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Article

Design and Application Research of a Digitized Intelligent Factory in a Discrete Manufacturing Industry

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Abstract: The intelligent flexible system is a powerful means for manufacturing enterprises to achieve high efficiency and high output. The physical structure of the flexible system is constructed in this paper. The three systems; workshop intelligent logistics system, management and control system and three flexible processing that produce four products are given by the deeper design. The local workshop net which contains; position sensors, radio frequency identification (RFID), AGVs, intelligent machine, robots, raw materials and operation devices is constructed in this paper. The software, which includes gages, real-time workshops, logistics trolley, and information of all kinds of logistics process and processing, in which the flexible intelligent manufacturing system was given. Intelligent identification, position tracking, device monitoring and control are realized. Within the system disturbed information from different raw materials, dynamic water and electricity, customer order uncertainty, on-site process parameters, management automation, and intelligence comes to be true. Physical and virtual simulation results and best-case data mining application processes were given. Finally, the system's next expansion and deployment interface is given and moves forward to the next step.

Keywords: Digitized intelligent factory; intelligent manufacturing system; discrete manufacturing industry; digitalization

1 Introduction

In 1967, the world's first flexible manufacturing system (FMS) appeared in the United Kingdom and the United States. Barenji [1] in 1975, was presented with the construction of the FMS system in Japan, and the CNC machine tools began to be used in large quantities.

Campos et al. [2] presented information and communication technologies by literatures on the application's review. The internet's intelligent monitoring system based on the new generation of information technology and the multi-agent technology of the production process are important methods of the mechatronic system. Dong [3] pointed out that the main goal of the modern intelligent manufacturing workshops is to have an independent organic manufacturing model. Generally, it has multiple intelligent manufacturing equipment and multiple intelligent flexible production lines. The basic means of these production lines is the real-time monitoring of the material and workshop information. The main feature is to realize the independent flexible production and optimization. The goal is to improve product quality and comprehensive production efficiency of the enterprise. Chen et al. [4] proposed the concept and model of the multi-agent collaborative design system based on the Internet environment. Based on the proposed model, this paper explains how to use a multi-agent to develop products, how to interact among multi-agents and how to organize and implement them. The design scheme of the multi-agent collaborative design system and the concrete application examples are given. Lin et al. [5] proposed the solved re-entrant multi-machine flexible flow shop scheduling problem by four different heuristic algorithms. Those algorithms are modified by existing algorithms. By experimental performances it is proven the effectiveness of the methods in this paper. Giret et al. [6] proposed a framework for the manufacturing systems, which are developed by the intelligent automation control and execution system. Those systems are associated with the engineering approach to assist the system developers. The methods are combined with the multi-agent system, which have service-oriented architectures.

Ruiz et al. [7] proposed an Agent-supported intelligent manufacturing system simulation environment. The different roles an agent plays in a simulation environment, which are defined by considering particular dynamics in the simulation of manufacturing. The aim is for the requirements of the intelligent manufacturing period. In addition, the interaction and collaboration scenarios are specified for the flexible manufacturing, which with different agents for the simulations of the manufacturing.

Qi et al. [8] aimed at the characteristics of the process industry modeling and simulation, a four-layer framework for modeling and the simulation is proposed, including the model entity structure, model library layer, model abstraction layer, factory model layer and the smart factory access system layer. This framework builds a smart factory multi-level modeling and simulation system.

Li et al. [9] proposed to promote technological innovation and management innovation through smart factories, support the upgrading and transformation of traditional industries with information technology, green low carbon, energy conservation and emission reduction, and actively implement resource strategy, market strategy, integration strategy and internationalization. The differentiated strategy and green low-carbon strategy, focus on continuous protection of energy supply, provide quality products and services to consumers, maintain safe and stable operation, and achieve green and low-carbon development.

Ai et al. [10] and Yuan [11] designed a new micro-plant factory control system based on embedded platform for the intelligent control of a micro-plant factory. The system uses high-performance STM32 chip and embedded real-time operating system μC/OS-Ⅱ is designed for hardware and software, and the decoupling and effective control of temperature and humidity are realized by fuzzy decoupling and fuzzy control, the system runs stable.

Ding et al. [12] proposed at present, the information systems such as the ERP and MES of enterprises are not able to quickly and comprehensively perceive various data, information and knowledge related to internal and external operations and production operations, and operation optimization and control, resulting in the lack of comprehensive and accurate existing systems. And the real-time production factor data acquisition capabilities show's a lack of multi-source heterogeneous production and operation of big data perception and processing capabilities, a lack of data aggregation and integration capabilities, a lack of efficient different levels of data analysis, and implicit knowledge association and deduction capabilities. It is not possible to sense production behavior and market changes in real time, and thus cannot automatically optimize production and operation decisions and scheduling instructions. Ali [13] developed a virtual simulation software platform, which was for the RFID-enabled MASCS examination in the situation of the FAL, meanwhile in this paper we considered several system performance measures with the software platform.

China's research on the intelligent manufacturing of the machine tool processing industry, earlier focused on the National Defense University. Liang et al. [14] discussed the intelligent processing of a single machine tool and provided the basic concepts and related research contents of intelligent processing. At the same time, the basic structure of realizing the corresponding system of the machine tool intelligent processing is put forward, and the basic functions and functions of each module are discussed. Li [15] briefly introduced the basic connotation and construction principle of the intelligent manufacturing technology and the intelligent manufacturing systems related technologies, and was centered on the modeling and signal processing problems of the mechanical manufacturing process, and summarized the height of the intelligent control, and provided relevant control strategy and methods. Zhao et.al. [16] and others from Huazhong University of Science and Technology conducted an in-depth research on the integrated development environment of the NC systemand the specific intelligent processing technology based on the NC characteristics [17].

