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Application Path Exploration of Intelligent Manufacturing Technology in the Machining Field

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Abstract: Intelligent manufacturing technology, as the core driving force of the fourth industrial revolution, is profoundly changing the production mode and industrial pattern in the field of mechanical processing. This paper starts from the application background of intelligent manufacturing technology in the field of machining, combined with the limitations of traditional machinery manufacturing technology, systematically analyzes the application status of intelligent manufacturing technology in CNC production, equipment fault diagnosis, sensing technology and industrial robots, and provides theoretical support and practical guidance for the transformation and upgrading of machining industry. The exploration of the application path of intelligent manufacturing technology in the field of machining not only helps to enhance the core competitiveness of the industry but also provides important support for the realization of high-quality development and sustainable development goals of the manufacturing industry.

Keywords: Intelligent manufacturing technology; Machining; Application path

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1. Application background of intelligent manufacturing technology in the field of machining

The implementation of intelligent manufacturing technology depends on the integration of several key technologies, such as Internet of Things (IoT), big data analytics, artificial intelligence (AI), robotics, and advanced sensor systems. By combining these technologies, the production process becomes more adaptable, precise, and productive. In the machining sector, the adoption of intelligent manufacturing not only substitutes conventional manual production techniques but also successfully mitigates issues related to human error, equipment wear, or changing environmental factors. This leads to a substantial enhancement in both manufacturing capabilities and operational efficiency [1].

2. Shortcomings of traditional machinery manufacturing technology

2.1. Low industrial production

In the industrial production process, traditional machinery manufacturing technology heavily relies on manual operations, which makes it challenging to achieve the high efficiency and quality standards required by modern industries [2]. Regarding production efficiency, traditional methods are constrained by the physical and cognitive limitations of human operators, leading to slower speeds and reduced accuracy. This hinders the ability to maintain efficient and consistent industrial output. Particularly when dealing with complex components, the error rate associated with manual operations tends to be higher, often causing processing deviations that further decrease productivity. In terms of product quality, traditional machinery manufacturing is highly dependent on the skills and experience of individual operators. This reliance can result in inconsistent product quality due to variations in operator expertise. In large-scale production settings, the inconsistency of manual operations may lead to subpar uniformity in products, making it difficult to satisfy the demand for high-quality, precise goods in modern industries. Additionally, the controllability of the production process is limited by the low level of intelligence inherent in traditional machinery manufacturing technologies. Each stage of production typically requires manual oversight, complicating efforts to implement full automation and intelligent management across the entire production process [3].

2.2. Long product production cycle

Traditional machinery manufacturing relies heavily on manual processes, with an overall workflow that lacks modern sophistication and efficiency. This results in extended production cycles for mechanical products [4]. During the design phase, conventional machinery manufacturing typically depends on two-dimensional drawings and empirical methods, lacking the integration of digital design tools. Consequently, the design process is lengthy and prone to errors. Once the design is finalized, multiple trial productions and adjustments are required to meet product performance standards, which is both time-consuming and labor-intensive, further elongating the production timeline. In terms of processing, traditional machinery manufacturing depends on manual operations and experiential techniques, with low levels of equipment automation, thus limiting processing efficiency. Particularly when dealing with complex components, numerous installations, adjustments, and measurements are necessary, increasing production time and raising the likelihood of human-induced errors. For quality control, traditional machinery manufacturing utilizes manual inspection methods, leading to low detection efficiency and susceptibility to human error [5]. The testing procedure involves a thorough examination of the product, encompassing dimensions, shapes, surface quality, and various other aspects, which is time-intensive. If issues are identified during inspection, rework, modifications, and retesting are required, further extending the production cycle.

2.3. Production efficiency needs to be improved

First of all, the traditional machinery manufacturing technology relies on a large number of manual operations in the production process, and the production efficiency is relatively low. Due to the lack of an intelligent production system, the real-time monitoring ability of equipment operating status and production schedule is weak, leading to the possibility of idle equipment or overload operation in the production process, further reducing production efficiency [6]. Secondly, due to the lack of advanced quality detection and control means, the processing accuracy and consistency of some products are difficult to meet industry standards. Especially in the processing of complex parts, the traditional technology is prone to dimensional deviation or surface quality not up to standard, and other problems, resulting in a low product pass rate. Finally, with the intensification of market competition, customers' demand for products is increasingly diversified and personalized, while traditional technology finds it difficult to quickly respond to changes in market demand. Problems such as long production cycles and slow product update speed put enterprises in a passive position when facing market changes, and it is difficult to achieve rapid product iteration and market expansion [7].

