Research and Application of Key Technology of Data-Driven Intelligent Manufacturing of Electronic Components

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Abstract. With the development of electronic equipment towards multi-function, high performance and miniaturization, the assembly density and complexity of electronic components become higher and higher. For the manufacturing characteristics of electronic components in many varieties, small batch and mixed production line, this paper uses intelligent manufacturing technology based on industrial big data, puts forward implementation architecture of electronic components digital workshop, explores the "perception - analysis - decisions" closed-loop mechanism of all data of manufacturing process of electronic component, sets up network security platform for industrial control system which ensures workshop operate transparently and safely. The necessity and feasibility of landing of data-driven intelligent workshop are verified by an application example of digital workshop of radar core microwave components, which effectively improves the production efficiency and workshop management level.

1 Introduction

Complex electronic equipment is widely used in the fields of machinery, power and aircraft. Its electronic components account for a large proportion of performance requirements and complex structure composition, which plays a pivotal role in the development and application of complex electronic equipment [1]. The development level of electronic components has become one of the important indicators to measure the performance of complex electronic equipment [2].

The research and development speed of electronic components is getting faster and faster. Electronic components have the typical characteristics of multi-variety, small-batch and parallel production. The traditional "manual record + human experience" based control mode can no longer meet the requirements of consistency and reliability of component manufacturing [3].Based on the data-driven intelligent manufacturing concept [4], this paper study the key technologies of intelligent manufacturing of electronic components to solve such problems as long product switching cycle, difficult wipe tracking and uncontrolled production line operation, which realizes the digitization and intelligent of electronic component manufacturing process [5].

This paper firstly analyses the characteristics of electronic components manufacturing and discusses the key technology of data-driven intelligent manufacturing. Then, the intelligent manufacturing technology is applied to the digital factory of radar core microwave components, providing a method reference for the implementation of intelligent manufacturing technology in the multi-variety and small-batch component manufacturing workshop.

2 Electronic components manufacturing and characteristics

Electronic component manufacturing is a manufacturing system with PCB or small module as the main object, including surface assembly, manual instrumentation, electrical test and other production organization forms.Compared with the traditional manufacturing system, the electronic component manufacturing system has some inherent characteristics [6], which are as follows:

(1) Complex system composition: there are both SMT production lines with high degree of automation, human-machine hybrid lines requiring manual assistance and the assembly line work by hand. The level of technology, automation and digitization of each unit vary greatly, so it is difficult to realize the integrated manufacturing of the whole system.

(2) A wide variety of products and raw materials: components are usually composed of PCB of different specifications and a large number of electronic components, connectors, cables and other materials. Most of these raw materials are of small size and complicated structure, with the characteristics of easy deformation, easy oxidation and easy metamorphism. Therefore, storage, supply and traceability management are highly required and difficult.

(3) Multiple quality control elements: The stability of personnel operation, the running speed and precision of equipment, the quality of raw materials, air quality,

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temperature, humidity and even electromagnetic interference will have a comprehensive impact on the product manufacturing quality [7].

Up to now, component manufacturing system has reached a high degree of automation. Only by focusing on the whole manufacturing process and based on the way of "perception-analysis-decision" of industrial big data, can a new intelligent manufacturing model of components be established with high efficiency, transparency and balance, so as to improve the capability and level of component manufacturing [8].

Foreign countries attach great importance to the research of intelligent manufacturing technology of electronic components and develop a large number of data-driven integrated management platforms. Mitsubishi motors applied the FIX for Windows to great success in the engine workshop, including the functions of material calibration and error prevention, equipment status monitoring, advanced scheduling and so on, which can realize the real variable batch and flexible manufacturing. The U.S. military and industry jointly developed the automatic test management system NxTest, which classified and managed test indicators, collected test data in real time, and gave accurate feedback on test results for the electrical performance testing process, thus improving the direct pass rate of products and realizing transparency in the manufacturing process [7].

Beijing institute of technology, Nanjing university of aeronautics and astronautics and other institutions of China have carried out pilot experiments in advanced planning scheduling, remote monitoring of equipment and other fields, but there are still many problems in engineering applications, and the integrity of the system needs to be further improved. CETC54 and ASIC23 have carried out intelligent manufacturing research and application verification on chip packaging. However, data acquisition and fusion analysis in complex manufacturing environment and network security are still to be studied.