Che et al. [18] states, according to the TBEA Automatic Equipment Co., Ltd., switchgear manufacturing problem, meanwhile deals with the flexible intelligent manufacturing technology as the core of modern society. The aim is to build the global solving method through the technology of the internet, detection and quality control. The final aim is to realize the device switch between the process design of the smart manufacturing, and the production work order processing, tool assembly, device checking, and material delivery. Fang et al. [19] describes the digital development existing state and structure of the workstation by literature review. In reviewing the current status of the intelligent manufacturing in the digital intelligent workshops, and methods, steps and measures are given for how flexible the manufacturing systems in digital workshops realize the intelligent manufacturing. Zhu [20] states on the STEP-NC standard aims is to establish a CNC system solution around the STEP-NC by an in-depth study. The article focuses on the STEP-NC application protocol. Based on the protocol, the contour cutting data model is established, and the existing STEP-NC application protocol is extended based on the established model. Wang et al. [21] focused on the technical characteristics of the intelligent equipment in the workshop and the special application environment of the equipment. The paper gives their views on the shortcomings of the existing general machine vision inspection and control technology system and makes up for the shortcomings of the current research through the research results.

Jia et al. [22] modeled the energy transfer in the intelligent workshop process and studied the model establishment method for the energy dynamic transfer demand of the processing unit. The method dynamically decomposed the energy and reduced it into corresponding activities. The establishment of the dynamic factors was carried out through the method research, and a total of fourteen basic dynamic factors were identified. Deng et al. [23] studied the efficient green manufacturing model of the CNC machine tools based on the actual constraints of tool life and tool surface quality during machining. The objectives considered in this model are multi-objective optimization models with the highest energy efficiency, lowest carbon emission and highest material removal rate and model solving. Wang et al. [24] proposed based on different product specifications, the different batch sizes, and considers the material utilization rate and processing path optimization problem of the workshop and determines the rectangular optimal path processing method for research. Yue et al. [25] for the coordination of human-machine interaction facing the main research content, the corresponding key scientific issues were discussed in detail.

Woo et al. [26] proposed that a robot partner iphonoid-c system integration on intelligent equipment is proposed. The system enhances the interaction between human and robot by establishing the emotional model and influences the emotional state of the robot for information output. The cognitive method is validated to be effective. Hu et al. [27] proposed the scheduling index, which is based on establishing the model of the optimization problem objective function. The optimization algorithm of Chaos and AHP were used to solve the problem, which is usual for manufacturing scheduling under the situation of the algorithm cloud environment. Experimental performances proved the effectiveness of the scheduling index in this paper. et al. [28] proposed an evolutionary clustering framework, which is modified from existing algorithms to analyze and comprehend the significance substructure, which is concealed under the dynamic networks in the real world. In this paper, we conducted two experiments, both on the real dynamic network and the artificial manner to demonstrate the method proposed in this paper. At the same time, the framework has higher superior performance compared with the methods of the state-of-the-art. Chang et al. [29] proposed an extended lattice hydrodynamic model, which considers the driver's sensory memory and delayed feedback control when problems occur. Experimental performances proved it can effectively enhance the stability of different traffic flow and aims to reduce the energy consumption. Gürdür et al. [30] introduced the data collection and analysis status of different industries in Sweden and analyzes the digital and intelligent software requirements of related industries in combination with survey results. Liu [31] based on access control technology designed an enterprise integrated automation system, meanwhile the application models based on workflow were bulit.

2 Problem Description

The workshop intelligent system is combined with the workshop subsystem, flexible automation subsystem, intelligent detection subsystem, intelligent logistics subsystem and intelligent storage subsystem. The system implements a series of processes such as; order management, advanced planning and scheduling, flexible automated production, intelligent inspection, and automatic transportation, and has the functions of a digital factory.

The workshop intelligent system produces four kinds of products, namely the bearing gland 1 and bearing gland 2, small impeller, and electric car wheel hub. The system realizes the automatic processing, turning, blowing, cleaning, visual inspection and testing of the workpiece by means of the intelligent management and control. Based on the automation integrated control platform of the production line, it integrates advanced technologies such as; management, control, information processing and network platform, and realizes the online monitoring of orders and equipment through the elements of people, machines, materials, methods and rings. Analysis and processing, test results display and other functions, is the goal is to achieve the coordinated operation and refined management of the workshop.

The overall control process for a flexible automation system is as follows:

Step 1: Convert the sales order into a production order in the WIS shop management system.

Step 2: Advanced planning scheduling for the production orders.

Step 3: The scheduling plan is issued.

Step 4: Processing the production order according to the scheduling plan.

Step 5: After processing, the order is processed, and the storage system automatically realizes the finished product according to the part model.

Step 6: The AGV trolley transports the goods to the relevant station.

Unattended processing. After the workpiece is processed, the matter tells the AGV dispatching system to take the finished product through the information interaction. At this time, the AGV dispatching system will automatically transport the finished product to the warehouse according to the set path.

All data in the whole process is collected and stored by the information system.

With the development of the internet of things, information technology, and intelligent hardware, manufacturing is facing a revolution from informationization to intelligence. The essence of intelligent manufacturing is to realize vertical integration across different levels of the enterprise equipment layer, control layer, management layer, horizontal integration across enterprise value networks, and end-to-end integration from a products life cycle. At the same time, standardization is to ensure the realization of enterprises. The full integration of components is a key approach to this situation.

Combining the intelligent manufacturing technology architecture and industrial structure, this paper constructs a smart manufacturing standardization reference model from three dimensions: The system level, value chain and product life cycle, which helps to understand and understand the objects, boundaries and levels of each part of intelligent manufacturing standards. Relationships and internal relationships provide reference and basis for the construction of intelligent digital factory hardware platform.

