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Flexible Manufacturing Assists Intelligent Manufacturing Upgrade of Automobile Industry

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Abstract: The automotive industry has always held a pivotal position in the manufacturing sector. As the manufacturing industry undergoes intelligent transformation and upgrading, flexible manufacturing technology has consistently played a crucial role in the "smart" manufacturing upgrade of the automotive industry. This technology effectively adapts to changes in both internal and external environments, promptly responds to and addresses various uncertainties, significantly reduces production cycles and costs, while ensuring product quality and efficiency. This article conducts research and analysis on the application of flexible technologies in the "smart" manufacturing upgrade of the automotive industry. It briefly explores the fundamental characteristics of flexible manufacturing technology. Subsequently, it analyzes the core value of applying flexible manufacturing technology in the "smart" manufacturing upgrade of the automotive industry. It investigates the application of flexible manufacturing technology in the automotive industry's "smart" manufacturing, focusing on flexible production equipment, flexible material transfer systems, flexible measurement systems, and flexible production lines. Through this research, this paper provides references and insights for the deep integration of China's automotive industry with flexible manufacturing technology.

Keywords: Flexible manufacturing technology; Intelligent manufacturing upgrade in the automotive industry; Application

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1. Characteristic analysis of flexible manufacturing technology

From the current perspective of automotive industry development, flexible manufacturing technology demonstrates the following fundamental characteristics as follows:

(1) Production equipment can simultaneously perform multiple types of processing operations, enabling mass production of automotive products. This effectively controls inventory costs and significantly improves equipment utilization rates;

(2) During raw material transportation, the utilization efficiency and availability of machinery can be comprehensively enhanced. When automotive processing techniques remain identical, various processing

operations can be employed. Even in cases of production machinery failures, flexible manufacturing can dynamically adapt to maintain production continuity, effectively mitigating the significant impact of mechanical failures on vehicle output and quality [1];

(3) The professional competence of manufacturing personnel can continuously improve, allowing for effective handling of various operational scenarios;

(4) Flexible manufacturing technology enables multi-line operations within processing spaces, maintaining balanced equipment loads across production workshops and significantly enhancing production stability and reliability.

2. Application value of flexible manufacturing in the upgrading of automobile manufacturing

2.1. Improving the stability of industrial production

During the intelligent manufacturing upgrade in the automotive industry, flexible manufacturing can establish a comprehensive automated processing system using one or several machine tools. When mechanical operation failures occur, the automated system will directly bypass the faulty machinery and employ multiple processing methods for materials, thereby avoiding production halts caused by equipment malfunctions. This enables efficient scheduling of production resources and significantly enhances the stability of automotive manufacturing.

2.2. Improving the utilization efficiency of production equipment

In automotive manufacturing, flexible manufacturing systems have significantly boosted production efficiency through computerized backend control of production workflows. When machine tool operations are interrupted, the system instantly initiates new tasks through intelligent task allocation, ensuring sustained equipment utilization and effective cost control. This approach reduces maintenance expenses compared to traditional equipment purchases, thereby enhancing both operational efficiency and economic returns [2].

2.3. Effective control of labor costs

The automotive production system built on flexible manufacturing technology features centralized control of the entire production process through a computer backend system. The system requires only 1–2 management personnel, who must be familiar with production workflows and proficient in system operation to ensure effective implementation of the flexible product management system. Compared to traditional manual production methods, flexible manufacturing technology significantly reduces labor costs in automotive production. Additionally, the system's high flexibility enables efficient equipment inspection and maintenance, reducing reliance on dedicated mechanical maintenance personnel and further controlling operational costs.

3. Application of flexible manufacturing technology in the process of intelligent manufacturing upgrade of automobile industry

3.1. Application of flexible production equipment

In modern automotive manufacturing, flexible production technology centers on adaptable equipment, with multi-axis CNC machine tools being the most prevalent solution. These tools are extensively used in precision machining of automotive components, particularly for new energy vehicle parts. Capable of performing complex

operations like milling, drilling, and cutting through pre-programmed control systems, multi-axis CNC machines demonstrate superior efficiency and quality control when processing materials and complex-shaped components. During production, they enable precise management of machining paths and depth, ensuring consistent quality standards across automotive parts. Additionally, these machines feature rapid tool changes and programmable adjustments, making them ideal for small-batch, diverse production needs [3]. By requiring only backend system control, multi-axis CNC machines effectively reduce human interference and enhance manufacturing efficiency.

3.2. Application of flexible material transfer system

In automotive manufacturing, ensuring production continuity and stability requires efficient material handling and management. The logistics system in flexible manufacturing integrates automated conveyor belts, robotic handling equipment, and smart storage systems, enabling automatic storage, transportation, and handling of various workpieces and raw materials. This system automates material handling and storage during production, significantly reducing manual labor time. Moreover, the flexible logistics system can dynamically adjust raw material supply based on specific production needs, adapting to manufacturing requirements of products of different scales and types. With support from advanced software systems, it also enables real-time tracking of material flow status and dynamic optimization of inventory management and production planning.

3.3. Application of flexible measurement system

In the automotive industry's transformation and upgrading process, introducing flexible measurement systems centered on high-precision instruments and automated inspection equipment is essential for enhancing product quality. These systems enable real-time monitoring and inspection of production processes by integrating modern technologies like laser scanning and 3D coordinate measuring machines with sensors, ensuring precise detection of dimensions and shapes in automotive components to meet quality standards. The flexible measurement system also effectively reduces human intervention during inspections, significantly improving efficiency while supporting 24/7 production line monitoring to promptly identify and correct quality issues. Additionally, the system comprehensively records production and inspection data, providing accurate data support for subsequent quality traceability and management.

3.4. Application of flexible production line

From the current perspective of automotive manufacturing, production lines must prioritize meeting diverse product manufacturing needs while enhancing overall efficiency and controlling costs. With the adoption of flexible manufacturing technologies, the automotive industry can establish adaptable production lines. These lines feature significant automation capabilities that enable real-time adjustments to equipment and processes, effectively accommodating various product specifications. A common practice involves using multiple production methods simultaneously on the same line to manufacture different body structures. Furthermore, flexible production lines maintain strong market responsiveness, allowing immediate adaptation to demand fluctuations and enabling customized, personalized manufacturing. This diversified approach effectively avoids the limitations of single-product production lines, significantly reducing operational costs, improving production line utilization rates, and optimizing resource allocation during manufacturing processes to prevent waste.

4. Conclusion

In summary, as the automotive industry advances toward intelligent manufacturing, flexible production technologies have become increasingly prevalent. These technologies play a vital role in enhancing production line efficiency, stability, and reducing labor costs, fully meeting the demands of China's automotive sector's intelligent transformation. Currently, flexible production lines, measurement systems, equipment, and material handling systems are widely adopted in automotive manufacturing. They enable continuous production while preventing downtime caused by minor malfunctions, thereby continuously improving both production efficiency and product quality. With ongoing refinements in flexible manufacturing technologies, the automotive industry's intelligence and automation levels will continue to rise.

Disclosure statement

The author declares no conflict of interest.

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