

Application of Green Manufacturing Processes in Machining of Automotive Parts

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Abstract: In the new era, to make the production process of automotive parts machining more environmentally friendly and sustainable, various green manufacturing processes and technologies can be flexibly applied to reduce energy consumption, control manufacturing costs, and improve operational efficiency. This paper outlines green manufacturing techniques, analyzes their significance in automotive parts machining, and explores their practical applications, aiming to promote the widespread adoption of green manufacturing in China's automotive industry and fully realize the value and advantages of these techniques.

Keywords: green manufacturing process; automotive parts; mechanical machining

1 Introduction

To address environmental pollution, resource waste, high energy consumption, and elevated costs in automotive parts machining, relevant enterprises need to recognize the value and significance of applying green manufacturing processes. They should actively introduce new green manufacturing technologies and replace traditional machining methods with them, thereby establishing a new eco-friendly model for automotive parts machining.

2 Overview of Green Manufacturing Processes

Green manufacturing processes are a new set of processing standards and systems developed with environmental protection as the premise, resource conservation as the goal, sustainable development as the principle, system optimization as the method, and innovation and reform as the driving force. These processes effectively enhance product quality and processing efficiency. The application of green manufacturing holds significant contemporary relevance and value, addressing environmental pollution and resource waste in traditional industrial production, thereby truly achieving green and sustainable development.

3 Significance of Green Manufacturing Processes in Mechanical Processing of Automotive Components

3.1 Reduce production energy consumption

Given the current state of mechanical processing in automotive parts manufacturing, some enterprises still face high energy consumption. As environmental policies continue to improve, automakers need to consistently reduce energy use in component machining. To achieve this, companies can adopt green manufacturing technologies to better control carbon emissions and facilitate the transformation and upgrading of automotive parts machining [1].

3.2 Enhancing Market Competitiveness

As China's manufacturing market continues to deepen its openness, competition in the industry will intensify, as automotive manufacturers must compete with both domestic and international peers. To remain competitive, companies must effectively control costs and increase investment in technology and research and development.

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Green manufacturing processes can enhance processing efficiency while ensuring that mechanical machining of auto parts meets quality standards, helping to manage production costs and thereby strengthening a company's market competitiveness.

3.3 Enhancing Operational Efficiency

Introducing green manufacturing processes in the mechanical processing of automotive parts within automobile manufacturing enterprises helps continuously improve operational efficiency, achieve high-quality development goals, effectively enhance resource utilization efficiency in automotive part machining, and boost overall business performance.

4 Application of Green Manufacturing Processes in Mechanical Processing of Automotive Components

4.1 Green Welding Process

4.1.1 Laser Tailor Welding Process

Laser welding technology primarily involves joining steel plates made of different materials, thicknesses, and coatings using laser welding to form a single integrated welded panel. This panel can then undergo stamping and manufacturing processes, preparing it for subsequent assembly of automotive components. The application of laser welding meets the diverse material performance requirements in modern automotive part machining. Moreover, laser welding not only significantly improves material utilization but also effectively ensures high-quality mechanical processing of automotive parts [2].

Analysis of extensive data from automotive parts machining practices shows that replacing traditional manufacturing processes with laser welding can reduce material weight by approximately 30%. This indicates that the technology will play a significant role in the ongoing development of lightweight vehicle structures. However, laser welding also has certain drawbacks: the weld seams formed during the process may affect the mechanical properties and surface quality of the material. If operators lack precision, sudden variations in thickness may occur in the welded panels, compromising smooth and seamless connections between components and increasing the likelihood of rework.

4.1.2 Aluminum Alloy Welding and Joining Process

The greater the vehicle's own weight, the more power is required to drive it. Therefore, to effectively improve energy efficiency and reduce fuel consumption, lightweight design of automotive structures can be adopted. To achieve this goal, aluminum alloy joining technology can be selected in the mechanical processing of automotive components, as compared to traditional steel sheet welding, aluminum alloy joining significantly reduces workpiece mass.

