Application of Intelligent Control Technology in Mechanical Manufacturing and Automation

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Abstract: With the global manufacturing industry stepping into the era of intelligence, digitalization and automation, traditional manufacturing methods are facing many challenges. Overcoming these bottlenecks through technical means has become an important research direction of the current machinery manufacturing industry. As an advanced production technology, mechanical manufacturing automation has gradually developed into a comprehensive solution integrating mechanical technology, control technology, information technology and network technology in most production fields. In this paper, the technical framework of mechanical manufacturing automation is analyzed, and the application of intelligent control technology in mechanical manufacturing and automation is discussed. On this basis, the specific path to realize the application of intelligent control technology in mechanical manufacturing and automation is put forward, aiming at providing constructive suggestions for the intelligent development of mechanical manufacturing automation.

Keywords: Mechanical manufacturing; Intelligent control; Automation

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With the rapid development of global manufacturing industry in the direction of intelligence and digitalization, machinery manufacturing and automation technology, as the core field of modern industry, has also been widely concerned in technological innovation and industrial upgrading. Due to the problems of low production efficiency, insufficient precision and high energy consumption, traditional mechanical manufacturing technology has gradually failed to meet the needs of modern manufacturing industry for high precision, high efficiency and flexible production. Intelligent control technology takes artificial intelligence, sensing technology, big data and machine learning as the core to realize real-time perception, autonomous learning and precise control of complex systems. The application of these technologies in mechanical manufacturing and automation not only improves production efficiency, but also optimizes product quality and effectively reduces energy consumption. The application of intelligent control technology has greatly promoted the transformation of traditional manufacturing industry to intelligence and information.

1. Mechanical Manufacturing Automation Technology Framework

The technical framework of mechanical manufacturing automation involves many technical fields and system components, and its core goal is to achieve high efficiency, precision and intelligence in the production process. The framework mainly includes key parts such as automatic production equipment, control system, intelligent algorithm

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and data integration and management. Automated production equipment is the basis of mechanical manufacturing automation, which usually includes CNC machine tools, industrial robots, automated assembly lines and so on. These equipments can accomplish heavy or dangerous tasks without human intervention, such as parts processing, assembly and inspection. For example, CNC machine tools automatically complete cutting, drilling and other processes through preset programs and control systems to ensure high precision and consistency of production. This system usually includes PLC (programmable logic controller), SCADA (monitoring and data acquisition system) and DCS (distributed control system). These systems are responsible for real-time monitoring the operation status of various equipment in the production process, collecting data through sensors and making feedback adjustment according to preset control strategies, thus ensuring the smooth operation of the whole production process. In the automatic production process, the control system works closely with sensors and actuators to ensure the accuracy and reliability of the production process.

2. Application of Intelligent Control Technology in Mechanical Manufacturing Automation

(1) Adaptive control of mechanical production

Adaptive control technology is an important branch of intelligent control technology, which is mainly used to dynamically adjust the system parameters according to the changes of environment and tasks in the production process of mechanical manufacturing to ensure the efficiency and accuracy of the production process. The traditional mechanical manufacturing control system relies on preset parameters, which is inefficient and unable to respond in real time in the face of complex and changeable production conditions, while adaptive control realizes intelligent adjustment of processing parameters by combining real-time sensor data and feedback mechanism.

In CNC machining, adaptive control can monitor cutting force, vibration, temperature and other data in real time. If it is detected that the tool wear increases or the vibration exceeds the standard during machining, the control system will automatically reduce the cutting speed or optimize the feed rate, so as to avoid the surface roughness of the workpiece exceeding the standard or accidental damage of the tool. Adaptive control can also intelligently switch the process parameters according to different material characteristics. When machining parts with different hardness, the system will dynamically adjust the tool path and cutting mode to improve the machining efficiency.

(2) Intelligent robots and automated production lines

The combination of intelligent robot and automatic production line is an important application in mechanical manufacturing automation. Robots can not only execute pre-programmed instructions, but also make independent decisions through machine vision and artificial intelligence technology to complete complex production tasks. Compared with traditional automatic production equipment with fixed programs, intelligent robots have higher flexibility and adaptability. In the field of automobile manufacturing, the intelligent welding robot can accurately locate the welding point by carrying a visual recognition system, and at the same time, adjust the welding parameters by combining with an adaptive algorithm, so as to realize high-quality and consistent welding operation. On the intelligent assembly line, the robot can cooperate with other equipment through the Internet of Things.

(3) Fault prediction and preventive maintenance of equipment

In the automation of mechanical manufacturing, equipment failure often leads to the shutdown and loss of production line. The introduction of intelligent control technology makes fault prediction and preventive maintenance possible. Based on sensor technology and data analysis, the system can monitor and predict the running state of equipment in real time, and make a reasonable maintenance plan based on the prediction results.