The system architecture is divided into three levels: The system level, life cycle and intelligent functions. In the system level, there are five levels of content; equipment, control, workshop, enterprise and collaboration. In the life cycle, it includes five levels of content; design, production, logistics, sales and service. At the level of intelligent functions, it includes five levels of content such as; resource elements, system integration, interconnection, information fusion and emerging formats.

The intelligent digital factory based on the distributed collaboration needs to refer to the system architecture of Fig. 1 when constructing. At the system level, it is ultimately necessary to achieve distributed collaboration between enterprises, workshops, equipment, and processing units.

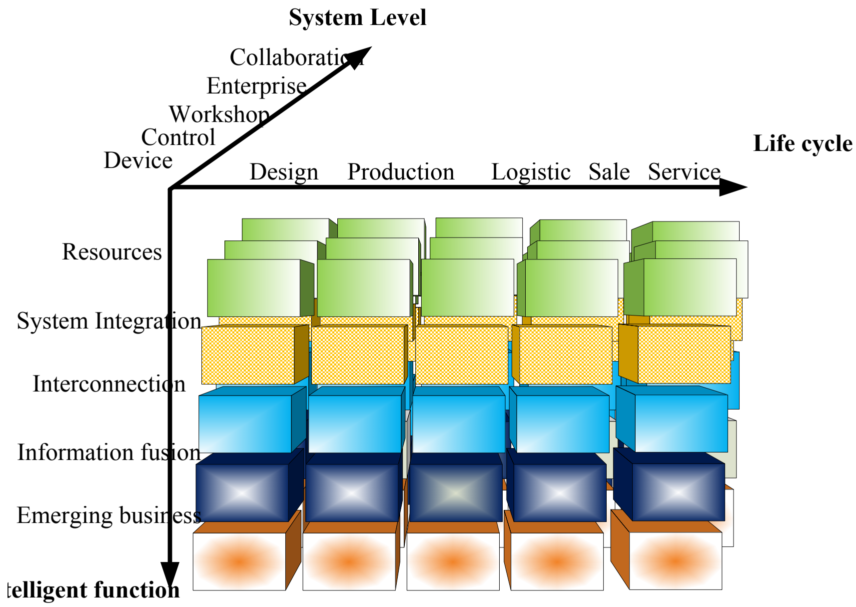

Figure 1: System structure of intelligent manufacturing

The entire intelligent digital factory hardware platform is divided into four levels, namely: Intelligent device layer, intelligent processing unit layer, workshop-level intelligent management layer, and intelligent cloud platform.

(1) The intelligent device layer includes the sensing and execution units such as smart sensors, intelligent instrumentation, bar code, intelligent radio frequency identification, intelligent CNC machine tools, and intelligent robots;

(2) The intelligent processing unit layer includes the intelligent warehouse logistics processing unit, the intelligent robot processing unit, the intelligent truss processing unit, and the flexible processing unit for new energy vehicle hub.

(3) The workshop-level intelligent management layer includes the Intelligent Programmable Logic Controller (IPLC), the Intelligent Data Acquisition and Monitoring Control System (IDAMCS), the Distributed Collaborative Control System (Distributed collaborative control system (DCCS), the Fieldbus control system (FCS), and the Industrial Wireless Control System (WIA), etc.

(4) The intelligent cloud platform: Realizing the geographical limitation, the factory is everywhere, realizing the real-time online operation of the factory.

On the basis of the automation integrated control platform of the production line, the information management system WIS is oriented to the production and processing process using advanced technologies such as the Internet of Things, and intelligent analyses on the online monitoring of people, machines, materials, methods and rings in the workshop. The aim of the process and display is to achieve the coordinated operation and refined management of the workshop.

3 System of Digital Flexible Workshop Management

3.1 System Introduction

This topic takes the industrial robot as the main body, applies the visual automatic inspection of the machine dimensions, realizes the automatic loading and unloading of the CNC machine tools and product inspection. An intelligent manufacturing system mainly includes several milling equipment, grinding equipment, industrial robots, machine vision, intelligence and the warehousing (AGV), intelligent quick-change fixture (AGV) and the central control system, etc. After selecting the processed products according to the requirements, the industrial robot automatically replaces the fixtures by visual guidance, and the intelligent storage system outputs the materials to the robots. The industrial robots first pass the vision. After reading the two-dimensional code information of the material, after confirming, the product is grasped by visual guidance and placed on the milling and the grinding devices. After the processing is complete, the workpiece is taken out for size inspection. After the completion of the inspection, the QR code information of the product is updated and placed in the warehouse. Complete one-time processing and automatic detection of the automatic loading and unloading and processing dimensions are done through vision.

The software of the intelligent manufacturing system mainly consists of a central control module, a robot control module, a machine vision module and a single-chip two-dimensional code module.

The programming language of the ABB robot is the RAPID language. The ABB program structure is composed of modules, including program data, main program, routine, and interrupt. Before programming, you need to establish the tool coordinate system and the workpiece coordinate system, configure the standard IO port and remote IO port, and set up the Ethernet communication, etc. After the setting is completed, you can directly write the RAPID program on the ABB or Robotstudio. The software flow chart of the ABB robot control module is shown in Fig. 2. The robot first initializes and returns to the home position to wait for the PLC command. After receiving the command, it sends the command to the vision system and the fixture library. The tool guide realizes the quick change of the fixture. After the fixture is installed, it is sent. The command is sent to the PLC to control the seventh axis to move to the warehouse. After the material is pushed out by the silo, the robot controls the vision to read the material information. After reading, the gripper grips the material, and the material is put into the lathe or milling machine according to the processing requirements, waiting for the processing to be completed. After the material is taken out into the silo, and the visual dimension is controlled, the information is sent to the PLC to update the material information after the measurement is completed.

The overall functional framework of the WIS is shown in Fig. 4.

