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Exploration of Process Improvement in Automotive Manufacturing Based on Intelligent Production

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Abstract: With the rapid development of intelligent manufacturing technology, automation has become the main means of improving efficiency, reducing costs, and ensuring product quality in automotive production. This paper discusses the application of automobile intelligent production technology, mainly investigating the current widespread robot applications, the role of robots in automated production assembly lines, the application of the Internet and big data in the production process and other issues. Through robot automation production technology, high precision and efficiency can be achieved, which is reflected in the processes of body welding and production part installation in automobile production. The combination of the Internet and big data makes the monitoring of the production process more intelligent and real-time, increasing the sensitivity of the production line and equipment utilization. This paper explores the obstacles encountered in the implementation of intelligent production technology, such as technology integration, data confidentiality and personal privacy protection, and shortage of technical personnel, and proposes relevant improvement measures, which can be used as a reference for automobile manufacturing enterprises in the process of implementing intelligent production technology transformation.

Keywords: intelligent production; automobile manufacturing; process improvement

1. Introduction

With the development of global industrialization, automated production is an effective way to improve production efficiency, reduce costs, and enhance product quality. It is a key means of integrating emerging technologies such as automation, the Internet of Things, big data analysis, and artificial intelligence to monitor production operations in real time, adjust and maintain machines. It is conducive to promoting the transformation of traditional industries towards digital and intelligent models. Especially in the automotive production process, the use of intelligent manufacturing technology is a fundamental guarantee for further improving the accuracy and flexibility of the production process, and enhancing the adaptability of the production system to diverse product demands. The implementation of intelligent production is not easy, such as integration issues, network security issues, and a lack of advanced skilled personnel, which are the main problems encountered in the process of enterprise transformation. Therefore, in order to effectively overcome these obstacles, enterprises need a complete set of technical, managerial, and human resource strategies, such as building a unified intelligent manufacturing platform, enhancing data security defense capabilities, and increasing training for senior technical personnel. This study will deeply analyze the application status and obstacles encountered by intelligent manufacturing achievements in automobile production, provide effective solutions, and look forward to its future development direction.

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2. Overview of Automotive Manufacturing Process Theory Based on Intelligent Production

The automotive industry, with intelligent manufacturing as its core, applies advanced information technology, automation technology, and big data processing technology to achieve higher production efficiency, greater variability, and higher precision in precise control of production. With new technologies such as robots, the Internet and big data analysis, intelligent manufacturing can improve productivity, ensure product quality and save resources. The core of this concept is to use real-time monitoring and information feedback to achieve intelligent management of the production process, respond to market changes in a timely manner, reduce human subjective influence and fault tolerance, and improve the agility of the production line [1].

Intelligent manufacturing is implemented from the initial stages of design, product manufacturing, and product quality to every stage of the terminal. Technologies such as unmanned production lines and intelligent robot welding have greatly improved production efficiency and accuracy; IoT technology can remotely monitor and predict faults in production machines; Big data analysis can optimize the production planning and quality control of enterprises, thereby reducing their loss and scrap rates. By applying these intelligent technologies, vehicle production not only improves production efficiency, but also promotes the development of personalized and customized production modes, thereby driving the manufacturing industry to achieve efficient, green, and sustainable development.

3. Application of Intelligent Production in Automobile Manufacturing

3.1. Automated Assembly and Robot Applications

In the automotive industry, the application of automated assembly and industrial robots has widely penetrated into various stages of the vehicle production process, especially in high-precision and high-load tasks such as body welding, component installation, painting, and handling. With the increase of factory automation rate, in addition to improving production efficiency, it can also ensure stable and reliable product quality. In the welding process of the entire vehicle, the robot can strictly follow the welding task to reduce human variability and ensure the high precision and quality of the welding points; In the component installation process, robots can also undertake the installation of complex components and are compatible with different models of vehicles, improving production efficiency; A large number of robots are also used in car body painting and material handling processes to avoid dangerous working environments for humans and improve work safety through automated operations [2].

