**Research on the Design and Manufacturing Process of Key Mechanical Components for New Energy Vehicles**

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**Abstract.** As the world's pollution gradually intensifies, the carbon emission content is gradually increasing. On September 22, 2020, China proposed the goal of achieving "carbon peak" by 2035 and "carbon neutrality" by 2060. At the same time, with the leapfrog progress of intelligent technology, people's environmental protection awareness has gradually improved and the cost of using new energy vehicles is relatively lower than that of fuel vehicles. The forces of new energy vehicles are beginning to rise. In order to enable people to have a better understanding of the design and manufacturing processes of key components of new energy vehicles, this article aims to discuss the design of key components of new energy vehicles, as well as the research on key components of new energy vehicles (such as gearbox bodies, sub-frames, motor shells, battery packs, steering joints) and their processing techniques (such as disappearing molds, low-pressure casting, 3D printing manufacturing techniques) and their process optimization.

# Introduction

At present, the global development of new energy vehicles is in a stage of rapid growth. With the advantages of policy support, industrial chain integration and profound market potential, China has become the largest market for new energy vehicles in the world. In 2024, the total sales volume of new energy vehicles in China has reached 12.866 million units [1]. Domestic enterprises in China, such as BYD, CATL, and NIO, etc., are leading in marketing strategies, battery technology, motor efficiency and vehicle integration, etc. [2]. Compared to them, although foreign traditional automakers have accelerated their transition towards electrification, they still face significant challenges in terms of the speed of core technology iteration, cost control, local marketing strategies and local supply chain integration, which has led to their relatively lagging market competitiveness [3]. Meanwhile, the key mechanical components of new energy vehicles play a crucial role in the overall performance of the vehicles. The performance and safety of new energy vehicles are highly dependent on the coordinated optimization of core mechanical components. Here are three examples mentioned. In the battery power system, energy density and thermal stability directly determine the driving range and safety [4]; in the drive motor system, power density and efficiency affect the acceleration performance and energy consumption level; in the electronic control system, precise control of power distribution and thermal management logic are required to ensure the reliability and durability of the system; in the lightweight vehicle frame structure, high-strength steel, aluminum alloy or composite materials are used to enhance the collision safety and driving range; in the thermal management system, multi-loop liquid cooling technology balances the temperatures of the battery, motor and electronic control unit to avoid failure under extreme conditions [5]. In terms of key component processing, the low-pressure casting process is usually applicable for the production of lightweight aluminum alloy sub-frame and battery box. The high-pressure casting process is usually applicable for the integrated die-casting technology to enhance structural rigidity. The lost foam casting process is usually suitable for complex-shaped motor end caps and radiator housings [6].

# Overview of Key Mechanical Components of New Energy Vehicles

## Technical Characteristics and Design Requirements of New Energy Vehicles

The technological innovation of the automobile industry benefits from the rapid development of the new energy automobile industry. The development process of new energy vehicles can be summarized as the following three characteristics, namely, the three major trends of electrification, lightweight and integration. These technical features directly determine the design direction and performance requirements of key mechanical components of new energy vehicles. Among them, electrification involves replacing traditional gasoline and diesel drives with electric drives powered by electricity. These changes require mechanical components to adapt to the characteristics of high-torque and high-speed drives of electric motors. At the same time, issues such as power transmission and conversion efficiency need to be addressed. Lightweighting is achieved by optimizing materials such as using aluminum alloys, carbon fiber composites and through structural innovations to reduce the overall vehicle weight, thereby enhancing the range and dynamic performance [7]. Integration is achieved through the integration of automotive functional modules, reducing the number of components to optimize the spatial layout, thereby aiming to enhance system reliability and reduce manufacturing costs. These design requirements not only need to take into account traditional mechanical properties such as strength and stiffness, but also integrate multi-disciplinary cross-disciplinary technologies such as electrification and thermal management.

## Classification And Function Analysis of Core Mechanical Components

# The core of new energy vehicles mainly has the following four categories, the first is the drive motor system, which includes the rotor, the stator and the shell. The drive motor system is the key component of the power output of new energy vehicles. The rotor rotates in the magnetic field generated by the stator to realize the conversion of electrical energy to mechanical energy, and the shell plays a role in supporting and protecting the internal structure of the rotor and the stator [8]. The second is the power battery system, which mainly includes the box and module structure. The power battery system is the energy storage unit of new energy vehicles. The box is used to house and protect the battery module, and the module structure is composed of a plurality of battery cells to meet the voltage and power requirements required by the car. The third is the electronic control system thermal management components, the electronic control system will generate heat when working, the thermal management components are used to control and adjust the temperature of the electronic control system to ensure that it works in the appropriate temperature range to ensure the performance and reliability of the electronic control system.

