Intelligent Tower Crane Technical Analysis of Key Features and Remote Control System

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Abstract

The development of China's economic construction and information technology has had a profound impact on the traditional manufacturing industry. In the transportation sector, the increasing demands for height, safety, speed, precise positioning, and stable operation have propelled the evolution of intelligent cranes. This paper focuses on the key characteristics of intelligent tower cranes and the development trends of remote control systems. It also explores the design and application of key technologies in the remote control systems of new types of intelligent cranes, further investigating the design theory and application techniques of their remote operating systems. This is aimed at better overcoming various challenges in future applications and fostering the innovative development of intelligent cranes.

Keywords Crane; Intelligent crane; Intelligent system

1. Introduction

Cranes are widely used in factories, stations, warehouses, high-rise buildings, seaport terminals, offshore oil drilling, mining, etc., and show the development trend of large tonnage, high efficiency, automation, and multi-purpose. At the same time, people's demand for work stability, operational safety, level of intelligence, action safety and reliability, mechanical equipment fault monitoring and detection level is also rising. Intelligent construction machinery involves a machine, electricity, water, sound, light, and other fields, based on machine science and technology, modern microelectronics science and technology, sensor science and technology, combined with a variety of information technology, to realize the information processing function within the machine, and the intelligent crane is a class of automated construction machinery and equipment, the modern intelligent crane control system to carry out an in-depth study of the significant value and significance of the research.

2. Characteristics and advantages of intelligent tower cranes

An intelligent tower crane refers to a tower crane with a high-sensitivity intelligent operation system, all the work can achieve a high degree of automatic control of the equipment, with mechanical action and motion characteristics, programmable functions, human-computer interaction, and self-testing capabilities. The intelligent tower crane is mainly composed of crane basic action layer, sensor layer, information acquisition and execution layer, control system layer, and human-computer interaction technology layer. With the development of artificial intelligence, intelligent cranes also have cognitive ability, computational technology, motor ability, coordination ability and decision-making control functions.

Compared with traditional cranes, intelligent cranes mainly have the following advantages. (1) Visualization and remote control technology. Visualization can be observed instantly on the working cond[1]ition of the device, wireless communication technology and hard-wired networking methods are used to assist the operator to complete remote management and make correct judgments and actions. (2) Complete

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data acquisition and fault recording technology. The parameters on the crane are extremely complex, with an intelligent tower crane utilizing a microprocessor, mass memory technology, and graphic LCD technology, among others, to swiftly gather, categorize, and process data, aiding operators in promptly assessing equipment status. (3) Anti-swaying technology. The swinging of the crane hook directly affects the operational safety and operational quality during the crane working process. An intelligent control system can monitor the displacement condition of the goods and make additional corrections to the system through acceleration, deceleration, etc., to prevent or reduce the swaying of the goods and make the operation more accurate. (4) Intelligent motor traction system. The use of a more reliable frequency conversion speed control controller, to achieve more rapid feedback on the torque and accurate monitoring of the rotational frequency.

3. The current development status of the intelligent crane remote control system

3.1 Intelligent crane application areas are increasing

With the construction of automated terminals, gantry cranes, railcars, and other applications, more and more, intelligent cranes can be said to be everywhere. From China's first automated bulk port Shanghai Luodonggang to the new port of Busan, South Korea, 73 intelligent unmanned rail crane units and 19 shore-side electric carts, to Taiwan's Taipei port area of 40 intelligent unmanned rail cart units, the port's fully automated ship unloading machinery, fully automated stacking and reclaiming machines and fully automated ship loading machinery, can use the remote centralized monitoring and control to achieve unmanned and automated operations.

The number of intelligent cranes in large cargo warehouses is also increasing, with unmanned overhead cranes accessing loads on their own. For example, the commissioning of the unattended overhead crane management system for the post-roll warehouse of the Tangshan Steel high-strength automotive panel project, which was developed in cooperation between the HSC Tangshan Steel Group and South Korea's Posco Group, has been completed. Baosteel Baoxin and Transportation Division near the 21 dock automation warehouse, has realized the fully automated unmanned warehouse control.

3.2 Intelligent crane remote control system continues to innovate

The remote control system of the intelligent crane is necessary for it to complete the operational tasks in the characteristic environment. In the collapse area, flammable and explosive area, harsh environment operating area, and poor vision operating area, all need to be precisely controlled through wireless remote control device machinery and equipment and instruments to complete the corresponding mechanical operation conveniently. At present, the world's economic powers on remote control technology to carry out vigorous research, in micro-motion control, composite action, working range, visualization of the remote control, and other aspects of great progress. Although China's industrial remote control system research started late, with the development of the economy and technology, many construction machinery manufacturers and universities, research institutes cooperated in the development of intelligent crane remote control systems, but also made more and more research results.

