VMS

to be continued

Category	Attention level	Indicator classification	Indicator description	Data source
	L	6S	6S warning time, frequency, etc.	VMS
Measurement	H, L	Master data	Basic information, i.e. specification of parameter description	MDMS
	L	Inspection procedures	Content of inspection procedures	MES
	H, L	Unqualified product	Unqualified components, time, location, and failure rate	IPQCS (In-process quality control system) or MES
	H, L	Variance/deviation permit	Variance/deviation permit components, time, location, and variance/deviation permit rate	IPQCS or MES
	H, L	Concession	Concession components, time, location, and concession rate	IPQCS or MES

2 Reference Architecture

The types and quantities of manufacturing resources in the production site of complex products will change with internal and external market environments, user requirements, product maps, and other factors. From a global management perspective, enterprises need to plan the management and control measures and its supporting means of manufacturing resources in the production site. Based on the analysis of data sources, a manufacturing resource management and control platform for the production site of complex products is proposed to address the core requirements. The goal is to support complex product manufacturing enterprises and their industrial chain enterprises in manufacturing resource centralized management and control for the production site of complex products through a digital platform. As shown in Fig.1, a hierarchical architecture style is adopted to design the reference architecture of manufacturing resource management and control platform for the production site of complex products, including the source data layer, access strategy layer, database layer, basic component layer, and APP layer.

(1) Source data layer

This layer covers the core data sources of manufacturing resources in the production site of complex products, including information systems, sensors, Excel, Word, etc.

(2) Access strategy layer

This layer encapsulates access strategies for multi-source heterogeneous data sources to achieve manufacturing resource status perception and control for the production site of complex products. The access strategies include:

① System interface access: Access to information system data can be achieved by utilizing technologies such as Web service and ESB (Enterprise service bus) to encapsulate the integration interfaces of existing information systems.

② Database access: Encapsulating database access interfaces to existing structured, semi-structured, and unstructured databases can enable acquiring and controling manufacturing resource status data in the production site.

③ Real-time data transmission based on standard industrial communication protocols: Encapsulating interfaces for real-time data acquisition and control of digital equipment that support standard industrial communication protocols can achieve real-time monitoring of operation status.

④ Image recognition based on computer vision: Encapsulating recognition interfaces for quick response codes, barcodes, and part external shape images can enable the status perception and tracking of manufacturing resources in the production site, such as personnel, mobile equipment, fixtures, tools, products.

⑤ Location acquisition based on RFID (Radio frequency identification) or UWB (Ultra wideband): By utilizing real-time location technologies such as RFID and UWB, the interface for obtaining real-time location information of manufacturing re-