3 Exploration of key technology

3.1. Data collection and management technology

The production process of electronic components is complicated and various, involving logistics distribution, surface mount, debugging and testing, module assembly and other types.In order to achieve the fusion of the underlying equipment information and the network, the production process data and equipment state are dynamically perceived and modeled, and the collected data are classified and managed by establishing databases [9].

3.1.1 Dynamic perception and modelling of production data

The manufacturing system of electronic components of complex electronic equipment is a dynamic system with constant information generation and change. Assembly data can be divided into product data, production process data and equipment data, as shown in figure 1 [2].

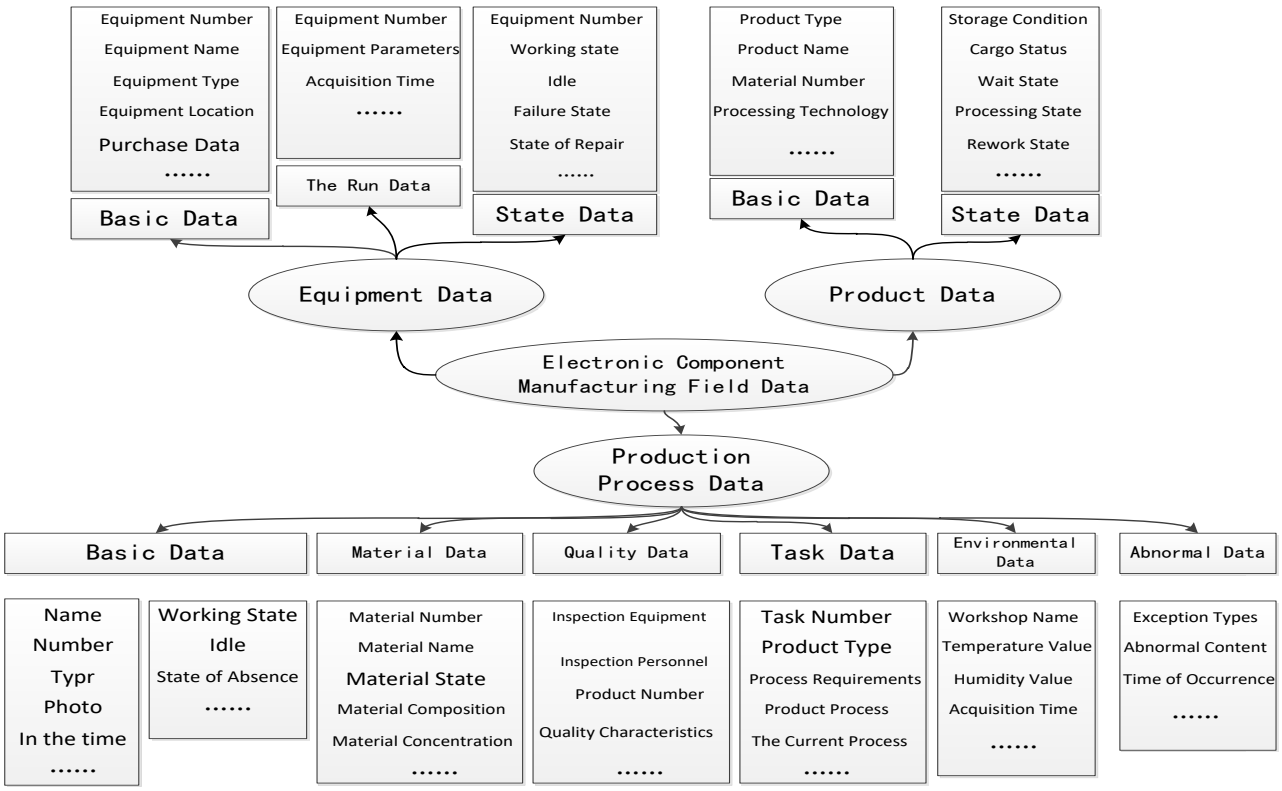

Fig. 1. Classification of manufacturing process data of electronic components

Based on the analysis and classification of these data, the data collection model is built according to the personnel, equipment, materials and testing equipment involved in the production of products. It is necessary to establish the object model of multi-source data collection with standard and formatted methods, so as to realize the unified expression of data collection. Based on the establishment of the acquisition model, the corresponding acquisition methods can be determined, including sensors, bar codes, device networking, human-computer interaction (HMI), and interfaces with MOM and ERP.