# Key Component Design Theories and Methods

## Lightweight Design Technology

In the lightweight design of new energy vehicles, material selection needs to take into account lightweight, strength, processability and cost-effectiveness. Common materials include aluminium alloy, which has a low density (about 2.7 g/cm³), high specific strength and strong corrosion resistance, and is suitable for body structure components, battery pack shells, etc. [9]. Magnesium alloy, which is lighter (with a density of 1.8 g/cm³), has a higher cost and is more difficult to process, and is mostly used for small components [10]. Carbon fiber composite materials, which have significant advantages in terms of lightweighting and strength, are costly and are suitable for key structures of high-end vehicles. High-strength steel is used in collision safety zones to balance lightweighting and structural strength. Among them, cast aluminum alloys (such as ZL101A) have become an ideal choice for key components of new energy vehicles due to their excellent comprehensive performance. ZL101A is an Al-Si-Mg series cast aluminum alloy (composition: Si 6.5-7.5%, Mg 0.25-0.45%), and its performance significantly improves after T6 heat treatment. It has the following advantages in new energy vehicles: remarkable lightweight effect. This material has a density only one-third of that of steel, which can significantly reduce the weight of components such as motor housings and battery trays, thereby enhancing the range. High strength and toughness balance, this material has a tensile strength of ≥ 240 MPa, a yield strength of ≥ 180 MPa, and an elongation of ≥ 3%, meeting the mechanical requirements under complex loads. Excellent fluidity, suitable for sand casting and metal mold casting, it can achieve integrated molding of thin-walled parts (≥ 3 mm), reducing welding processes and lowering manufacturing costs. This material has excellent thermal management performance. It has a high thermal conductivity (about 150 W/m·K) [11], which is conducive to heat dissipation of the battery pack shell and enhances the thermal runaway protection capability. This material is highly corrosion-resistant and recyclable. Its surface is prone to form a dense oxide film, which is resistant to environmental corrosion. It conforms to the green design concept of new energy vehicles and has a recycling rate of over 95%.

## Case Study Analysis

I will give the following three examples, the first is the motor housing, engineers through integrated casting to reduce the risk of magnetic leakage of the motor housing, through lightweight to improve the power efficiency. The second is the battery tray, which can be combined with high rigidity and lightweight to protect the battery cell and achieve the role of reducing the quality of the vehicle. Finally, the suspension system components, which are topologically optimized to replace traditional steel components, can reduce the weight of 30% or more.

Advanced Manufacturing Technology Research

Forming Process

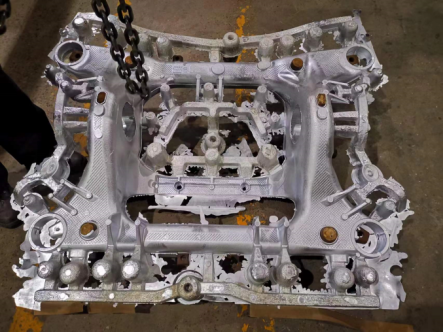
At present, the three most widely used molding processes on the market are the lost mold process, low pressure casting process and 3D printing process, in which the lost mold process can be applied to the aluminum alloy variable speed box, the lost mold process has unique advantages in the manufacturing of new energy automobile parts. In this process, the traditional shape is replaced by foam shape (Figure 1). The shape is coated with refractory paint, dried and buried in dry sand. When poured into liquid metal, the foam shape vaporizes under heat and disappears, and the metal liquid solidifies in its place to form a casting [12].



**FIGuRE 1.** Foam plastic parts(Picture credit: Original)

In the field of new energy vehicles, the disappearing mold process is often used in the production of components such as aluminum alloy variable speed boxes. It can make the casting structure design more flexible, reduce the processing allowance, improve the material utilization rate, and reduce the production cost. At the same time, because this process does not require operations such as mold drawing and core cutting, it can greatly improve production efficiency, and the casting size accuracy is high, the surface quality is good, can effectively improve the performance and reliability of new energy vehicle components, and provide strong support for the high-quality development of new energy vehicles.

The second is low-pressure casting, which is widely used in frames, gearboxes, battery packs and steering knuckles, and low-pressure casting is also one of the key processes for the manufacturing of new energy vehicle parts.It is a method of smoothly pressing liquid metal from bottom to top into the mold cavity in a low pressure environment, and crystallizing under pressure to obtain castings. In the production of new energy vehicles, low-pressure casting is widely used in important components such as sub frame (as shown in Figure 2), gearbox, battery pack, steering knucks, etc. For the sub frame, it can cast parts with complex structure and high strength to improve the overall rigidity and safety of the vehicle; Applied to variable speed box, can guarantee its dimensional accuracy and internal quality, to ensure the stability of power transmission. In the manufacturing of battery packs, low-pressure casting can produce a well-sealed housing to provide reliable protection for the battery. When the knuckle is cast, a dense casting is obtained to meet the demanding component performance requirements of the steering system. The parts produced by this process have reliable quality and excellent performance, which has effectively promoted the development of the new energy automobile industry.