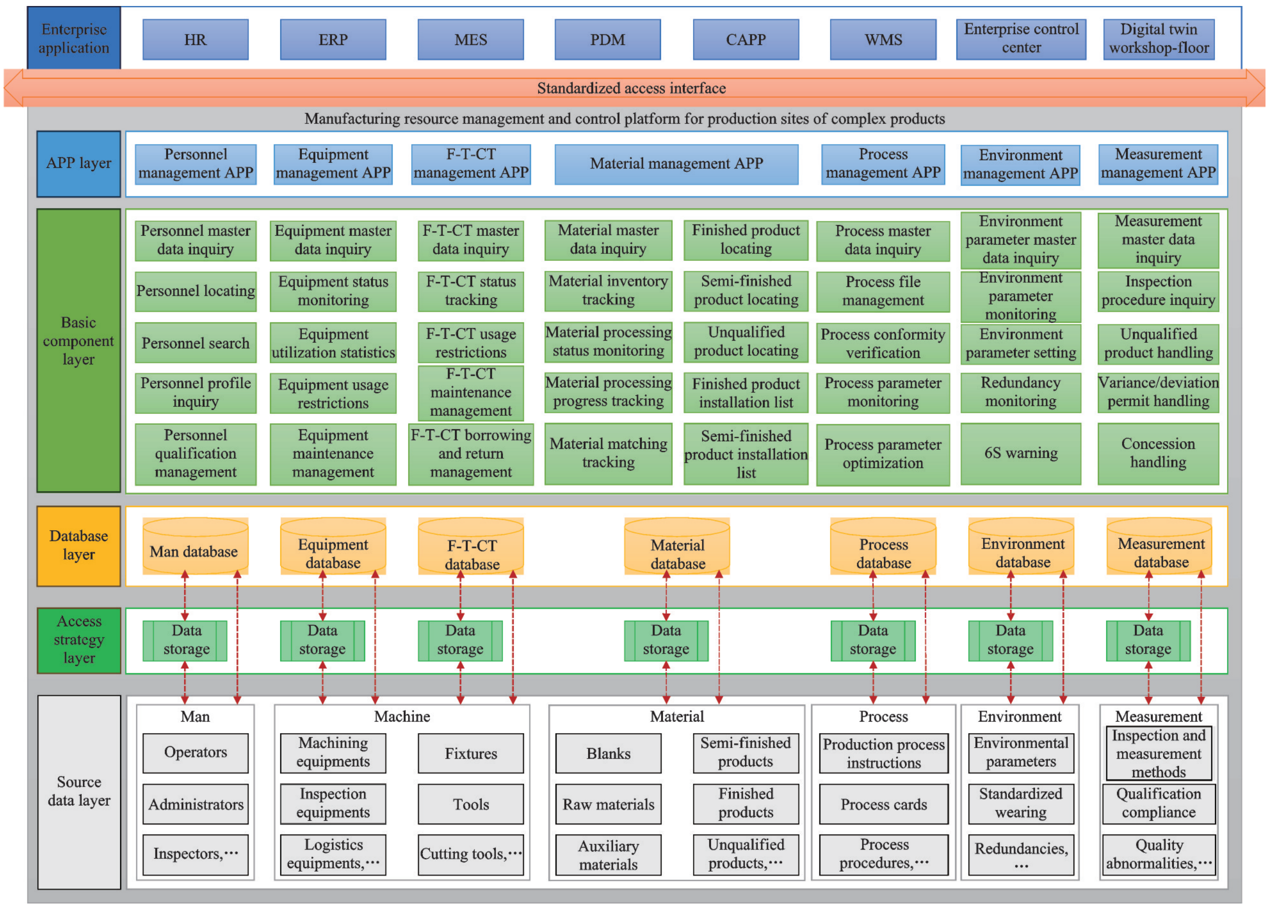

Fig.1 Hierarchical architecture of manufacturing resource management and control platform for the production site of complex products

sources in the production site is encapsulated to achieve locating, searching, and inventory.

⑥ Document parsing: Encapsulating the parsing interfaces of documents such as Excel and Word can facilitate the acquisition of manufacturing resource ledger information, status information, location information, etc.

(3) Database layer

This layer stores structured, semi-structured, and unstructured manufacturing resource data obtained through access strategies for multiple heterogeneous data sources, realizing the aggregation of manufacturing resource data and providing data support for manufacturing resource tracking, control, and decision analysis.

(4) Basic component layer

This layer addresses the core requirements of manufacturing resource management and control for the production site of complex products and constructs universal functional components through abstraction, peeling, and encapsulation. It forms the core application support capability for manufacturing resource management in the production site, supporting the realization of resource status perception and control, refined management, and global unified management. The basic components include as follows.

① Personnel management components: Support the construction of personnel management APP, such as personnel master data inquiry, personnel locating, personnel search, personnel profile inquiry, personnel qualification management.

② Equipment management components: Support the construction of equipment management APP, such as equipment master data inquiry, equipment status monitoring, equipment utilization statistics, equipment usage restrictions, equipment maintenance management.

③ F-T-CT management components: Support the construction of F-T-CT management

APP, such as F-T-CT master data inquiry, F-T-CT status tracking, F-T-CT usage restrictions, F-T-CT maintenance management, F-T-CT borrowing and return management.

④ Material management components: Support the construction of material management APP, such as material master data inquiry, material inventory tracking, material processing status monitoring, material processing progress tracking, material matching tracking, finished product locating, semi-finished product locating, unqualified product locating, finished product installation list, and semi-finished product installation list.

⑤ Process management components: Support the construction of process management APP, such as process master data inquiry, process file management, process conformity verification, process parameter monitoring, and process parameter optimization.

⑥ Environment management components: Support the construction of environment management APP, such as environment parameter master data inquiry, environment parameter monitoring, environment parameter setting, redundancy monitoring, and 6S warning.

⑦ Measurement management components: Support the construction of measurement management APP, such as measurement master data inquiry, inspection procedure inquiry, unqualified product handling, variance/deviation permit handling, and concession handling.

(5) APP layer

This layer is designed to meet the management and control requirements of manufacturing resources in the production site of complex products. By separately calling or arranging services for the basic components, it is packaged into an APP that meets the needs of manufacturing resource management and control business in the production site, including personnel management APP, equipment management APP, F-T-CT management APP, material management APP, process management APP, environment management APP, and measurement management APP, etc.

The manufacturing resource management and control platform for the production site of complex products, as the only data source for enterprise manufacturing resource status information in the production site, can provide standardized external access interfaces to HR, ERP (Enterprise resoure planning), MES, PDM (Product data management), CAPP, WMS, enterprise control center, digital twin workshop-floor, and other enterprise core applications. It realizes the sharing of manufacturing resource information among enterprise core applications, supporting the manufacturing resource control, production management decision-making, and resource operation performance evaluation.

