Innovative Path to Intelligent Management of the Entire Production Lines Full Process and Full Element

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Abstract: (IoT) the environment of the manufacturing business that was getting more and more up to date with the rapid development of its manufacturing sector; intelligent production line management is starting to be the main force that enterprises need to increase the level of competitiveness of their companies. Intelligent production lines have not only considerably increased production efficiency and product yield rates, but they also have accomplished optimized cost control by completely combining the Internet of Things, the Internet, and artificial intelligence of other innovative technologies by deeply combining advanced manufacturing technology with the Internet of things (IEE).Intelligent technology, which is based in automated equipment with real-time data analysis, makes it possible to continuously optimize and dynamically adjust the manufacturing process, support the monitoring of the production environment, and effectively eliminate human interference and error rates, all of which will help to achieve the goal of real-time data collection and the environment. Businesses must deal with the problems of technology integration and talent development as a result of the constant technological advancement of these technologies, which is why they need to use intelligent production lines in a way that is both innovative and intelligent, which makes them perfect to optimize the production efficiency of these devices and the number of resources used in those parts.

Keywords: Intelligent production line; Production efficiency, Artificial intelligence; Full-element integration; Manufacturing transformation

1. Introduction

In the current wave of transformation and upgrading in the manufacturing industry, intelligent production lines are becoming the core engine driving this advancement. This innovative production model, by integrating advanced manufacturing technologies, information technology, and artificial intelligence, is reshaping traditional manufacturing methods. The application of intelligent production lines not only enhances production efficiency but also brings dual benefits of quality improvement and cost reduction for enterprises [1].

Intelligent production lines demonstrate significant advantages in industrial practice. Through the application of automation and intelligent equipment, enterprises can achieve automation and high efficiency in production processes, substantially boosting production efficiency. Simultaneously, the deployment of intelligent production lines effectively reduces reliance on manual operations,

improves product consistency, and lowers error rates during production [1]. In terms of cost control, the application of intelligent technologies shifts enterprise cost management from experience-driven to data-driven, significantly enhancing the level and effectiveness of cost control [2].

Regarding production process optimization, intelligent production lines achieve comprehensive perception of the production process, environment, equipment status, and product information through upfront planning and real-time data collection and analysis. This deep data analysis capability provides enterprises with support for scientific decision-making and improves product quality through precise control [3]. The application of intelligent technology is also reflected in supply chain management, where information sharing and collaborative management optimize the connection between various supply chain links, effectively reducing inventory backlog and logistics costs.

The construction of intelligent production lines is essentially a systems engineering project involving the deep coupling and co-evolution of physical and information systems. In the physical system dimension, it encompasses multiple aspects such as the intelligent upgrading of process equipment, optimization of production line system integration, digital reconstruction of engineering design solutions, application of new functional materials, integration of green and environmentally friendly technologies, and the construction of eco-friendly factories. By introducing intelligent equipment like cranes, robots, and AGVs [Automated Guided Vehicle, a transport vehicle equipped with electromagnetic or optical automatic guidance devices, capable of traveling along a defined guided path, with safety protection and various transfer functions.], combined with software platforms such as knowledge-based process design software, dynamic scheduling software, intelligent production management and decision-making systems, quality inspection software, precision distribution smart logistics, and digital twin production line monitoring and control software, the intelligence level of the production line is significantly enhanced.

At the management level, intelligent production lines utilize systems such as Manufacturing Execution Systems (MES) and material batching management and control systems to achieve automated and intelligent operation of production equipment [4]. These systems enable real-time monitoring and analysis of production data, predict potential equipment issues through data mining, achieve predictive maintenance, and reduce production interruptions [5].

From an industrial structure perspective, the development of intelligent production lines promotes the formation of industrial agglomeration effects. Through mechanisms such as resource sharing, cost savings, and technology spillover, enterprises can optimize resource allocation and enhance production efficiency [6].

In specific applications, intelligent production lines rely on technologies such as artificial intelligence, data analysis, and the Internet of Things to achieve real-time monitoring, data analysis, and optimized control of the production process. Through automatic control and management, enterprises can improve the stability and efficiency of processing techniques, reducing manual control errors and energy consumption. This intelligent innovation not only increases production efficiency but also creates favorable conditions for green innovation within enterprises, enabling them to maintain high output while reducing environmental impact [7].

2. Implementation of Full-Process Management

Intelligent production line management requires a comprehensive system covering process planning, production scheduling, execution, and finished product storage. Automation and

intelligent control systems reduce labor costs, improve efficiency, and ensure precise control throughout production.

Optimal production line layout considers the rational arrangement of equipment and smooth material flow. Modern intelligent production lines separate key process areas, auxiliary areas, and power support zones, connecting them via smart logistics systems [8].

Material management employs intelligent AGV for autonomous delivery, optimizing routes based on production plans to enhance transport speed. Production execution relies on PLC systems to coordinate equipment, ensuring continuity and stability [9].

Real-time data collection systems, supported by sensor networks and RFID technologies, gather equipment status, process parameters, and product quality data. Intelligent analysis of multi-source heterogeneous data supports decision-making. Industrial IoT-based central control systems enable collaborative control of equipment like stereoscopic warehouses, loading robots, and CNC machines, integrating functions such as order management, smart scheduling, and dynamic dispatching to form a data-driven closed-loop system.