**FIGURE 2.** Aluminum alloy subframe casting component(Picture credit: Original)

The third is 3D printing, it is applicable to the development stage. For any new energy vehicle component to achieve mass production, molds are necessary, which means the first two processes are indispensable)3D printing plays a unique and significant role in the manufacturing of components for new energy vehicles. It is based on digital models and creates components by layering materials one by one. During the development stage of new energy vehicles, 3D printing has remarkable advantages. Designers can quickly transform their creative ideas into physical prototypes. For complex components such as new aerodynamic kits and personalized interior components, they can quickly verify whether their structures and functions meet expectations, significantly shortening the R&D cycle and reducing development costs. Meanwhile, for some small-batch and customized component production demands, 3D printing can also easily meet them, such as the manufacturing of exclusive components for racing cars or high-end customized new energy vehicles. However, at present, 3D printing has limitations in mass production. The large-scale production of components for new energy vehicles still needs to rely on traditional mold manufacturing techniques. But with the continuous progress of technology, 3D printing is expected to play a greater role in the manufacturing of new energy vehicles.

## Joining Process

## The three main connection processes on the market are laser welding, resistance spot welding and arc welding, laser welding is the use of high energy density laser beam to melt the surface of the parts to achieve connection. For example, in the battery module, the battery pole ear can be accurately welded with the bus bar, and the weld seam is narrow, the depth to width ratio is large, and the heat affected zone is small, which can improve the safety and stability of the battery module [13].Resistance spot welding is to apply pressure and current to individual points on the contact surface of the welding part through the electrode, so that the contact point is heated and melted to form a welding spot. It is often used for body frame connection, which can efficiently connect sheet parts with high production efficiency and low cost [14]. Arc welding includes MIG (MIG/MAG) and tungsten argon arc welding (TIG). It is widely used in the manufacturing of frames, chassis and other components of new energy vehicles, and can realize the connection of larger thickness plates with high weld strength.

## Processing Technology

High-precision CNC machining holds a significant position in the manufacturing of components for new energy vehicles. It utilizes computerized digital program control of machine tools to achieve precise processing of components for new energy vehicles. In the drive motor system, CNC machining can precisely manufacture key parts such as rotors and stators, ensuring their dimensional accuracy and surface quality, thereby enhancing the performance and efficiency of the motor. For the box body of the power battery system, numerical control machining can ensure that it has precise dimensions and good sealing performance, providing reliable protection for the battery. In the processing of lightweight body and chassis structural components, through numerical control machining, complex shapes can be processed for materials such as aluminum alloy and carbon fiber, achieving structural optimization design, and reducing weight while ensuring strength and stiffness. High-precision CNC machining, with its characteristics of high efficiency, accuracy and flexibility, can meet the processing demands for high-precision and complex structures of components in new energy vehicles, thereby contributing to the enhancement of the performance of new energy vehicles and the development of the industry.

# Process Optimization and Quality Control

# Analysis and Improvement of Manufacturing Defects

Common manufacturing defects in new energy vehicles include problems related to batteries and motors. Regarding batteries, capacity reduction and increased internal resistance may occur, which is attributed to mechanisms such as natural aging of battery materials and changes in chemical reactions during charging and discharging cycles. Motor faults such as short circuits in winding are mostly caused by manufacturing defects and foreign objects entering. To address these issues, efforts should be made to develop materials with higher energy density and optimize the battery management system in battery technology. During motor manufacturing, the precision of production processes should be enhanced and quality inspections strengthened. Meanwhile, automakers need to improve production processes, strengthen post-production inspections, and enhance the reliability and safety of new energy vehicles.

Optimization Methods for Process Parameters

The following is a process optimization method based on machine learning. In the processing of new energy automobile parts, the optimization of the processing machine process can be started from many aspects. The first is tool path planning, through the use of advanced CAM software, according to the shape, size and processing requirements of the parts, to generate the shortest and most reasonable tool path. For example, in the processing of complex motor housing, by optimizing the path to reduce empty travel, improve processing efficiency, reduce tool wear. The second is the adjustment of cutting parameters, which precisely matches the cutting speed, feed rate and cutting depth according to different materials and processing techniques. For example, the processing of the battery box made of aluminum alloy can improve the cutting speed and reasonably reduce the feed amount, which can not only ensure the surface quality but also improve the processing efficiency. Cooling lubrication improvement, through the selection of new cooling lubrication fluid, combined with micro-lubrication (MQL) technology, while ensuring machining accuracy and surface quality, reduce cutting heat generation, reduce processing costs and environmental pollution. Finally, equipment maintenance and upgrading, through regular comprehensive maintenance of processing equipment, timely replacement of worn parts; Intelligent monitoring system is introduced to monitor the operating status of equipment in real time and to warn of failure in advance. Timely upgrade equipment, such as replacing high-precision lead screw, guide rail, improve processing accuracy.

# Conclusion

Under the backdrop of environmental protection and technological advancement, new energy vehicles are emerging as the backbone of future transportation. With continuous breakthroughs in battery technology, range anxiety will gradually become a thing of the past, and charging speed will also be significantly enhanced. The intelligent driving assistance systems are becoming increasingly mature, making travel safer and more convenient. Driven by the dual forces of policy support and market demand, the market share of new energy vehicles will continue to expand. In the future, not only will they become the mainstream of private cars, but they will also be widely applied in public transportation, building a green and efficient new travel ecosystem.

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