The system is divided into 12 functional modules, which are; module of manufacturing basic data base, module of scheduling, module of production scheduling, module of inventory management, module of quality management, module of production management, module of equipment management, module of processing unit/workstation, module of Kanba, module of program management, module of traceability management, and module of equipment data. The integration management for production enterprises is to build a manufacturing intelligent and efficient collaborative management platform.

3.2 The Warehouse Logistics Management System

The stacker, the AGV subsystem, conveyor, high-speed sorting subsystem, electrical control subsystem and the corresponding software subsystem are composed in the i5 intelligent storage system.

Figs. 3 and 4 are the control flow charts of the warehouse logistics management system.

3.3 The Digital Flexible Machining Cell

3.3.1 The Bearing Gland Processing Unit

The material of the motor bearing end cover is made of grey cast iron HT250. This material is widely used in pump casings and containers due to its small thermal deformation, high strength and certain corrosion resistance, good casting, vibration damping, wear resistance and cutting performance. Parts are towers, flanges, glands, machine bed, columns and cylinders. In the original processing, according to the thickness specification of the sheet, the blank is made of 40 mm thick sheet, and the saw is cut into a rectangular parallelepiped of 457 mm × 360 mm × 40 mm with a margin of 5 mm on one side. According to the structure of the bearing end cover in Fig. 5, the main work of the machining is concentrated on the front side of the end cover, milling the end cover surface, the cavity, and then drilling and tapping, so the press plate is selected as the fixture during the front processing, it is the residual material on the back of the end cap and a small 125 mm circle, and the positioning in the circumferential direction is not high. The back processing utilizes a simple fixture, and all processes are completed on the vertical machining center.