The Table 1 below shows the main areas and advantages of automated assembly and robot applications:

Table 1. Application Fields and Advantages of Automation Assembly and Robotics.

Application area	Major function	Advantage
Body welding	Precision welding of various components of the vehicle body	Improve welding accuracy and ensure product consistency
Component assembly	Automated assembly of components	Improve assembly efficiency and reduce manual errors
spray	Automated spraying of vehicle bodies and components	Improve coating uniformity and reduce artificial pollution
Handling and Material Handling	Automated handling and delivery of parts and materials	Reduce labor intensity for workers and improve production efficiency

High risk assignments	Replace manual labor to complete high-temperature and high pollution environmental operations	Improve work safety and protect workers' health

Through the extensive application of robot technology, various stages of automobile production can be automated, improving the efficiency and flexibility of the production line, thereby changing the working environment and safety of workers.

3.2. Application of Internet of Things and Big Data in Production Process

The Internet of Things (IoT) and big data technology play a decisive role in intelligent production. It greatly enhances productivity and product quality through continuous monitoring, data management, and intelligent decision-making. Using the Internet of Things for production, sensors and network devices can be installed on each stage of the production line to continuously collect important information such as temperature, humidity, machine status, etc. Then forward it to the big data platform in the operation center for analysis and interpretation. Through detailed research and analysis of large-scale production, companies can predict machine failures, improve production, and enhance asset efficiency [3].

The following is a framework diagram of the application of the Internet of Things and big data in the production process (Figure 1).

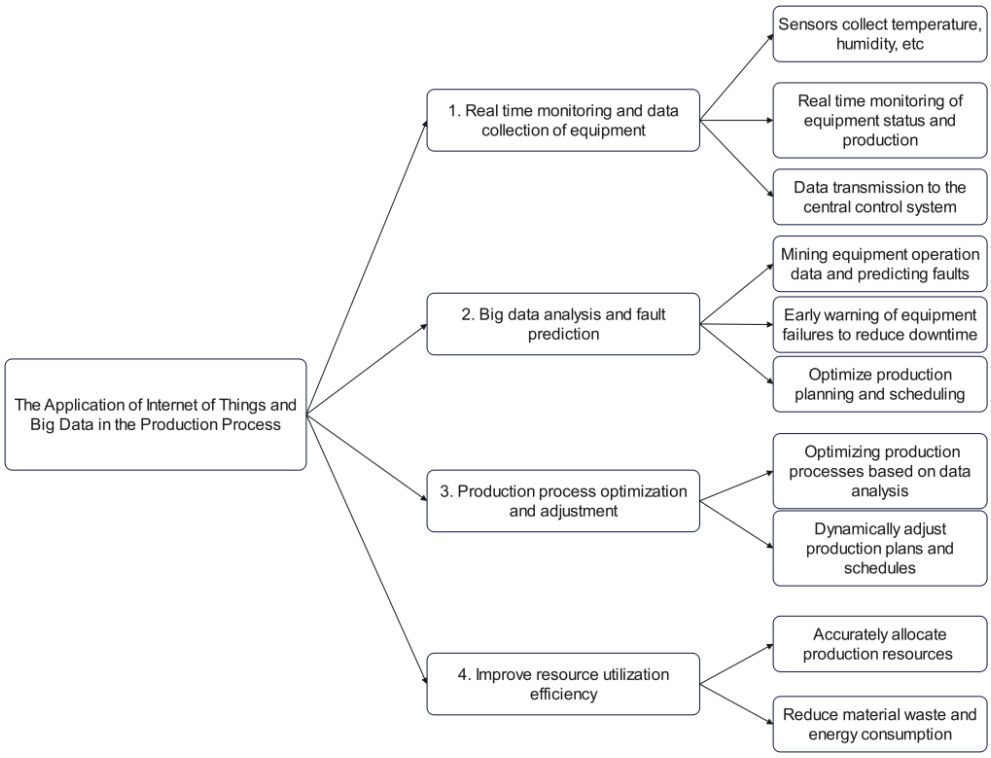

Figure 1. Application Framework of IoT and Big Data in Production Process.