According analysis and classification of the data during assembly process, combined with the data collection model, with modern sensor and the corresponding intelligent terminal as the main acquisition methods, and combining the industry establish a IOT workshop environment of Internet technology, using the unified and efficient data exchange protocol and the data interface, realize electronic components manufacturing field of multi-source heterogeneous data real-time, accurate, reliable, acquisition and transmission.

3.1.2 Production data classification management

The production process data of electronic components is the core of the digital workshop. As a transitional stage, data classification and management is of great significance to the continuity and integrity of data.

The most important point of production data classification and management technology is to establish the original basic database. The specific methods are as follows:

1) Build the data collection interface on the production site of electronic components and establish the original basic database;

2) Progressive compression of the database, management of historical records within a specified time, automatic deletion of redundant data;

3) Historical data query, manual deletion, addition, modification and other functions;

4) Provide data interface with other information systems in the workshop;

5) Report output as required by the management.

3.2 Data processing and fusion analysis technology

By combining large data processing method of artificial intelligence as the main tool, character of data fusion, data extraction, data mining, data visualization technology as support [10], such as the production of electronic components to the mass data processing and analysis, by extracting rules, establishing the model, data filtering, the methods of simulation run, forming production scheduling and quality control prediction result, the intelligent decision of business management to provide data support for the factory.

3.2.1 Hybrid production dynamic scheduling and configuration technology

Application of dynamic scheduling mixed production line configuration with rhythm coordination as the core process - location level automatic production scheduling method, based on the unified scheduling services - resources - processing model, simulation of production capacity assessment of electronic component workshop, to identify bottleneck resources, provide support for task allocation decisions. At the same time, based on the unexpected events of schedule deviation, quality abnormality, material loss and external production task adjustment and switch in the production process, a rapid dynamic adjustment plan can be formed to support orderly and coordinated production process management and realize pipelined production scheduling based on flexible station combination.

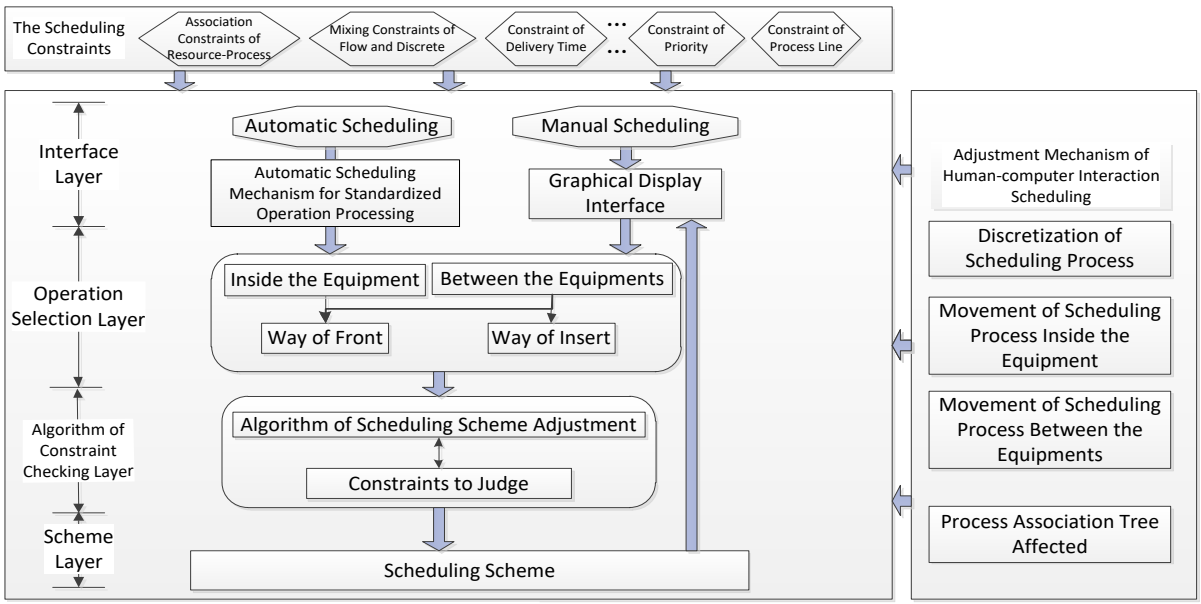

Fig. 2. Hybrid production dynamic scheduling and configuration technology

As shown in figure 2, the technical scheme of dynamic scheduling configuration for mixed-line production is mainly manifested in two aspects: scheduling processing mechanism and scheduling processing process:

• Scheduling processing mechanism

Firstly, the scheduling process is discretized, objectified and graphical. Secondly, the adjustment specification of the scheduling process is divided into two forms: in-device movement and inter-device movement, and the arrangement of the positions of the two processes are provided. Thirdly, the affected correlation tree is established to realize the overall adjustment of scheduling through traversal processing.