This integrated technological framework establishes a full-process intelligent management system, significantly improving efficiency while enabling real-time, visual monitoring and dynamic optimization. It enhances responsiveness to emergencies and operational quality, providing robust technical support for the intelligent transformation of manufacturing.

3. Importance and Practice of Full-Element Integration

Full-element integration is essential for effective production line management. In modern manufacturing, elements such as production, quality, and equipment must be quantified, digitized, and integrated. An intelligent management platform consolidates these elements into a cohesive data chain.

The core of production management lies in order, delivery, and cost control. Smart order consolidation and scheduling systems, combined with big data analysis, enable visual analysis of full-process and full-element data, supporting informed decision-making and optimized production models. Production lines typically consist of conveying, inspection, and control systems, automated through management systems.

Full-element integration involves advancing automated factory levels, equipment networking, and efficiency optimization. It encompasses equipment status monitoring, preventive maintenance, MES integration, production records, energy management, and environmental monitoring. By linking equipment and production data with Computer Integrated Manufacturing (CIM) systems, a continuous data flow is established, extending to strategic planning and decision-making for high-level integration [10].

In logistics systems, production personnel must accurately track work-in-progress quantities to determine optimal supply strategies. Information system personnel need real-time insights into equipment status, material readiness, and machinery operation to issue timely alerts and ensure smooth production [11]. Sensors and data acquisition systems collect critical production parameters, transmitting them securely to central control for prompt issue resolution.

4. Technical Support for Intelligent Production Line Management

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conference for the name of your paper. In this newly created file, highlight all of the contents and import your prepared text file. You are now ready to style your paper; use the scroll down window on the left of the MS Word Formatting toolbar.

In the digital transformation of manufacturing, intelligent production line management serves as a key enabler, elevating production to higher, smarter levels and enhancing competitiveness. Integrating automation control systems, smart sensor networks, and industrial big data platforms forms a unified production line. Full-process and full-element intelligent management improves scientific rigor, precision, and accuracy. The operational effectiveness can be expressed as follows:

$$\eta = \frac{T_{effective}}{T_{total}} \times \frac{Q_{actual}}{Q_{theoretical}} \times 100\%$$

Let $T_{effective}$ be effective production time, T_{total} be total operating time, Q_{actual} be actual output, and $Q_{theoretical}$ be theoretical output.

The technical support system for intelligent production line management consists of three layers:

The bottom layer is the automation control system, which reduces human intervention through precise mechanical motion control and sensors, improving efficiency and consistency while minimizing errors.

The middle layer is the data acquisition and analysis system, enabling real-time data collection and decision-making based on analytical results.

The top layer is the intelligent decision-making system, a machine learning-based platform that automatically adjusts production parameters to enhance efficiency.

Intelligent transformation of production lines integrates sensors, automation controls, and data acquisition devices into industrial processes, enabling flexible and adaptable production models [8].

Current challenges in manufacturing digitalization include the difficulty of integrating physical and information systems. While some non-standard automated production lines offer cost and quality advantages, their intelligence, informatization, and real-time capabilities require further improvement [9]. Continuous innovation and refinement of technical systems are needed to advance production line management.

5. Case Analysis and Future Prospects

The application of intelligent production line control in actual production has become increasingly widespread, demonstrating strong representativeness within the industry. For example, numerous practical cases in the industry have shown that adopting intelligent production line control can significantly improve work efficiency, reduce human interference, and lower error rates and defect rates. In mechanical manufacturing, enterprises achieve cost reduction, quality improvement, and efficiency enhancement through automation and intelligent production line control. The production process exhibits characteristics such as continuity, high speed, and precision, along with a certain degree of flexibility and scalability, enabling rapid adaptation to product updates. Data from over 230 smart factories nationwide indicate an average productivity increase of 22.3%, a 50.2% reduction in defect rates, a 20.4% decrease in carbon emissions, and a 28.4% shortening of R&D cycles.

The realization of intelligent manufacturing in the industrial sector drives enterprises to transition from traditional management methods reliant on experience and intuition to modern scientific management. At the same time, big data analytics enables companies to fully grasp the actual market performance data of their products, facilitating more rational business decision-making. Moreover, in practical applications within the textile industry, intelligent workshop material handling

systems can be employed to enhance overall production efficiency. For instance, transport robots adjust their routes based on changes in production processes to achieve efficient distribution [12], reducing labor costs by 62% and improving cargo turnover efficiency by 2.3 times.

From a long-term perspective, intelligent production line control still has a long way to go. Issues such as technological standardization, data security, personnel training, and cost management will require ongoing attention and improvement in the coming period. Additionally, worker health and safety must be considered, necessitating the establishment of comprehensive safety monitoring and automated protection measures. Furthermore, with the continuous evolution of digital and network technologies, enterprises must also invest in the construction, upgrading, and timely maintenance of related infrastructure while cultivating high-quality technical personnel [13].

The development of intelligent production line control will inevitably trend toward comprehensive and refined planning and design. Manufacturing management systems will increasingly prioritize process design, enhance functionalities such as intelligent scheduling and dispatching, and leverage large-scale data for visual analysis to facilitate decision-making. Smart manufacturing technologies will drive the optimization of entire supply chains, enabling resource sharing and collaborative management among enterprises, thereby reducing inventory backlogs and logistics costs. Intelligent production lines will place greater emphasis on flexible and modular designs, allowing them to adapt swiftly to market changes and support the long-term sustainable development of enterprises.

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