3 Case Verification

Company A is an aircraft manufacturing enterprise that produces products with complex production processes, long manufacturing cycles, and high-quality requirements. Due to the large factory area, long assembly cycle, and complex manufacturing resources in the product assembly site, Company A hopes to build an information system (i.e., a digital means) to quickly search for personnel in the assembly site, verify their qualifications, initiate abnormal problems, and issue safety helmets, as well as track product entry and exit workstations and provide fixture position prompts and equipment abnormality prompts, achieving refined management of personnel, products, equipment, and fixtures, and providing support for management and control for the assembly site of products.

To this end, the development team has sorted out the core business scenarios of resource management in the assembly site of products (as shown in Table 2), and based on the architecture of manufacturing resource management and control platform for the production site of complex products, a management platform for the assembly site of products of Company A has been constructed. The highlights of this platform are as follows.

(1) By encapsulating the image recognition interface, the real-time monitoring of personnel without safety helmets, the product entry and exit workstation prompts, and the product and fixture loca-

tion are achieved.

(2) Integrate with HR and SCADA through system access interfaces to achieve personnel qualification verification and equipment abnormality alarms.

(3) The problem initiation page and device (hardware) can achieve problem tracking and personnel locating in the assembly site (Fig.2).

Using this platform, Company A has achieved that the reporting time of on-site abnormal problems has been shortened to less than 1 s (as shown in Fig.2), personnel information has been published and display in real time (as shown in the yellow box in Fig.3), the abnormal inspection time of on-site has been shortened to seconds (as shown in Fig.3), and the product information at the station has been updated in real time (the product number at the station shown in Fig.3), where the original delay time feedback through MES is greater than the duration of the first assemble order (usually measured in hours).

Table 2 The core business scenarios

Category	Scenario description	Implementation method
Personnel	Without a safety helmet	Image recognition
	Arrive at the assembly site	Information system registration (reading cards)
	Conduct qualification verification	HR system interface integration
	Conveniently initiate abnormal problems in the production site	Initiate using information systems; initiate using hardware
	Conveniently initiate personnel search information in the production site	Initiate using information systems
	Leave the assembly site	Information system registration (reading cards)
Product	Enter the assembly workstation	MES feedback (poor real-time performance); image recognition product identification plate (with good real-time performance); image recognition product appearance (good real-time performance)
	Leave the assembly workstation	Image recognition product identification plate
Equipment	Equipment abnormality prompt	SCADA system interface integration
Fixture	Fixture locating	Image recognition fixture identification plate

Fig.2 Abnormal problem initiation page

Fig.3 Abnormal problem dashboard

Company A utilizes the platform to gather and manage manufacturing resource information in assembly sites, especially through information integration to uniformly display on-site resource information. The tedious operation of repeatedly switching between different systems and the workload of production management personnel (switching login systems and viewing required information takes at least 60 s) are reduced. Thus, this ensures the accuracy and real-time nature of manufacturing resource information in the assembly site, and effectively supports digital management of manufacturing resources. To some extent, this further verifies the feasibility, effectiveness, and practicality of the architecture of manufacturing resource management and control platform for the production site of complex products.

4 Conclusions

Focusing on the complexity of manufacturing resources, heterogeneity of data, and hierarchical management in the production site of complex products, researching and applying digital technology can improve the digital management level for the production site of complex products and lay the foundation for enterprise digital transformation and upgrading. This paper focuses on the current situation of manufacturing resource management for the production site of complex products. Firstly, it analyzes the basic requirements and core requirements for global management and control of manufacturing resources in the production site of complex products. Secondly, it sorts out the indicators and data sources for low-level and high-level managers to manage and control manufacturing resources in the production site of complex products, supporting the implementation of refined management. Thirdly, it proposes a reference architecture of manufacturing resource management and control platform for the production site of complex products, achieving status perception and control, information integration, and global unified management of manufacturing resources in the production site by implementing hierarchical encapsulation. Finally, it verifies the feasibility, effectiveness, and practicality of the architecture through the management platform for the assembly site of products of Company A, providing a resource management reference for the production site of complex products.

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复杂产品生产现场制造资源管控

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摘要：针对复杂产品生产现场制造资源组成复杂、数据分散、分层管控差异等特点，开展生产现场制造资源感知与管控的数字化技术研究与应用，对加速复杂产品制造企业数字化转型升级具有重要意义。本文重点围绕复杂产品生产现场制造资源局部管理要素单一、数据多源异构集成成本高、全局状态清理难度大等问题，深入分析了企业全局管控生产现场制造资源的基本要求和核心需求；对不同类型的制造资源，进一步地分析了不同层级管理者所关切的指标和数据源，为精细化管理提供指导；提出了复杂产品生产现场制造资源管控平台参考架构，通过访问策略层、数据层、基础组件层和APP层支撑实现生产现场制造资源管控信息的访问、集成和全局统一管理；通过应用案例验证了该架构的可行性、有效性和实用性，旨在为复杂产品制造企业的制造资源管理提供参考。

关键词：复杂产品；制造资源；管理；控制；平台；参考架构