• Scheduling process

Firstly, under the constraints of electronic component production, the scheduling rules are selected to arrange the location and time nodes of the process in the equipment/station to form the scheduling scheme. Secondly, with the support of scheduling processing mechanism, man-machine interaction adjustment based on scheduling personnel experience is realized. Thirdly, the form of man-machine interaction is changed into an automatic processing mechanism to realize automatic dynamic adjustment.

3.2.2 Mixed line production quality control technology

Electronic component production requires high dynamic process stability. According to the production control characteristics of multi-variety and small-batch, production quality control technology can diagnose the running state of the process dynamically and accurately, which is of great significance to timely adjust the production process and improve the economic benefit.

The technical scheme of quality control for mixed line production of electronic components is shown in figure 3. The specific working process is described as follows.

1) Process capability analysis: on the basis of the data collection process capability analysis, upon confirmation of the production process are in a stable state of statistical control, for a short period of time (like a week) of the sample data statistics calculation, calculate the process capability index to establish the lower the standard of statistical process.

2) Establish the criteria for judging process anomalies: the judgment method that violates the random process and produces certain regular process characteristics. Through a comprehensive consideration of technical characteristics, test experience, field production, etc., it provides support for the correlation analysis of abnormal fluctuations with production line faults or product quality defects.

3) SPC analysis based on six sigma management: optimize the grouping of sample data collected in the short-term process, optimize the design of sample size and sampling frequency under the principle of data collection, statistical economy and small disturbance to normal production, and realize accurate, reliable and timely SPC control.

4) Graphical results show: using the mean - poor control chart, the average - standard deviation control charts, nonconforming rate/nonconforming drawing graphics, defects such as form, the key equipment of automatic line or process parameters for real-time analysis, abnormal condition of process for real-time alarm, monitor the production process stable.

3.3 Data network security protection technology

Building real-time, high speed, safe and reliable network infrastructure, provide interactive channels for data of materials, equipment, testing and management such as production process to realize the exchange of information and communication security between products and products, devices and equipment, equipment and products, and at the same time using the network security monitoring and border security protection technology, deal with the different requirements for information security of enterprise layer, management layer, control layer and equipment layer level such as.

