Construction of Intelligent Perception Network Based on Rocket Assembly Workshop

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Abstract: The rocket assembly is a crucial link in the rocket production process. With the increase of national space missions, how to quickly adapt to the high-density launch stage and improve the efficiency and quality assurance of the assembly workshop has become an urgent problem to be solved. Aiming at the problems of the low production efficiency caused by low information level of production site and the low intelligent degree of material management and distribution, an intelligent perception network based on the rocket assembly workshop is proposed in this paper. This intelligent perception network is equipped with functionalities such as intelligent perception, adaptive adjustment, data communication, remote monitoring, and management. It is designed to not only increase the intelligence level of assembly workshops but also effectively address the issue of low production efficiency.

Keywords: Rocket Assembly; Intelligent Perception Network; Production Control; System Integration; Digitalization

1. Introduction

As an important link in the rocket production process, the rocket assembly primarily involves the installation of various components such as segments, instrument cables, and pipeline valves, culminating in the assembly, docking, adjustment, and testing of different subsystems and components to form a complete product. The characteristics of rocket assembly, including multiple models, complex structures, and low production volumes, form the adoption of a single-fixed workstation assembly mode. Consequently, low assembly efficiency and challenges in data collection and quality management are inevitable issues in the assembly workshop. With the advancement of digitalization and automation technologies, "Made in China 2025" highlights the promotion of intelligent and digitalized factory construction in key areas. It emphasizes the digitalization, networking, and intelligence of production processes, accelerating the transformation of the national manufacturing industry towards intelligent manufacturing [1]. Simultaneously, as the number of national space missions increases, how to rapidly adapt to high-density launch stages and swiftly improve the efficiency and quality assurance of assembly workshops has become an urgent problem to be solved in rocket assembly. Therefore, improving the development of rocket assembly workshops towards intelligence and automation is imperative [2].

The intelligent perception network is a new LAN mode of the assembly workshop. It integrates the interconnection and mutual inductance of various components, personnel, equipment, tools and other resource information of the workshop [3], and realizes the data and instruction interaction, data edge calculation, data storage and management functions among multiple equipment. The structure of the intelligent perception network is shown in Figure 1 [4].

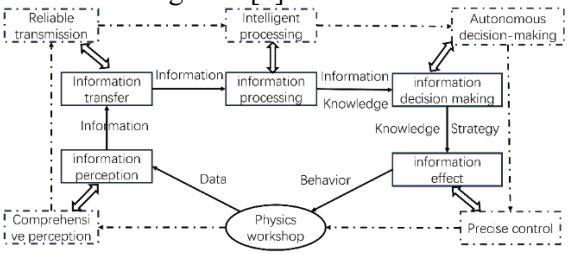

Figure 1. Intelligent Perception Network Structure

2. Production Status of Rocket Assembly Workshop

2.1 Low Information Level of Production Site [5]

Due to the limitation of rocket assembly work,

manual operation is still the main mode on site. The workers on site use on-site tools, tooling and measuring instrument to operate according to paper process documents, and manually record the operation results. The manual record-keeping is time- consuming, meanwhile, the data entry is susceptibility to errors. The absence of automated data collection equipment makes it difficult to ensure the accuracy and timeliness of the data.

2.2 Low Intelligence Level of Material Management and Distribution

Material distribution primarily relies on manual retrieval and handling, where workers must first go to the warehouse to sign and confirm before receiving standard parts, components, instruments, and cables for their tasks. This process is time-consuming as it involves manual transportation back to their workstations. Moreover, any issues with incomplete sets severely hamper production progress. The lack of advanced manufacturing systems and intelligent material distribution equipment further compounds these challenges [4].

2.3 Limited Quality Assurance Means

Due to the low level of automation in rocket assembly operations, manual operations cannot guarantee the consistency and quality assurance of the operations. It is necessary to record and judge the data during the operation process. Some data can be judged on-site, while others require processing before interpretation. However, there is a lack of data analysis means, leading to manual judging and interpretation. Moreover, on-site measurements can only record results, making it difficult to record data during the process. Therefore, algorithms and equipment are needed to collect, record, and analyze process data, and historical data analysis can be used to optimize the current process.

3. Requirements of Rocket Assembly Workshop

3.1 Increasing Productivity

The rocket assembly workshop needs to ensure an efficient production line to meet the requirements of the space mission. Improvement of production efficiency is its primary objective. Through optimization of the assembly process, application of automatic assembly equipment, intelligent management and other means [6], production cycle can be shortened, production cost can be reduced, and output can be improved.

3.2 Quality Control Assurance

As a spacecraft, rockets have extremely high safety requirements, and any quality problems can lead to catastrophic consequences. Therefore, the rocket assembly workshop needs to strictly control the quality of each step to ensure that the quality of all operation and assembly meets the standard, and ensuring the flight safety and reliability of the whole rocket [7].

3.3 Data Real-time Monitoring and Analysis

The rocket assembly workshop needs to carry out real-time monitoring and data analysis on the production process to identify problems and adjust them in time. Through data acquisition and analysis, the production status can be known, the failure risk can be predicted, and the production process can be optimized, to improve the production efficiency and quality level.

4. Features of the Intelligent Perception Network

4.1 Intelligent Perception

It is responsible for collecting real-time data from sensor nodes and performing preliminary data processing and integration. The data acquisition module may communicate with the sensor nodes in a wired or wireless manner to transmit the acquired data to the subsequent processing module. The acquisition equipment is internally provided with an intelligent algorithm and a processor, which can carry out real-time analysis and processing on the acquired data, identify abnormal conditions and send out an alarm. In this way, potential problems can be found in time for real-time monitoring of production status, prediction of failure risk and optimization of the production process, etc.