4. Problems in Intelligent Production Based Automotive Manufacturing Process

4.1. Difficulties in Integrating Intelligent Production Systems and Poor Equipment Compatibility

The difficulty in building integrated platforms and interconnecting devices is considered by enterprises as one of the major obstacles they face in achieving intelligent manufacturing processes. Intelligent manufacturing is based on various technological means such as automated robots, automatic control, the Internet of Things, and big data analysis,

and most of these technological means are provided by different suppliers, adopting different technical architectures, interface protocols, etc. Due to the lack of unified technical standards, interfaces, etc., information exchange and coordination between various devices are difficult, resulting in information silos in the production process, which in turn reduces production flexibility and efficiency [4].

In short, the connection between traditional machines and intelligent manufacturing technology lacks compatibility, and the benefits that can be brought by integration are not high, and the assembly cost is not low. In addition, the integration of current software such as Enterprise Resource Planning (ERP) and Manufacturing Execution System (MES) with intelligent manufacturing technology still faces technical barriers, further affecting the improvement of integration level.

The following is Table 2 showing the integration challenges and poor device compatibility of intelligent production systems:

Table 2. Analysis of Integration Challenges and Equipment Compatibility Challenges in Intelligent Production Systems.

Problem areas	Describe	Effect
Poor compatibility between devices	The interface and communication protocol between traditional devices and smart devices are different	Difficult to achieve seamless connection between devices, resulting in poor information flow and reduced production efficiency
The difficulty of system integration	There are technical barriers to integrating ERP, MES and other systems with newly introduced intelligent devices	The serious problem of information silos affects the real-time and accuracy of production management
Differences in Technical Support and Services	The equipment and system technical standards provided by different suppliers are different, and there is a lack of unified support	Poor system stability, long troubleshooting and technical support cycles

4.2. Data Security Issues and Privacy Risks in Intelligent Production

In intelligent manufacturing, a large amount of data needs to be continuously collected, transmitted, and analyzed, including equipment operation, production statistics, quality inspection data, employee data, supply chain data, and other information in the production process. Mining big data is the key to improving production efficiency, but it also faces threats to data security and privacy information security. The use of IoT technology, big data, cloud computing and other technological means to collect and process data more efficiently also increases the risk of data leakage, abuse or attack. Due to the fact that data exchange between devices and systems in intelligent manufacturing takes place over the network, malicious attackers can use network intrusion to steal confidential data, such as important production process parameters, production equipment status data, etc. Without password protection, data leakage may occur, leading to reduced competitiveness of the enterprise. Personal privacy information may also be compromised, especially sensitive information of employees and customers.

4.3. Shortage of Technical Talents and High Training Costs

The rapid development of Internet-based intelligent production technology has created an increasing demand for highly skilled talents in the automobile industry. However, the supply of high-end talents in the market is insufficient and they are mainly concentrated in fields such as robot automation, artificial intelligence, big data, etc., which has led to many problems: the automobile industry cannot recruit suitable talents to achieve the transformation of intelligent production mode, and the cost of existing employees to

improve their skills for further study is also very high. Because intelligent production integrates knowledge from multiple disciplines and has high complexity in various aspects, employees have to learn a lot of professional skills from courses, which increases learning time and causes certain additional costs. Therefore, automobile companies choose to outsource manpower or establish intelligent production training departments internally, resulting in cost investment and time waste for the enterprise.

The following is Table 3 showing the analysis of the shortage of technical talents and the challenges of training costs:

Table 3. Analysis of Shortage of Technical Talents and Challenges in Training Costs.