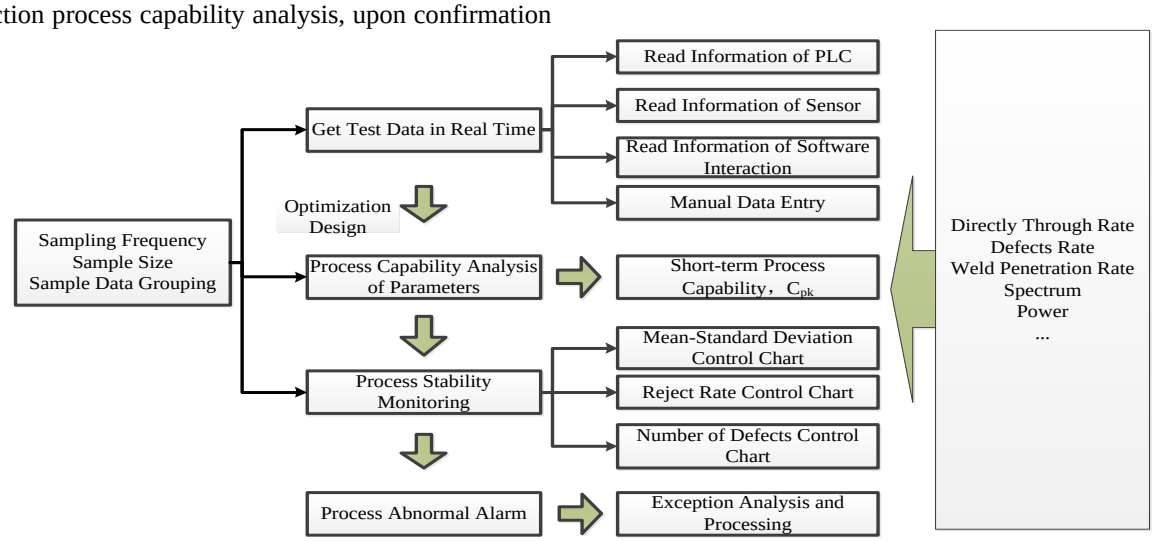

Fig. 3. Quality control of mixed line production technology

(1) Security network infrastructure construction technology

The manufacturing network of electronic components demands high safety standards. Analysis the intelligent manufacturing system for industrial control, security risk and demand for the traditional network information security system of OSI, P2DR, PDRR, IATF, WPDRRC model, combined with advanced industrial control system for the confidentiality, integrity and reliability of information transmission, controllable and availability requirements, building the security system DPDRRA model based network. At the same time from the safety management, technical support, operation maintenance and other aspects of the establishment of a unified throughout the production process of the system, effectively ensure the safe development of industrial control system; improve the safe operation of intelligent manufacturing production lines. As shown in figure 4, the DPDRRA model respectively represents Diagnosis, Protection, Detection, Response, Restore and Adjust.

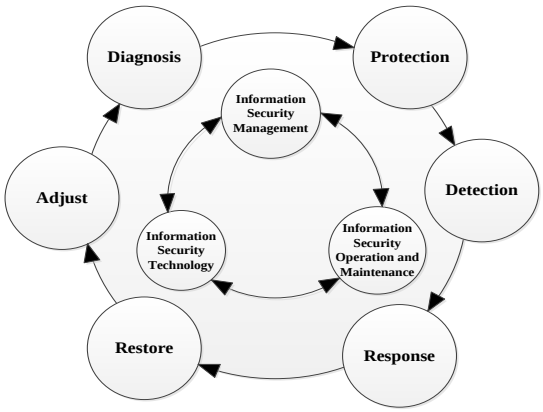

Fig. 4. Intelligent manufacturing security network foundation system DPDRRA

(2) Network security monitoring and border security protection technology

Electronic components manufacturing workshop equipment quantity, variety, communication protocols are different. Through in-depth study of intelligent manufacturing system communication protocol, invasive monitoring technology, safety isolation technology, etc., parse the OPC, Modbus, IEC40, DNP3.0 dozens of different protocols, such as the deployment of security detection strategy, suspicious of network behaviour or attack response, multi-stage monitoring ability, timely find any illegal operation or wrong operation in the control network, illegal access and the spread of worms, viruses and other malicious software such as different types of network security hidden danger; Build an effective industrial firewall to resist Dos/DDos, LAND, SNORK and other typical attacks and a variety of malicious port scanning, to achieve virus attacks, Trojan attacks, database attacks and other protection functions.

4 Application example of radar core microwave component digital workshop

Radar is a complex electromechanical coupling system, which is a typical complex electronic equipment.Its core microwave components show the characteristics of variety, quantity and high performance requirements, which play an important role in military equipment at home and abroad.The development level of microwave module has become one of the important symbols to measure radar performance. The traditional operation mode is faced with such problems as poor production strain capacity, lack of means of optimal allocation of resources, and difficulty in controlling real-time production schedule, so it is urgent to improve the overall production level of microwave component manufacturing workshop through data-driven intelligent manufacturing technology, so as to meet the production capacity demand of radar products.

4.1 Overall architecture of microwave component digital workshop

According to the characteristics of intelligent manufacturing of microwave components, the function modules and the relationship between layers of digital workshop are sorted out.In the vertical end of microwave component manufacturing, four platforms, including the enterprise layer, the management layer, the control layer and the equipment layer, are built to upload and transmit the production control orders and the production process information, so as to realize the transfer of the task "order - work order - execution" layer by layer, and complete the internal circulation of the manufacturing system.The overall structure of the microwave module digital workshop is shown in figure 5 [2].

Through the docking of PLM, ERP, MOM, SCADA and other systems, knowledge can be transversal in the whole product life cycle, providing the most real-time and accurate manufacturing information for the intelligent decision-making of the management.

4.2 Microwave component mixed line production data collection and management

Data acquisition and management in production process is the key to realize integrated control and information integration of microwave components. The production process of microwave components includes set, assembly, test, etc. The content and data of these three production links are analyzed.