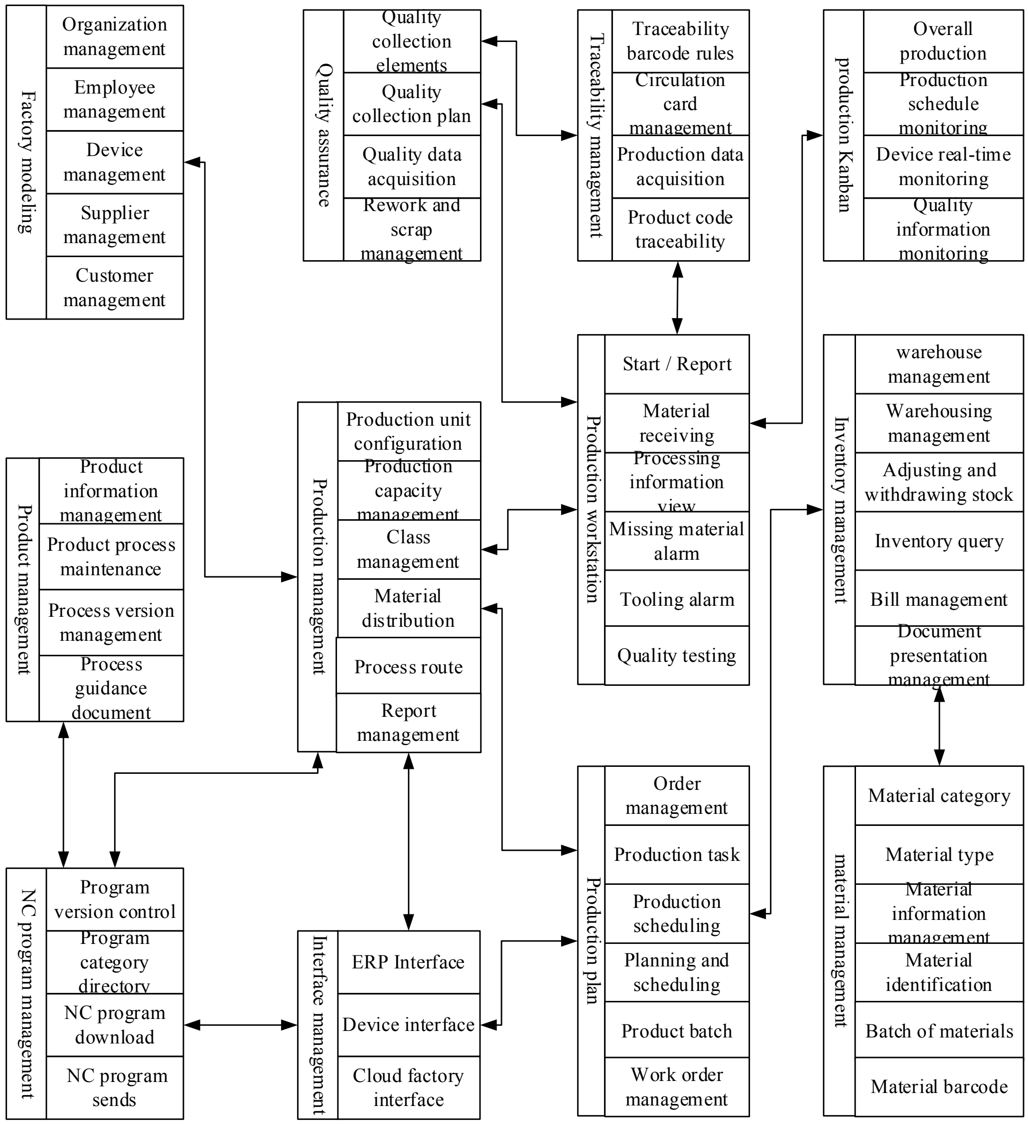

Figure 2: The WIS overall functional framework

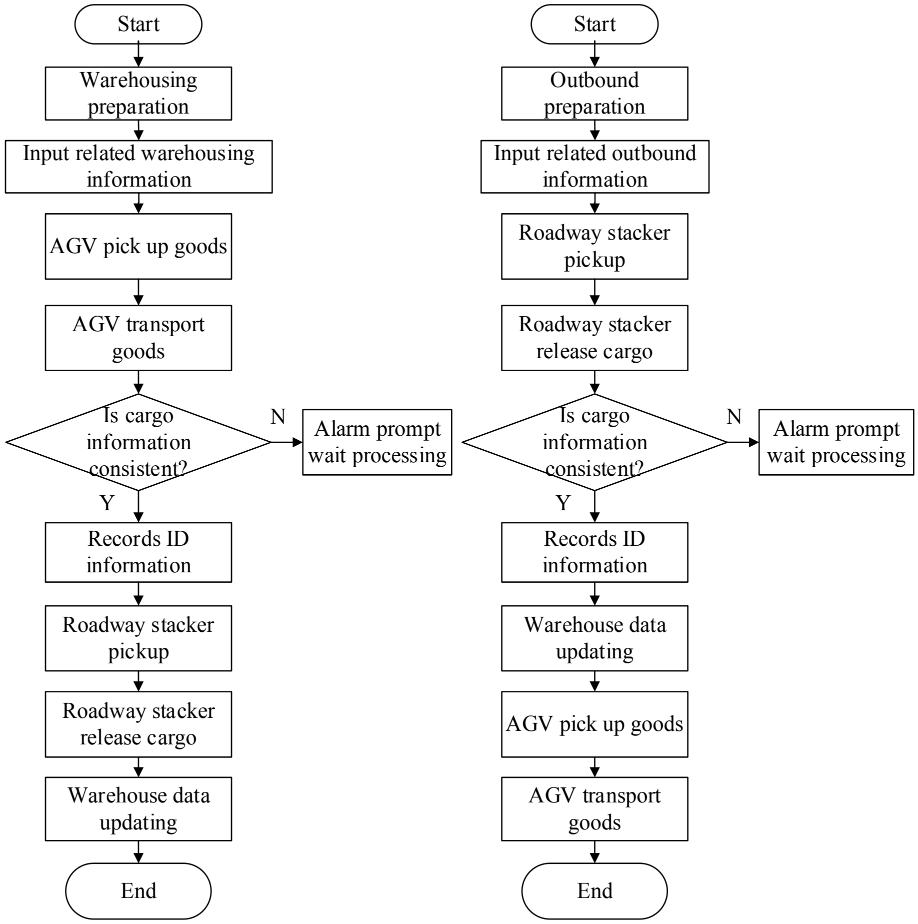

Figure 3: The flow chart of the intelligent warehouse logistics system

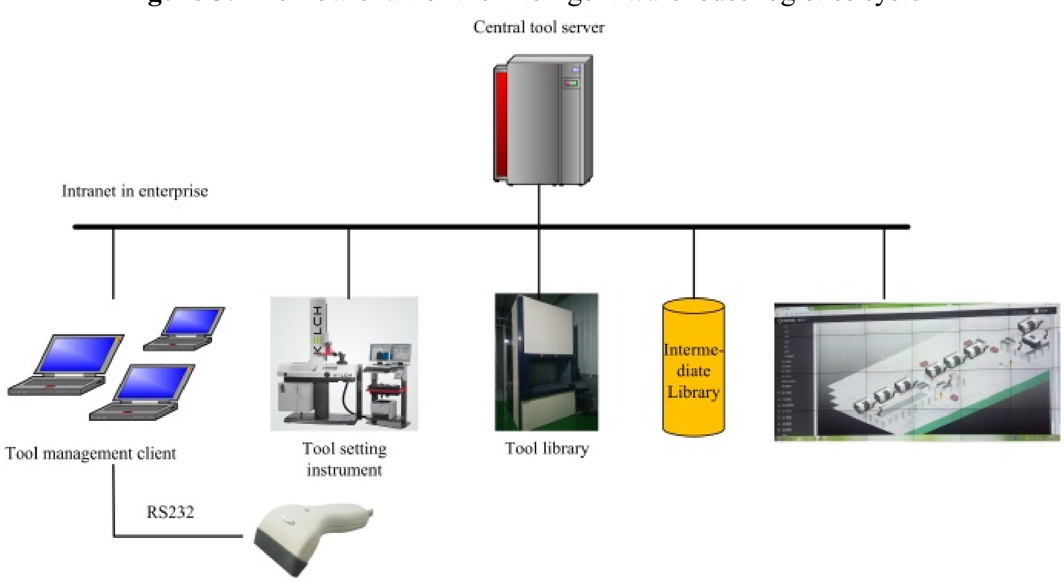

Figure 4: The structural diagram of the tool management system

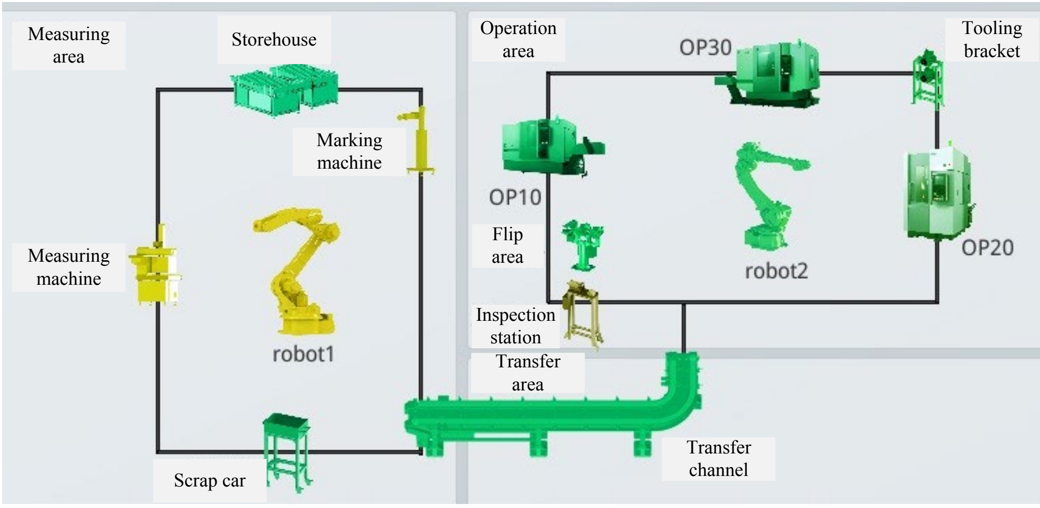

Figure 5: Layout of the bearing gland processing unit

3.3.2 The Impeller Machining Unit

The automated unit layout with the impeller as the carrier: 1. The machining impeller automatic processing island (includes a set of A2. 3 racking system and a set of A6. 3 flexible automatic loading and unloading system), which are connected by a stacking silo. The third-order machining of the impeller is realized. 2. The automatic unit island also includes the logistics system composed of the AGV and stereo library, and the MES system, and the core processing equipment of the 3-unit island is (2) Siemens 828D T2C CNC turning centers and (1) Siemens 840D VMC0656e gantry. The moving beam structure cradle five-axis machine tool and the parts handling and turning between the two lathes are realized by the A2.3 lifting frame. Part handling between the lathe and the five-axis machine is realized using the ABB robots.

The machining process uses the Shenyang machine tool T2 C machine to machine the rough reference of the outer circle and the end face for the turning process of the OP10. The OP20 turning process uses the same T2 C machine to machine the fine reference of the end face and the impeller cover surface. The OP30 milling process uses the VMC0656e for roughing, semi-finishing, and finishing of the outer contour surface of the impeller.

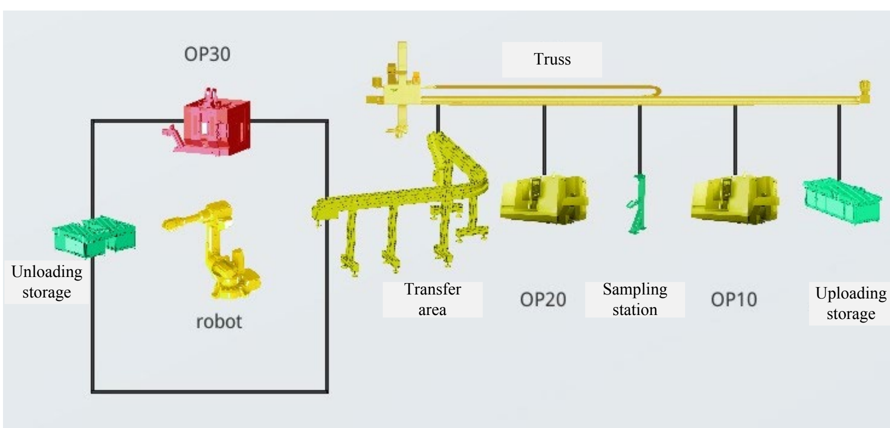