On the one hand, the key operating parameters of equipment, such as vibration, temperature, current and speed, can be collected and transmitted to the central control system through the Internet of Things sensors. By analyzing

the changing trend of these parameters, intelligent algorithms (such as time series analysis, machine learning and deep learning) can identify the abnormal behavior of equipment in advance. For example, when an abnormal temperature rising trend of a bearing is detected, the system will predict the possible fault types and their severity, and send maintenance tips to arrange replacement. On the other hand, compared with the traditional regular maintenance mode, preventive maintenance can not only greatly reduce the unplanned downtime of equipment, but also prolong the service life of equipment and reduce the maintenance cost. Combined with digital twin technology, manufacturers can simulate the operation of equipment based on virtual model to further optimize the maintenance strategy. Through digital simulation, the effectiveness of different maintenance schemes can be evaluated and the optimal scheme can be selected.

3. The Realization Path of Intelligent Control Technology in Mechanical Manufacturing Automation

(1) Construction of sensor topology network system

In mechanical manufacturing automation, the sensor topology network system is the basis of intelligent control. It constructs a distributed network by organically integrating various sensors to realize real-time perception and monitoring of production equipment and environment. The system needs to arrange nodes reasonably according to the manufacturing scene, including temperature, pressure, vibration and visual sensors, to form a multi-dimensional perception network. This distributed deployment can cover the complex production environment and improve the sensing accuracy. The sensor network realizes efficient data transmission through industrial Ethernet, wireless network or 5G technology, ensuring real-time data to flow to the central controller or edge computing nodes. Through the construction of efficient sensor topology network, the data acquisition and analysis ability in the mechanical manufacturing process is significantly enhanced, which provides a reliable basic support for the landing of intelligent control technology.

2) Intelligent algorithm integration and optimization of control model

The introduction of intelligent algorithm is an important way to realize the automation of mechanical manufacturing, and its core lies in integrating advanced algorithms and optimizing control models to cope with the dynamic changes of complex production environment. Specifically, intelligent methods such as fuzzy control, neural network and genetic algorithm are adopted to make the control system have adaptive and learning ability. Different algorithms realize efficient division of labor according to production requirements, such as fuzzy control for dynamic parameter adjustment and neural network for process optimization. It is also possible to build a mathematical model of production equipment through dynamic modeling technology, and modify model parameters by combining real-time data, which greatly improves control accuracy and system stability. Intelligent algorithm can analyze based on real-time data and historical data, dynamically adjust production parameters, and realize the transformation from passive control to active optimization.

(3) Multi-domain penetration of edge cloud collaborative architecture

Edge cloud collaborative architecture is an important way to realize intelligent control technology in mechanical manufacturing. By combining edge computing with cloud computing, resources are fully utilized to enhance the intelligence and flexibility of the system. On the one hand, edge computing nodes can be introduced into the equipment terminal to realize local data processing, reduce communication delay and improve real-time response ability, and rapid analysis and fault warning of vibration signals can be completed at edge nodes. On the other hand, the cloud computing platform is responsible for the storage and analysis of global data, such as product quality traceability, big data modeling and forecasting, etc., providing in-depth insight and optimization suggestions for the manufacturing process. In addition, the edge and the cloud cooperate closely through the high-speed

communication network to form a layered processing architecture, in which the edge nodes are responsible for rapid decision-making and the cloud performs complex operations to ensure the overall efficiency and security of the system. The architecture also supports deep integration with the Internet of Things and industrial Internet, providing technical support for cross-domain applications (such as predictive maintenance and energy consumption optimization) in intelligent manufacturing, and promoting the overall intelligence of manufacturing.

4. Conclusion

The realization of intelligent control technology in mechanical manufacturing automation is the core driving force for the transformation and upgrading of modern manufacturing industry. Through the establishment of sensor topology network system, accurate perception and multi-dimensional data acquisition of complex manufacturing environment are realized, which provides basic support for intelligent control. By integrating intelligent algorithm and optimal control model, an efficient control path from dynamic adjustment to active optimization is realized. The multi-domain penetration of edge cloud collaborative architecture fully combines the real-time processing ability of edge computing with the global analysis ability of cloud computing, which provides a guarantee for precise control of manufacturing process and resource optimization. In addition, based on adaptive control, intelligent robots and automated production lines, as well as specific application scenarios such as fault prediction and preventive maintenance of equipment, intelligent control technology shows great potential in improving production efficiency, enhancing equipment stability and optimizing quality control. In the future, by combining innovative paths such as modular design and digital twinning, and deepening the penetration of technology into the industrial Internet of Things and big data fields, the level of intelligence and flexibility of machinery manufacturing will continue to improve, providing powerful kinetic energy for the industry to achieve high-quality and high-efficiency development.

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