(1) Set: material preparation is the first step of microwave module production and the source of data collection [11].Collect basic material information by scanning code, including material code, material name, batch number, order number, etc. Material consumption and inventory in the assembly process are counted by means of system integration. Record the information of new supplement material demand and device batch number caused by repair of faulty parts, and bind with current products to facilitate follow-up inquiry.

(2) Assembly: SMT automatic assembly and assembly line assembly are the two main processing modes of microwave components. The assembly line is

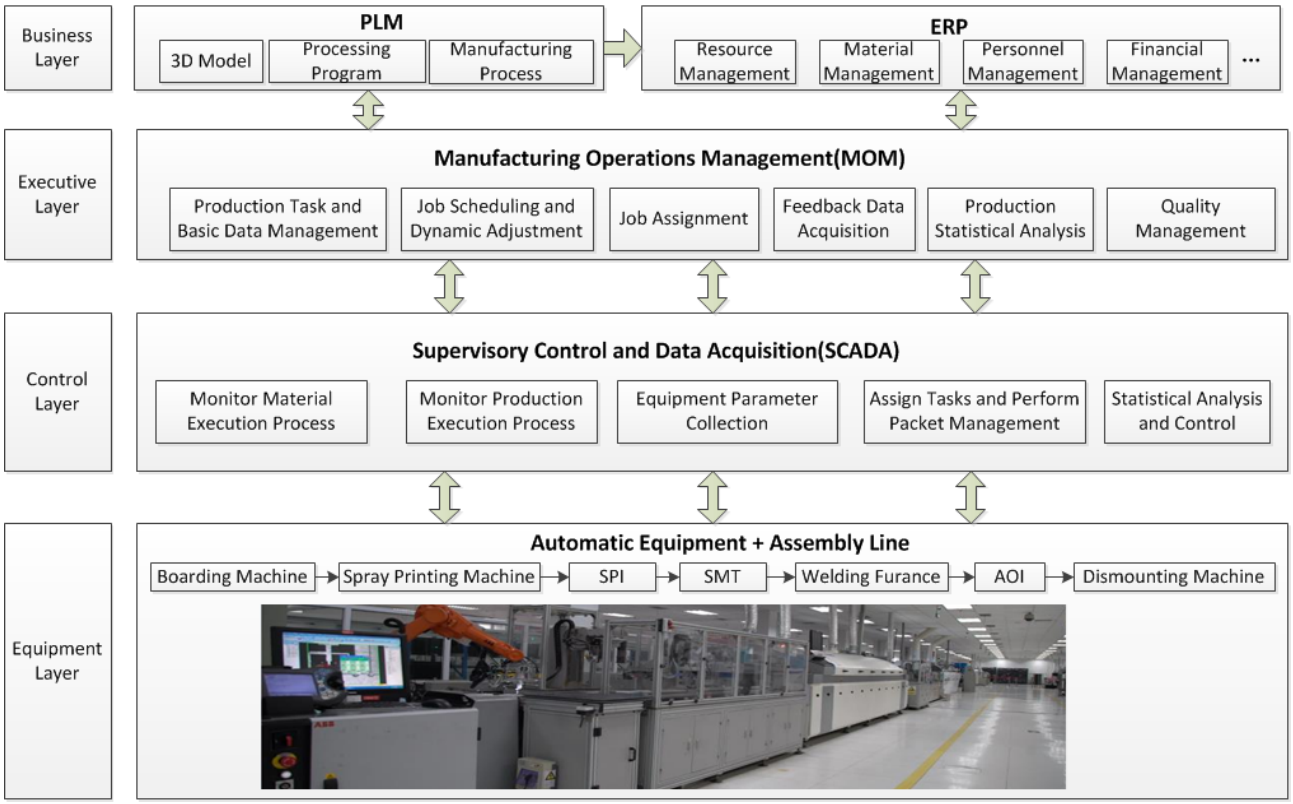

Fig. 5. Overall architecture of microwave component digital workshop

mainly operated manually, and the information data in the production process is manually input, including the batch number of key components, the processing process information, the production schedule information, etc. The SMT automated assembly line consists of a set of automated devices that access the machine's raw data through a communication interface or by adding sensors.

(3) Test: The electrical performance of microwave module is tested with many indexes and long time. For components with poor test results, it's necessary to accurately and in detail record fault phenomena, conduct secondary analysis on a large amount of accumulated fault history data, find out the week links in the assembly process and improve quality accordingly.