3. Application of intelligent manufacturing technology in the field of machining

3.1. Application of numerical control production

Overall, the implementation of intelligent control technology enhances the precision of CNC machine tool operations. By fine-tuning and optimizing machining parameters, this technology can continuously track various data during the machining process, such as tool condition, accuracy levels, and machine vibrations, thereby achieving real-time dynamic optimization of the machining procedure [8]. At the same time, online diagnosis technology provides strong support for the fault prevention and maintenance of CNC machine tools. By equipping machine tools with a variety of sensors, real-time collection of operational data can be achieved. This data can then be analyzed using specific algorithms to identify potential issues promptly. For instance, if a part of the machine tool experiences unusual vibrations or an increase in temperature, online diagnostic systems can immediately issue a warning signal, prompting the operator to perform inspections and maintenance as needed. Additionally, the integration of 3D simulation technology represents another significant advancement of intelligent manufacturing within CNC production processes. Through 3D simulation, the machining process of CNC machine tools can be simulated in a virtual environment to verify the feasibility of the processing program and optimize the processing parameters. This can not only reduce the cost of trial and error in the actual processing, but also improve the accuracy and reliability of the processing scheme [9]. In addition, 3D simulation can also be used to train operators to help them better understand and master the operation skills of CNC machine tools [9].

3.2. Application in equipment fault diagnosis

During the extended operation of mechanical equipment, failures are likely to occur as a result of component wear, environmental influences, or incorrect operations. Conventional methods for diagnosing equipment faults depend on manual checks, which often encounter issues such as inefficient detection and delayed troubleshooting. These shortcomings can lead to prolonged equipment downtime, reduced production efficiency, and even financial losses. By incorporating intelligent manufacturing technology, real-time equipment operational data can be gathered via smart monitoring and diagnostic systems. These systems enable the analysis of equipment conditions and the identification of potential faults at an early stage, thereby facilitating precise maintenance and repairs [10]. With the support of intelligent manufacturing technology, the equipment fault diagnosis system can monitor the key parameters such as vibration, temperature, pressure, and current of the equipment in real time through sensors, Internet of Things technology, and other means. Following the collection of data, it will be sent to either a cloud or edge computing platform for further examination. By leveraging machine learning techniques and big data analytics, the system can detect irregularities in equipment performance and assess whether the machinery is functioning properly or if there is a likelihood of impending issues. For instance, during the operation of CNC machine tools, the system can identify preliminary indicators of tool deterioration or spindle bearing faults through the analysis of spindle vibration information. This enables proactive scheduling of maintenance activities, thereby preventing operational interruptions that could arise from unexpected breakdowns [11]. Secondly, intelligent manufacturing technology is also able to achieve accurate positioning of equipment failures. By utilizing the fault diagnosis system, companies can swiftly pinpoint the location and cause of faults, thereby decreasing the time and effort required for manual inspections. For instance, in a production line, if a particular piece of equipment experiences an unexpected shutdown, the system can promptly ascertain whether the issue stems from a mechanical malfunction, electrical failure, or software problem by examining both historical and real-time data. It can then offer relevant maintenance recommendations. Another significant benefit of intelligent manufacturing technology is the implementation of predictive maintenance. Over time, as the equipment fault diagnosis system operates, it accumulates extensive operational data and establishes a predictive model for assessing equipment health. Leveraging historical operational data and the current condition of the equipment, the system can forecast potential failures within a specific future timeframe and create preemptive maintenance schedules. This approach minimizes equipment downtime and enhances production efficiency. In actual applications, the equipment fault diagnosis system of intelligent manufacturing technology can also be integrated with the production management system. Through shared data and interconnected information, the system provides real-time updates on equipment health to the production management system, optimizing production planning and resource allocation accordingly [12].

3.3. Application in sensing technology

By integrating sensors, companies can attain continuous oversight and management of multiple parameters during the manufacturing process. This enhances productivity, refines product quality, and cuts down on expenses. In machining operations, sensors must encompass critical points across the production area, such as machine tool performance, tool deterioration, workpiece precision, and environmental conditions. With sensor placement, information is gathered instantaneously and relayed to the central control unit. This system evaluates and processes the collected data to facilitate adaptive modifications and improvements in the production workflow [13]. In the field of machining, a fiber optic cable sensor is a type of sensor that is widely used at present. Optical fiber sensors are known for their high accuracy, sensitivity, and strong resistance to interference, making them well-suited for complex industrial settings. For instance, during machine tool operations, these sensors can continuously track tool wear. Once the tool approaches the end of its service life, the system will generate an automatic alert for replacement, thereby preventing any potential decline in processing quality due to tool deterioration [14]. In addition, the optical fiber sensor can also be used for the detection of the surface quality of the workpiece by analyzing the intensity change of the reflected light, to determine whether there is a scratch or depression on the surface of the workpiece. To enhance the application of sensor technology further, implementing standardized interfaces serves as a critical method to decrease the complexity involved in mechanical processing design. By utilizing these standardized interfaces, sensors can be effortlessly integrated with CNC systems, industrial robots, and other manufacturing equipment, thereby streamlining the system integration process. This type of standardized design not only boosts system compatibility but also cuts down on equipment maintenance expenses. In real-world applications, incorporating sensor technology can markedly elevate the intelligence of machining processes. For instance, during production, sensors are capable of continuously monitoring the vibration parameters of machine tools. If the vibration surpasses the predetermined threshold, the system will automatically modify the processing parameters or halt operations to prevent equipment damage or defective workpieces.