Problem areas	describe	effect
Shortage of technical talents	Insufficient supply of high-end technical talents, especially in fields such as robotics and big data analysis	Enterprises are facing recruitment difficulties, resulting in limited production efficiency and slow project progress
Cross disciplinary technical requirements	Intelligent production technology involves multiple fields, such as robotics, artificial intelligence, and the Internet of Things	Existing employees find it difficult to quickly adapt to new technologies, and the training cycle for skill transformation is relatively long
Training costs are too high	Providing relevant training for existing employees requires paying high fees	Enterprises need to invest a large number of resources in training, and there may be additional costs due to employee turnover during the training process
Talent loss issue	The loss of high-end technical talents and the problem of job hopping after employee training	Trained employees may leave the company, resulting in a lack of return on the company's training investment

5. Strategy for Improving Automotive Manufacturing Processes Based on Intelligent Production

5.1. Building a Unified Intelligent Production Platform and Standardizing the System

To improve the efficiency of intelligent production and reduce the difficulty of technological integration, it is necessary to build a unified intelligent manufacturing platform and promote system standardization. Intelligent manufacturing covers many technological fields, such as robotics technology, Internet of Things technology, big data analysis technology, automatic control technology, etc., and is composed of equipment and systems with different technical standards and specifications provided by different manufacturers. Therefore, it is necessary to create a single platform that integrates various systems and devices, eliminates information barriers, and opens up data channels. A unified platform should have openness and compatibility, allowing various devices and systems to operate seamlessly without boundaries, cooperating with enterprises to achieve intelligent control over the entire process, including self-owned equipment and quality monitoring. At the same time, system standardization should be promoted, that is, establishing the same data model, access methods, and communication standards, realizing the unified access of various component technology equipment, and reducing the cost of equipment and system replacement and upgrade.

For example, considering a universal formula for an intelligent production system, it can be expressed as:

$$S = \sum_{i=1}^{n} Ci \cdot Ti \quad (1)$$

Among them, S is the total benefit of the production system, C_i is the cost of the i-th device, T_i is the production efficiency of the $i-$th device, and n is the number of devices. Through standardization, the cost and efficiency of each device can be optimized, thereby improving the overall efficiency of the system.

For enterprises, building a unified intelligent production system and implementing standardization is an effective way to integrate intelligent devices, which can enhance the flexibility and scalability of the production system, and promote the efficient and accurate direction of intelligent production.

5.2. Enhance Data Security Protection and Establish a Multi-Level Security Protection System

In the process of intelligent production and manufacturing, information security is of paramount importance. With a large amount of production data being analyzed and processed by the Internet of Things and big data, ensuring data security and preventing theft or leakage is the primary issue that enterprises need to address. Therefore, enterprises should attach great importance to data security protection, implement encryption measures for data flow, protect the security of data flow, deploy firewalls and network intrusion detection devices (IPS) to prevent external attacks, implement multi-factor authentication, and prohibit unauthorized users from accessing critical data. In addition, enterprises need to establish a multidimensional information security protection system, including physical domain, network domain, software domain, data domain, and other security areas that must have certain security policies, such as setting up dedicated security zones to protect data storage through isolation, protecting data access through access control and access codes, and ensuring that stored information is not stolen or lost. Through regular security checks and vulnerability scanning, potential security vulnerabilities can be quickly and timely discovered, reducing security risks and ensuring the long-term security of intelligent production and security data.

For example, considering an overall protection formula for data security, it can be expressed as:

$$D = Sf \cdot Sn \cdot Sa \cdot Sd \tag{2}$$

Among them, D is the overall data security protection index, S_f is the physical security level, S_n is the network security level, S_a is the application security level, and S_d is the data encryption and storage security level. By enhancing the protection capabilities of each security level, the overall security of data can be effectively improved.