Currently, aluminum alloy joining technologies used in automotive parts machining mainly include non-vacuum electron beam welding and tungsten inert gas arc welding. Due to the physical and chemical properties of aluminum alloys, welding presents certain challenges. During the welding process, issues such as loss of alloying elements and reduced material structural strength may occur. Additionally, some welded areas might develop gaps or hot cracks, which hinder the widespread application and promotion of aluminum alloy joining techniques.

To effectively address this issue, technicians developed friction stir welding, a novel joining process for aluminum alloys. In this process, the tool, composed of a probe and shoulder, is precisely inserted into the workpieces to be welded. The tool then rotates along the weld direction, generating friction between the shoulder, probe, workpiece surface, and base material, rapidly increasing the temperature at the weld zone and thereby softening the material effectively. As the probe advances forward, the thermoplastic metal ahead moves rapidly backward and accumulates. At this point, the forging force generated by the shoulder causes the deformed metal atoms at the joint to diffuse and quickly crystallize, resulting in a strong bond through solid-state joining and achieving the desired welding outcome.

When applying aluminum alloy joining technology, friction stir welding avoids the need for melting the base

material by welders, thereby preventing deformation and porosity that can occur after melting of aluminum alloy sheets, which could otherwise affect the final mechanical processing quality of automotive components. Additionally, in practical applications of friction stir welding, no special filler materials or shielding gases are required, and no smoke or fumes are generated during the welding process, making it a green, efficient, and low-carbon environmentally friendly welding technique.

4.1.3 Cold Metal Transfer Welding Process

Compared to traditional inert gas shielded welding techniques, cold metal transfer welding involves relatively lower heat input. During the actual welding process, this method primarily relies on alternating temperature cycles of hot, cold, and hot, effectively controlling heat input and thereby managing welding energy consumption. In practical applications of cold metal transfer welding, four key welding process parameters must be properly controlled.

First, during the mechanical processing of automotive parts, effective heating of the components and the molten welding wire is achieved through arc burning. Second, as the wire advances forward, the molten droplet contacts the component; at this point, the welding current drops to zero, allowing the operator to promptly retract the wire. Third, typically, mechanical methods are used to separate the wire from the molten droplet, ensuring smooth transfer of the droplet into the weld pool. Fourth, once the wire detaches from the weld and an open circuit occurs, the arc must be reignited, enabling the wire to slowly advance again and enter the next cold metal transfer welding cycle, thereby achieving efficient welding of the workpiece.

4.2 Green Forming Process

4.2.1 Internal High-Pressure Forming Process

In the mechanical processing of automotive parts, internal high-pressure forming technology can be applied to shape raw materials, thereby meeting the dimensional requirements for part manufacturing. Analysis of the internal high-pressure forming process reveals that it primarily involves machining tubular materials. By precisely introducing ultra-high-pressure hydraulic fluid and axial thrust into the tube, the tube blank is pressed into the mold cavity, ultimately producing the desired automotive component. When applying internal high-pressure forming technology, three key process considerations should be noted.

First, filling. By placing the relevant tubing into the mold cavity and closing the mold, the ends of the tube can be advanced horizontally under specific water injection conditions, creating a sealed processing environment. Subsequently, related techniques can be used to quickly expel air from inside the tube. Second, forming. A certain pressure is applied to the medium filled inside the tube to achieve the desired mold shape. Third, shaping. Through continuous pressure application, the mold cavity and mold angle are tightly integrated, ultimately producing the target workpiece.

Compared to traditional stamping processes, internal high-pressure forming can effectively control the machining quality of automotive components, efficiently manage energy consumption in component manufacturing, and fully realize the application value of this technology.

4.2.2 Hot Pressing Process

Hot pressing forming primarily involves processing workpieces using heated molds. In the mechanical machining of automotive components, workers need to inject appropriate materials into the mold and apply specific pressure to firmly bond the mold and material. Once the material is securely shaped, the finished product can be removed. To fully leverage the advantages of hot pressing forming, it is essential to control three key process parameters.