Figure 6: The layout of the impeller machining unit

3.3.3 The Hub Machining Unit

The hub is one of the most important components of the vehicle wheel and is used to connect the brake drum to the drive shaft. The hub is divided according to structure, including a spoke wheel hub.

The inner surface of the hub component is generally a stepped hole, and the outer surface is also stepped. In addition, certain features of the hub components are identical to the bushing components. The two end faces of the hub are generally the surfaces to be machined, and the dimensional and geometric tolerances are relatively high, and the quality of the machined surface is also required. In addition, the inner surface of the hub generally contains internal splines, also which is difficult to process.

Considering the processing methods, processing order, production batch and economy of each surface, the machining process of the automobile hub is as follows: Blanking → stress relief processing → hole roughing processing → hole semi-finishing → reference surface processing → outer circle and so on. Processing → semi-finishing such as outer circle → datum surface processing → mounting hole processing → deburring → final heat treatment of parts → cleaning → final inspection.

4 Design of the Master Control and Automation Unit

The machine status data, along with the CNC machine axis data and plant master control system realize the interconnection, interoperability, and data transfer through the EtherCAT bus. Through the flexible intelligent manufacturing system and through the Internet cable or wireless network it can be seen in the mobile terminal automatic line of the real-time data. The M4.2 real-time machine data axis is shown in Fig. 8.