Comprehensively considering the confidentiality, integrity and availability of data, through multi-level security protection means such as data security encryption technology, data hierarchical protection technology, security firewall, multi-level identity authentication and encrypted communication, data security in the production process under the background of industrial Internet can be protected to prevent production data leakage, tampering, loss, and ensure the operation of production systems and the company's commercial security.

5.3. Strengthen Talent Cultivation and Cross Disciplinary Cooperation

With the advancement of intelligent manufacturing, the iteration of technology has made traditional education systems and training mechanisms unable to meet the demand of enterprises for advanced skilled talents. Therefore, cultivating and improving labor force and cross-border cooperation have become the long-term strategies of the company, utilizing cooperation between universities, research institutes, and technology suppliers to achieve rapid training of skilled personnel and accelerate scientific and technological achievements and industrial development.

For example, a well-known enterprise has jointly established a research center called "Intelligent Manufacturing Innovation Laboratory" with local universities, with the aim of researching key core technologies for intelligent production, such as robots, the Internet of Things, and big data analysis. After the project was implemented, college students not

only received rich practical training, but also had the opportunity to directly participate in actual production and help solve problems. It not only provides a practical platform for college students, but also addresses the skills required by frontline enterprises, providing them with qualified technical personnel.

Finally, the company collaborates with technology service companies and invites external technical personnel to provide technical guidance and education, assisting its existing employees in mastering the latest technologies and skills in modern production. Through this cross disciplinary cooperation, the company quickly enhances its technological strength, compensates for its own manpower shortage, and accelerates the use and promotion of modern production technology. This different form of collaboration has brought continuous guidance to the company, while also encouraging universities to cultivate a large number of high-quality talents suitable for market needs, promoting the development of the entire industry.

6. Conclusion

The application of intelligent manufacturing technology is vigorously promoting the transformation of traditional automobiles, effectively improving automobile production, quality, and resource utilization efficiency. However, it also faces problems such as system integration, equipment interoperability, information security, and labor costs. In the face of these challenges, companies should strengthen information protection, promote system standardization, build a unified intelligent manufacturing system, expand investment in talent training and cross domain cooperation.

Through continuous innovation and integration of technology, enterprises can solve problems that arise in automated production, increase their production flexibility, and improve their production efficiency. Future automation will further make the automotive industry smarter, more precise, efficient, and competitive, which will be beneficial for enterprises to gain greater advantages in the international market. Automated production will also become the main driving force for improving industrial competitiveness and promoting long-term development.

References

1. S. Nimbulkar, N. Sawarkar, S. Choudhary, and B. Chede, "Process optimization (improvement) using lean six sigma in production process for PEB & heavy steel structure manufacturing & fabrication industry," in *AIP Conf. Proc.*, vol. 2753, no. 1, Apr. 2023, doi: 10.1063/5.0129077.
2. I. Daniyan, A. Adeodu, K. Mpofu, R. Maladzhi, and G. M. Kanakana-Katumba, "Improvement of production process variations of bolster spring of a train bogie manufacturing industry: a six-sigma approach," *Cogent Eng.*, vol. 10, no. 1, p. 2154004, 2023, doi: 10.1080/23311916.2022.2154004.
3. P. Kumar, S. B. Prasad, D. Patel, L. Gupta, M. B. Nag, and P. Chadha, "Production improvement on the assembly line through cycle time optimization," *Int. J. Interact. Des. Manuf. (IJIDeM)*, vol. 17, no. 5, pp. 2617–2630, 2023, doi: 10.1007/s12008-022-01031-8.
4. V. Sisodia, S. Salunkhe, P. Pantawane, B. Rajiv, R. Diggi, and S. Raut, "Process and dimensional variation analysis of automobile assembly in development phase using Six Sigma DMAIC," *Int. J. Six Sigma Compet. Advant.*, vol. 14, no. 4, pp. 437–467, 2023, doi: 10.1504/IJSSCA.2023.134442.