Information of personnel, equipment, material, test result and production orders in intelligent manufacturing plant is collected, combined with visualization display function to achieve data acquisition rate is above 95%, equipment connectivity rate 100%, implement transparent management workshop[2].

4.3 Quality control of microwave component mixed line production

Based on already collected device status information, order information and test results, using statistical process control (SPC) techniques, with different patterns of control chart, realize the equipment running status information, production process and product quality indicators such as fluctuations of automatic graphic display, set up production status and product quality control rules, the implementation of the abnormal state real-time judgment and warning.

Carry out the six sigma project aiming at the quality key characteristic index of automatic production line, complete the establishment of SPC control chart through the steps of defect definition, problem analysis, improvement measures and SPC, define the production process capability and control parameters, and finally form the SPC analysis module. According to the control chart information, the process personnel can quickly grasp the fluctuation information of the production line, and in combination with the quality kanban, analyse the abnormal fluctuation factors and formulate measures to stabilize the automatic production process and avoid a lot of rework.

Figure 6 shows the effect diagram of SMT solder joint defect statistical process control. Based on AOI sample data, SPC technology was used to control and analyse welding defects [12].The collected samples can be combined in multiple dimensions according to time, order and material packaging [13].Through the implementation of SPC management technology, the pass rate of primary product inspection was increased by 25%, and the rework cost was reduced by 60% for the component manufacturing workshop.

4.4 Intelligent manufacturing information security of microwave components

Surrounding security microwave components of real-time intelligent manufacturing system, recommend suite, reliability, security, communication ability, and deal with production line equipment, technology, information

system and so on all aspects of the attacks, expand security protection path, security network based system based on intelligent manufacturing system overall technology and depth control protocol parsing and safety equipment centralized management technology and cutting-edge technologies such as equipment safety testing technology, construction of intelligent manufacturing system security network.

The specific technical route is shown in figure 7.

Security monitoring and detection: realize the capability of self-inspection, analysis and evaluation of threat security. The industrial control vulnerability scanning system supports multi-task parallel detection, equipment parallel detection and multi-thread parallel scanning. Realize the controllable ability of predicting, foreboding and preventing the potential danger of intelligent manufacturing system.

Security protection: carry out research on OPS, Modbus and dozens of common protocols, deploy security monitoring strategies, respond to suspicious behaviors or attacks on the network, realize multi-level monitoring capability, timely find any illegal operation or misoperation, illegal equipment and spread of malicious software, and form a firm industrial firewall.

Security protocols: intelligent identification of more than 60 typical industrial protocols, in-depth analysis of 20 industrial protocols such as Zigbee, ICE and TCP/IP, realizing intelligent topology management and comprehensive state monitoring, integrating equipment asset management, policy centralized configuration, and equipment security management into a unified platform.