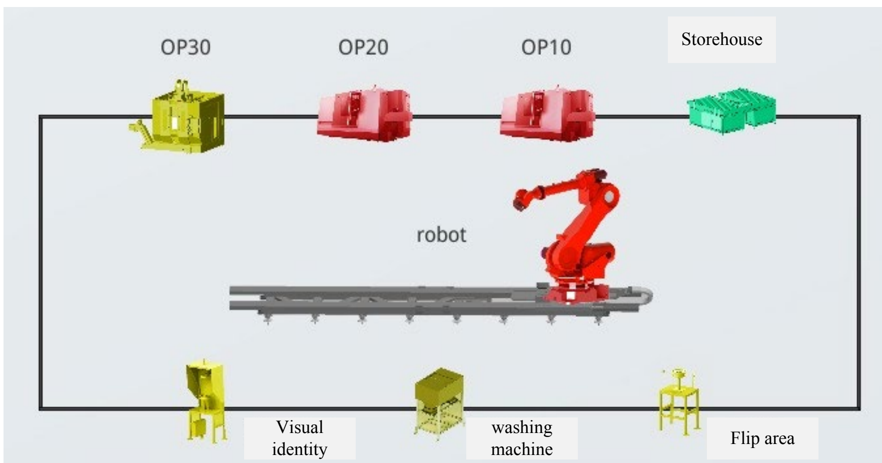

Figure 7: The layout of the hub machining unit

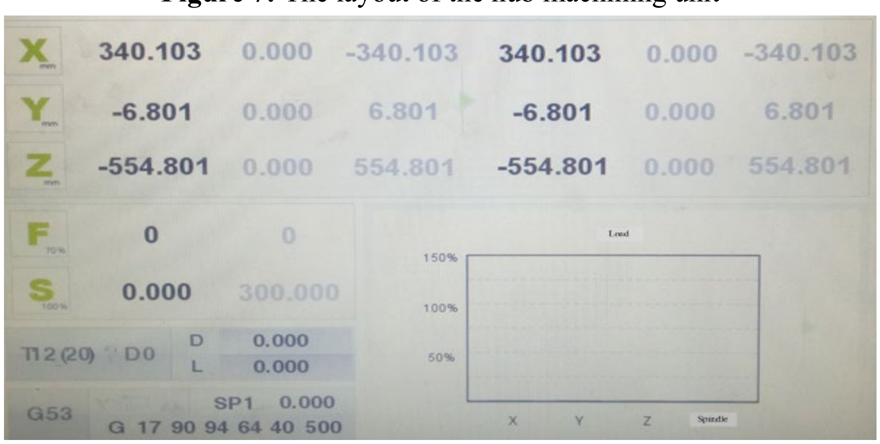

Figure 8: The real-time data display of the M4.2 machine axis

4.1 The Interactive Design of the Machine and the Central Control

Below is the processing procedure choice and execution of the central control system through Tab. 1 of the numerical control machine tool I/O condition realization.

Table 1: The I/O address table of the machine

Machine main program I/O	Function
IX13.0 = 1	Machine Execution Type A machining program
IX13.1 = 1	Machine Execution Type B machining program
IX13.2 = 1	Machine Execution Type C machining program
MB4502.0 = 1	No material on the machine, the implementation of processing procedures
MB4503.0 = 1	Material on the machine, the implementation of cleaning procedures

The interactive program of the bearing gland unit T3.3 machine and the main control part is as follows:

N10 (Sign)

t2d0 (Change the No. 2 tool withdraw knife complement)

G75 (Back to the second zero)

m333 (Spindle limit cancel; no clamping can be M19 orientation)

m19sp0 (The spindle is positioned at 0 and cannot interfere with the robot gripper)

m334 (Spindle limits take effect)

M22 (Machine protection open the door)

M301 (The machine is ready to wait for the total control signal)

M23 (Machine protection closed)

WAITRUNOUT (The cycle begins)

IF $IX[13.0]==“ON” (Read the central control issued X13.0 I/O points, determine the type of workpiece)

GOTO N20 (The program jumps to N20)

ENDIF (End of the cycle)

WAITRUNOUT (Start of the cycle)

IF $IX[13.1]==“ON” (Read the total control issued X13.1 I/O points, determine the type of workpiece)

GOTO N30 (The program jumps to N30)

ENDIF (End of the cycle)

N20 (Sign)

......

GOTO N10 (Loop rewind)

In the main program of the machine, the machining program is invoked by reading the status of the commands; IX13.0, 13.1, 13.2, which are sent from the master control, and the process is continuously cycled.

4.2 The Master Control and Master Control User Interface (UI) Interaction

The control unit compiles the collected automatic line signals and forms the UI variables. The state data of the machine is shown in Tab. 2 for the UI interface to be allocated accordingly. The UI variable 0 No effect; 1–100 alarm status, 101–200 Idle status, 201–300 status is shown in Fig. 10.

Table 2: The data acquisition list of the machine tool

Acquire the signal	Address of the central control
Protective door open	MB4500.0
Protection door closed	MB4501.0
Claw tight	MB4502.0
Claw loose	MB4503.0
Liquid open	MB4504.0
Liquid off	MB4505.0
Machine alarm light red	MB4506.0
Machine alarm light yellow	MB4507.0
Machine alarm lights green	MB4508.0

4.3 The Interactive Programs of the Industrial Robot and the Central Control System

The AGV car sent raw materials by means of the relay channel to the feeding port. The Yaskawa Industrial Robot MH50 grabs the blank for optical inspection, according to the type of light inspection, and the replacement of the corresponding fixture for processing.

Part of the robot processing program code.

NOP Robot program head

WAIT IN#(19) = ON//The condition signal of central control WAIT IN#(18) = ON// The condition signal of central control