First, place the material to be processed into the mold in a controlled manner after it has been heated. Second, apply a certain amount of pressure to the mold using the upper and lower dies, while expelling air from the cavity through the exhaust pipe. Third, remove the cooled mold and perform shearing to obtain the finished product.

Compared to traditional mechanical processing methods for automotive parts, hot stamping technology can enhance material strength and enable rational control over part thickness and usage quantity.

4.2.3 Roll Pressing Forming Process

When using roll forming to mechanically process materials, the workpiece undergoes special treatment under the rolling pressure of rotating rollers, ultimately taking on a specific shape. When applying this process to the mechanical processing of automotive components, it is essential to properly utilize the interaction between presses and forming machines to ensure effective implementation of the roll forming technique.

4.3 Green Machining Process

4.3.1 Selection of Process Parameters

In green machining processes, high-speed cutting is a commonly used method evolved from traditional machining techniques. To fully leverage the advantages of this technology, it is essential to select appropriate process parameters carefully, avoiding improper control that could compromise the mechanical processing quality and performance of automotive components. High-speed cutting has certain unique characteristics; during machining, high-speed friction occurs between the cutting tool and the workpiece. Since different materials vary in physical properties and chemical composition, they may exhibit distinct behaviors under such conditions. Therefore, when performing high-speed cutting on specific workpieces, it is necessary to analyze parameters such as thermal expansion coefficient and thermal deformation temperature, and then refer to material heat treatment specifications to clearly understand the structural features and processing considerations of the workpiece, thereby preventing significant material deformation during cutting that might affect the machining quality of automotive parts. For example, when processing aluminum alloy materials with high-speed cutting, to maximize the benefits of this technique, operators should appropriately apply rough cutting, semi-finishing, and polishing processes to effectively treat the workpiece and reduce surface roughness. Additionally, to ensure dimensional tolerances, feed rates should be increased to shorten machining time and effectively reduce scrap rates.

4.3.2 Scientific Process Planning

When performing high-speed machining of automotive parts, it is essential to scientifically and rationally plan the cutting processes to avoid the impact of repeated positioning errors on the final workpiece quality and performance. For example, when drilling related components, simultaneous use of a tapping machine and a drilling press may easily cause workpiece misalignment, resulting in poor hole diameter machining quality. To prevent this issue, during high-speed cutting operations, the cutting process plans should be carefully analyzed and evaluated, and optimized and refined accordingly [3].

4.3.3 Proper Selection of Cutting Tools

When performing high-speed machining of automotive components, it is essential to consider the characteristics of different materials and select the optimal combination of cutting tools to fully realize the application value and effectiveness of high-speed machining processes. For example, during the machining of aluminum alloy automotive parts, operators can choose coated carbide tools and appropriately select coolant to ensure effective cutting performance. Since many automotive components require high machining standards, multiple cutting operations are often necessary to meet quality requirements and technical specifications. Therefore, a combined tooling strategy should be adopted to achieve efficient workpiece processing. Additionally, due to the unique nature of high-speed machining, tools must be replaced regularly to maintain machining efficiency.

5 Conclusion

This paper provides an overview of green manufacturing processes and analyzes their significance in the mechanical processing of automotive components, including reduced energy consumption, enhanced market competitiveness, and improved operational efficiency. It explores specific applications of green manufacturing technologies in automotive part machining, such as green welding techniques—including laser welding, aluminum alloy joining, and cold metal transition welding—green forming methods like internal high-pressure forming, hot

stamping, and roll forming, as well as green cutting processes represented by high-speed machining. Against the backdrop of rapid development in China's automotive industry, to effectively advance the technological level of automotive component machining, it is essential to embrace environmentally friendly production principles and actively promote the research, development, and application of green manufacturing processes, thereby fully realizing their practical value.

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