3.4. Applications in industrial robots

Considering the current situation, the implementation of industrial robots in China's industrial production and manufacturing processes has yielded significant outcomes, particularly within the machining sector, where they have demonstrated substantial influence. Primarily, industrial robots are capable of executing high-precision and highly efficient processing tasks, showing exceptional performance when dealing with complex components. Moreover, these robots can adjust to various processing environments, such as those characterized by high temperatures, high pressures, or high levels of dust—conditions that typically challenge human operators—thereby diminishing reliance on manual labor. Additionally, industrial robots can integrate with other intelligent manufacturing technologies to establish a smart production system, which further enhances both productivity and product quality. Despite these achievements in the machining domain, limitations still exist regarding their specific application scope. The capabilities of industrial robots in handling intricate parts and coordinating multi-process operations require further enhancement. Consequently, relevant authorities and enterprises must prioritize the research, development, and practical application of industrial robot technology, allocate appropriate financial resources, and intensify efforts in researching and transforming key components of industrial robots [15]. In terms of technology research and development, enterprises should pay attention to overcoming the technical difficulties of the core components of industrial robots, such as controllers, servo motors, retarders, etc., improve the localization rate, and reduce the dependence on imported parts. At the same time, enterprises should strengthen the integration of industrial robots and a new generation of information technology, such as artificial intelligence, Internet of Things, big data, etc., to further enhance the intelligence level of industrial robots. In terms of application promotion, enterprises should actively promote the application of industrial robots in more mechanical processing fields, especially in small and medium-sized enterprises. Small and medium-sized enterprises play a crucial role in China's mechanical processing sector. However, constrained by factors such as capital and technology, the adoption level of industrial robots in these enterprises remains relatively low. To address this, relevant departments and businesses can facilitate the application of industrial robots in SMEs by offering technical assistance, training programs, and favorable policies, thereby assisting them in their transformation and upgrading efforts.

4. Conclusion

In conclusion, the exploration of the application path of intelligent manufacturing technology in the field of machining is not only an inevitable trend of technological development, but also an important measure to promote the transformation of manufacturing industry to high-end, intelligent and green, and the exploration of the application path in the field of machining provides an important direction for the traditional manufacturing industry to intelligent and digital transformation. Through the introduction of advanced intelligent manufacturing technology, the production efficiency, product quality and intelligent level in the field of mechanical processing have been significantly improved, and the field of mechanical processing will usher in a better development prospect under the promotion of intelligent manufacturing, and inject new impetus into the sustainable development of manufacturing industry.

Disclosure statement

The authors declare no conflict of interest.

References

[1] Ge X, Guo Y, Qin T, et al., 2020, Forging Process of Middle Flange of Drive Shaft Without Flash. Hot Working Technology, 49(5): 108–110.

[2] Wang G, 2018, Analysis on the Development Trend and Practice of Automation Machinery Technology. Regional Governance, (7): 179.

[3] Zhang H, 2017, Development of Mechanical Engineering and Automation Technology. Equipment Management and Maintenance, (17): 119–120.

[4] Yang L, 2018, Research on the Relationship between Intelligent Manufacturing, Industry 4.0 and Digital Manufacturing. Information and Computer, 30(9): 133–134.

[5] Luo H, 2018, Feasibility Study on Intelligent Manufacturing Technology and System in Machining Field. Modern Industrial Economy and Information Technology, 8(14): 59–60.

[6] Liang Y, 2018, Research on the Development of Mechanical Engineering Automation Technology. Modern Economic Information, (9): 387.

[7] Gao C, 2019, Safety Management and Maintenance of Mechanical Manufacturing and Processing Equipment. Southern Agricultural Machinery, 50(1): 212.

[8] Jiang X, 2019, Feasibility Study on Intelligent Manufacturing Technology and System in the Machining Field. Southern Agricultural Machinery, 50(3): 109.

[9] Shi D, Bi S, 2019, Provincial Practice and Theoretical Construction of Professional Literacy Training for Technical Talents from the Perspective of Type Education: A Case Study of Hunan Province. China Vocational and Technical Education, 37(16): 37–42.

[10] Gong D, Chen S, Wang W, et al., 2019, On the Development of Intelligent Manufacturing and the Practice of Intelligent Factory. Machine Building, 57(2): 1–4.

[11] Huang H, 2019, Construction of the New Generation Training Mode of "Furong Craftsmen" in Hunan Higher Vocational Colleges. Science and Education Guide, (28): 3–4.

[12] Zheng Z, 2020, Application of Mechanical Manufacturing Technology in Chemical Equipment. Paper Making Equipment and Materials, 49(3): 17.

[13] Liu S, Chen Z, Shi K, et al., 2020, Analysis of Development Thinking of Intelligent Manufacturing for Special Equipment based on Intelligent Network Connection. Engineering Science, 22(6): 143–150.

[14] Li J, Li Q, 2023, Research on Training Mode of "Furong Craftsmen" in Higher Vocational Machinery Manufacturing. Journal of Hunan Polytechnic of Industry, 23(5): 75–78.

[15] Jia X, 2024, Discussion on the Relationship between Intellectual Physicochemistry and Artificial Intelligence Ethics in Intelligent Manufacturing. Academic Research of Xi'an Institute of Transportation Engineering, 9(1): 66–70.