DOUT OG#(1) 72//Decoding feedback central control code set 72

WAIT IN#(11) = ON The condition signal of central control

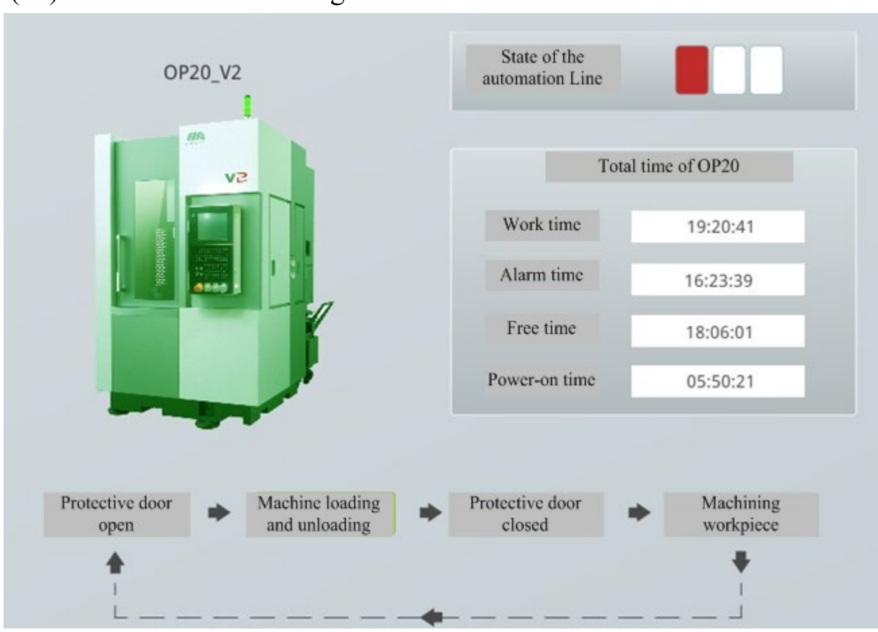

Figure 9: The machine tool status of automatic online

SET B000 0//Set B000 as 0

MOVJ C00000 VJ = 100.00 PL = 0//Back to safety point

MOVJ C00002 VJ = 100.00//Sent material

MOVL C00003 V = 600.0 PL = 0//Optical inspection

```
CALL JOB:Z2S//CALL robot loose claws subroutine
MOVL C00004 V = 1000.0//Sent material
MOVJ C00005 VJ = 100.00 PL = 0//Pick material
PULSE OT#(24) T = 1.00//Save
END
```

5 System Applications and Conclusions

After two years of exploration, the gap between the production site and the simulation has been shortened to a few millimeters. Since last year, the digital twins have been successfully implemented in actual production companies. Fig. 10 shows that through all these links, the WYSIWYG, and the virtual and physical can be exactly the same.

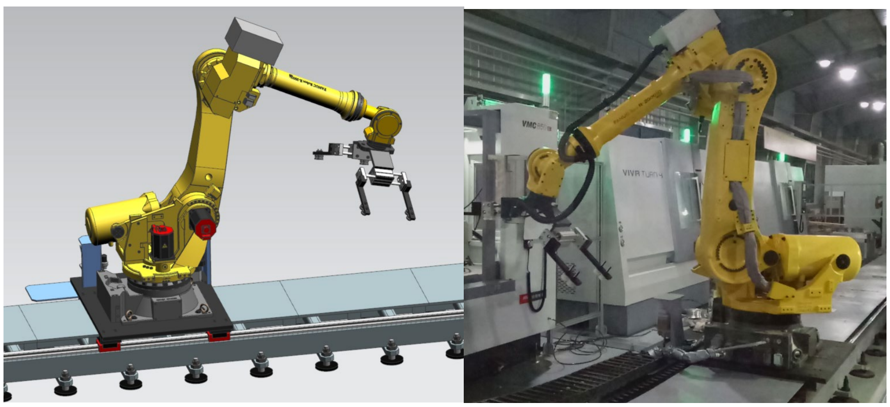

Figure 10: The physical and virtual simulation results

99% of the data produced today is useless data. Based on the industrial big data platform, the entire production of real-time data is obtained, and according to the system requirements, it is defined as which data needs to be acquired and which data can be discarded. After more than two months of deployment, it was found that 99.9% of the data in the data is useless data. Only 0.1% of the data can be said to really bring benefits to the manufacturing, upgrading, prevention and maintenance of the company, and get the best parameters through data mining. The implementation process is shown in Fig. 11.

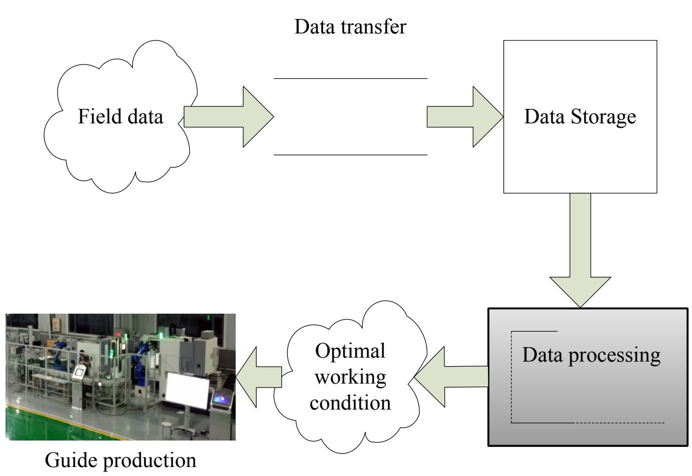

Figure 11: The best-case data mining application process

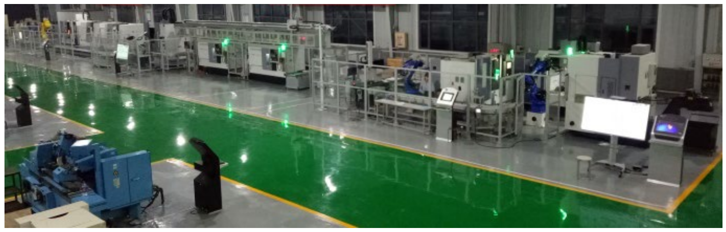

Figure 12: System application scenario

The information physical fusion system also known as the “virtual network-physical physics” production system, completely changes the traditional manufacturing logic. In an information physical fusion system, an artifact figures out which services it needs. The existing production facilities are gradually upgraded by digitization so that the production system can realize a completely new architecture. Digitalization has promoted the development of the manufacturing industry, which has largely benefited from the development of the computer network technology, but it also poses a threat to network security of the workshop. Skilled workers who used to be accustomed to paper now rely more and more on computer networks, automated machines, and ubiquitous sensors. The jobs of technicians are to convert the digital data into physical components and components. The digital technical data of the manufacturing process supports the entire process of product design, manufacturing and service and must be protected. The collaborative technology in the digital factory requires the overall solution of design technology, equipment installation and debugging technology, human-computer interaction interface, human-machine coordination technology, digital twin technology and abnormal alarm intelligent processing technology. In the 21st century, with the development of technology, intelligent manufacturing services continue to innovate and evolve, and many technologies need to be used and solved in the future. However, it can be confirmed that the development direction of the intelligent manufacturing services is based on real-time, reliability, efficiency and low-cost., and these factors will help China's manufacturing industry usher in a new era.

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