4. Intelligent tower crane remote control system design and key technology analysis

4.1 Overall program of remote control system

The design of the remote control system of a tower crane mainly includes three major mechanisms action control systems, safety monitoring systems, and human-computer interaction interface design.

(1) The three major mechanisms action control system. The PLC controller is used to complete the intelligent control of the three mechanisms, and the frequency converter control reduces the mechanical loss and improves the working efficiency. CAN bus communication is used to realize the connection between the PLC and frequency converter. Online programming and fault diagnosis can be realized through this scheme, and it also facilitates the common role of multiple inverters in the later stage.

(2) Safety monitoring system. The safety control system adopts computer technology, automatic control technology, sensor technology, etc., to collect data and perform data processing. The role of the safety monitoring system includes monitoring the weight of the crane, the hook amplitude, the slewing mechanism, the wind speed, etc., and feeding the calculation results back to the operator; through the remote monitoring platform, it realizes the acquisition of real-time data of the crane and controls it accordingly.

(3) Human-computer interaction interface design. Many manufacturers of intelligent cranes are using industrial touch monitors as an information interaction platform to complete the two-way interaction of information between the control system and the equipment. Through the main interface and system settings, system query, and control interaction, the interaction content includes weight, amplitude, torque, rated weight, wind speed, and other safety-related parameters, as well as equipment operating speed, frequency, and other related parameters, but also includes the action logic, maintenance, maintenance, fault warning, and other expert diagnosis-related parameters.

4.2 Analysis of key technologies of the remote control system

(1)Artificial intelligence technology. The integration of fuzzy reasoning, neural network manipulation, and artificial intelligence driving technology divide the intelligent control of the crane. Specifically, it includes the integration of fuzzy manipulation and variable structure manipulation. The birth of various machine learning algorithms has driven the progress and development of modern computers, and the application of this type of technology in remote control systems is also increasing. For example, reinforcement machine learning, ant colony computing, particle swarm algorithms, genetic algorithms, etc., can be widely used in intelligent startup device systems, so that the system produces an autonomous learning intelligence similar to that of a human body or mammal, to cope with an increasingly complex, ambiguous and unstructured environment.

(2)Multi-sensor information fusion technology. The development and exploitation of high-performance sensors are essential for intelligent cranes that can respond to different conditions and work flexibly. Enhancing and improving sensor characteristics is a key part of enhancing artificial intelligence in the process. However, how to integrate with data from sensors, including sensors, becomes a very significant issue. The integration of multifunctional sensors plays an important role in the intelligent realization of cranes.

(3)Human-Machine Interaction Technology. The sophisticated requirements of intelligent human-machine interfaces are trending towards refinement, multilingualization, heightened intelligence, and humanization. A core issue in remote control systems is achieving high availability and reliability of the human-machine interface. In line with the demands for high speed, precision, digitalization, and intelligence, human-machine interaction technologies encompass sensor information fusion techniques, intelligent management and remote control, advanced functional components, novel digital drive systems, high-speed and precise data transmission mechanisms, and open-network controllers, which are fundamental components and systems of advanced standing.

(4)Intelligent Path Planning Technology. Optimal route design involves finding the best or near-best path from an initial state to a final goal within a target space, based on certain principles or minimal objectives such as minimum work cost, shortest travel path, or shortest travel time limit. This can be utilized to avoid obstacles and improve work efficiency. Path planning methods include global path planning and local holistic path planning. Given the need for improvement in route search efficiency and route selection, intelligent path planning methods must incorporate computational intelligence techniques such as genetic algorithms, particle swarm optimization, fuzzy logic, and neural networks. The development of new intelligent path planning methods aims to enhance the accuracy of obstacle avoidance and work efficiency of intelligent cranes, thereby meeting the demands of practical applications more effectively.

(5)Intelligent Structural Optimization Design Technology. Although the optimization design of the mechanical structure of intelligent cranes has become a research focus, the complexity, multi-objective functionality, multi-legal constraints, multi-parameter characteristics, and broad implications of the mechanical optimization model pose significant challenges in constructing and solving the mathematical model of optimization design problems. Therefore, there is a need to select a new type of intelligent optimization computing system that is computationally simple, efficient, and easy to implement for the optimization design of the crane's metal structure. This represents a key line of thought in the current research and development of intelligent crane structures and is a focal point for the future development of intelligent collaborative design between intelligent cranes and unmanned cranes.

5. Conclusion

The foundational technologies for intelligent tower cranes have matured, and their application scope continues to expand, especially in harsh environments such as steel, chemical, and offshore facilities, where there is significant room for promotion and application. The further development of intelligent cranes necessitates the integration of artificial intelligence technologies for detection, management, control, and structural design, establishing a computer-controlled, reconfigurable modular system. Further exploration of the system's design theory and application techniques, along with enhanced research in kinematics, dynamics, technical planning, and control, will foster the innovative development of intelligent cranes.

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