4.2 Adaptive Adjustment

Based on the results from the data processing and analysis module, it formulates intelligent production management strategies and decision-making schemes, translating them

into practical operational instructions. This module may include control algorithms, optimal scheduling strategies, automatic execution systems and so on, which are used to realize intelligent control and management of production process.

4.3 Data Communication

Intelligent acquisition equipment usually has multiple data communication interfaces, which can interact with other equipment or systems to realize information sharing and integrated management. For example, it is arranged at each key position of the rocket assembly workshop to monitor various parameters of the production environment, such as temperature, humidity, pressure, vibration, etc. The sensor node may include a temperature sensor, a pressure sensor, etc. In this way, the collected data can be integrated with other systems to realize comprehensive information management.

4.4 Remote Monitoring and Management

Intelligent acquisition equipment usually has remote monitoring and management functions, which can remotely access the equipment through the network and monitor the acquired data in real time. In this way, the remote monitoring and management of the production process of the rocket assembly workshop can be realized, and the management efficiency and timeliness can be improved.

5. Content of the Intelligent Perception Network

5.1 Automated Equipment Assembly

At present, the rocket assembly workshop is mainly operated manually, and it is difficult to establish a complete automatic assembly line, but the auxiliary assembly process of automatic equipment can be introduced, such as automatic turning and docking equipment of engine, automatic docking equipment of shell section and large-section transfer equipment, etc. [8]. This equipment includes robotic arms, conveyor systems, automated fixtures, etc. capable of facilitating efficient assembly processes. In order to ensure the quality of rocket components, the rocket assembly workshop uses automatic quality inspection equipment, such as automatic docking equipment, infrared detection system, etc., to conduct non-destructive inspection and quality assessment on the assembled components.

5.2 Intelligent Process Control System

By adopting the advanced process control system, the real-time monitoring and adjustment of the rocket assembly process can be realized. 1) Process document management: Store and manage process documents (process flow, process parameters, assembly drawings and operation procedures) in a digital manner to ensure that each production link is operated according to the specified process flow to improve production efficiency and product quality. 2) Intelligent decision-making and optimization: The intelligent process control system also has the function of intelligent decision-making and optimization, and realizes the real-time monitoring and adjustment of production task, equipment operation state and material supply by collecting and analyzing various data in the production process [9]. Based on these data, the system can make intelligent decision and optimization to optimize the production process. 3) Scheduling system: The scheduling system is the core part of the whole process control system and is responsible for scheduling and managing production tasks. It can intelligently arrange the execution sequence and time of production tasks according to the production plan, process requirements, equipment state and other factors, so as to improve production efficiency and resource utilization rate to the maximum extent.

5.3 Augmented Reality System

With augmented reality technology, 1) Real-time guidance and assistance during assembly can be obtained through an AR display or headset. AR system can display the assembly instructions, operation steps, parts information and so on in real time in the visual field of the workers to help them complete the assembly task accurately. 2) The AR system can employ image recognition and localization techniques to assist workers in swiftly identifying and locating components. Virtual markers or instructions displayed via the AR monitors can guide workers to precisely locate the required parts, thereby reducing errors and improving assembly efficiency.

5.4 Intelligent Sensors and Monitoring Systems

The intelligent sensor can be installed at the key positions of the rocket assembly line and can be used for monitoring various parameters and indicators in the assembly process in real time, such as temperature, pressure, vibration and the like. By monitoring the assembly process in real time, assembly problems and abnormal conditions can be found in time, and corresponding measures can be taken to adjust and repair. The Intelligent sensor and monitoring system can collect a large amount of real-time data, and realize real-time monitoring and optimization of production process through data analysis and mining technology. Through real-time monitoring and analysis of production data, potential problems and bottlenecks can be identified, and corresponding measures can be taken for optimization and improvement [10].

5.5 Intelligent Logistics System

In order to realize the efficient scheduling and transportation of materials, the rocket assembly workshop may adopt intelligent logistics system, including an automatic storage system, AGV (Automated Guided Vehicle) and so on, to ensure the timeliness and accuracy of material supply. Based on the material distribution procedures within the rocket assembly workshop, automation is employed using automated vertical storage systems to replace traditional manual methods for material management and recording. This facilitates automated inbound and outbound material processes, inventory checks, and electronic identification. Material distribution is conducted through material delivery robots, reducing delivery times and enhancing automation levels. Additionally, an intelligent logistics management system can be developed. This system integrates functionalities of automated vertical storage management software while transitioning from traditional passive retrieval to proactive material distribution methods. Overall, this improves the automation level of material storage management and improves the efficiency of material distribution [11].

6. Potential Outcomes

Through upgrading and transformation of the assembly workshop for a specific model of rocket, an intelligent perception network can be established. This is achieved by introducing automation equipment and augmented reality systems for assembly, constructing intelligent process control systems, and deploying sensor monitoring systems to oversee the manufacturing processes. These systems facilitate process control and data collection and analysis during production. Additionally, the implementation of an intelligent logistics system for material management and distribution can significantly improve the production efficiency of the assembly workshop. Furthermore, this initiative can effectively ensure quality control throughout the production process. Moreover, it enables remote monitoring and management of the rocket assembly workshop's production processes, thereby improving management efficiency and responsiveness.

7. Conclusion

As a crucial link in rocket production, how to adapt to the high-density launch task, improve the efficiency of assembly workshop and ensure the quality has become an urgent problem to be solved in rocket assembly. In this paper, the intelligent perception network based on the rocket assembly workshop is constructed. Through the application in the rocket assembly workshop, the production efficiency of the assembly workshop is greatly improved, the quality of the production process is well controlled and guaranteed, and the remote monitoring and management of the production process of the rocket assembly workshop are realized, and the management efficiency and timeliness are improved.

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