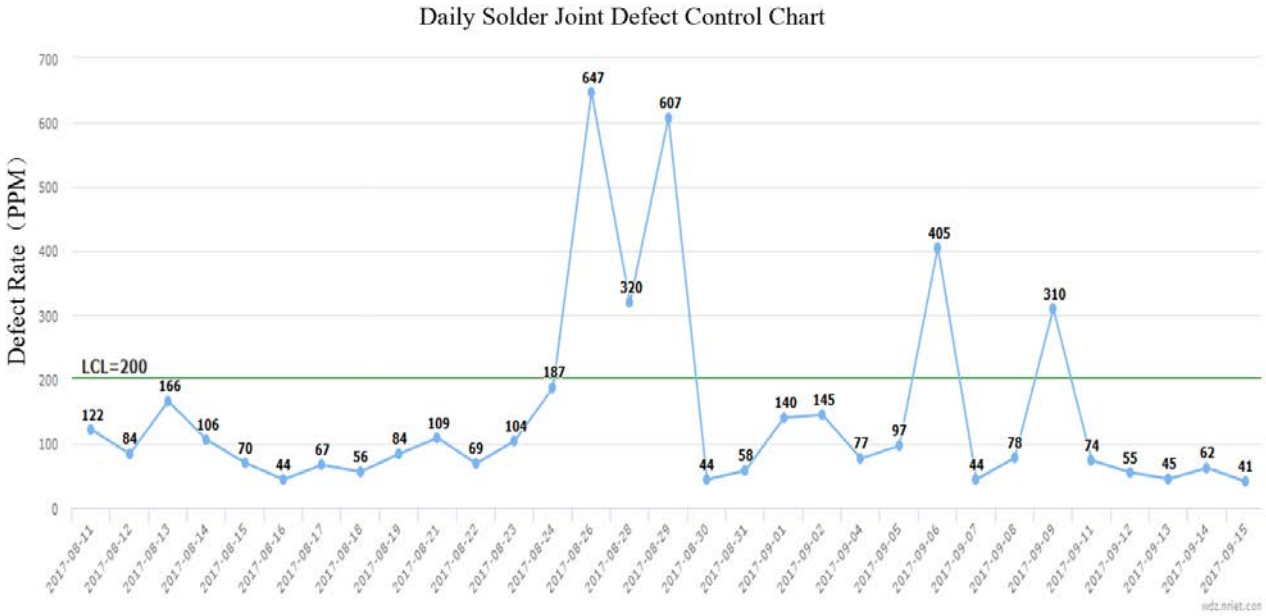

Fig. 6. SPC chart of welding defects in automatic production line

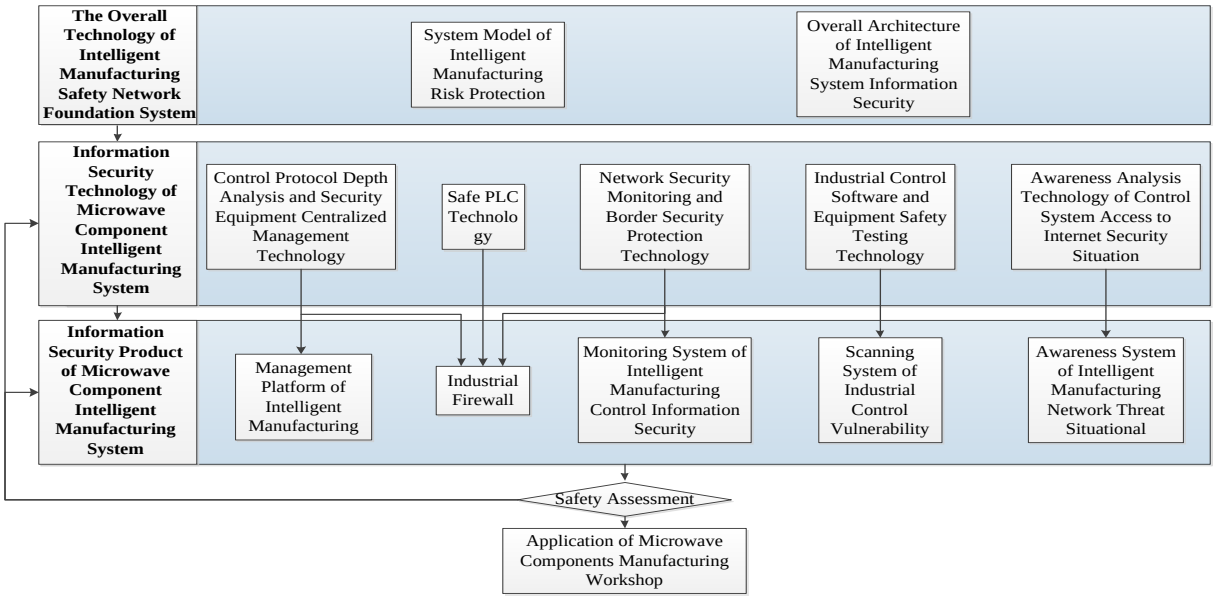

Fig. 7. Technology route of microwave component information security protection

The implementation of the microwave module information security protection system ensures the continuous operation of the workshop, avoids the production interruption caused by the network, shorts the production cycle by more than 20%, and effectively guarantees the digitalized and intelligent process of the workshop.

5 Conclusion

This paper studies the key technology of intelligent manufacturing, data driven in complex electronic equipment electronic components for the application object, based on the data acquisition and data management, data processing and analysis as well as the key technology such as network security, data acquisition system is developed, production quality control system, network security management system such as workshop control platform, improve the production efficiency and quality of microwave components, built the model of mixed production line more microwave components of intelligent manufacturing demonstration workshop.In the future, focusing on the goal of moving from "digital workshop" to "intelligent workshop", the emerging technologies such as artificial intelligence, machine learning and additive manufacturing will be deeply studied and applied.

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