Prospects For Application of High-Efficiency and High-Power Electric Motors in New Energy Vehicles

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Abstract. With the global energy crisis and the increasingly serious greenhouse effect, haze and other environmental pollution problems have caused many global issues. In addition, the transformation of the energy structure, the adjustment of the global government policy on carbon emissions, making the world's growing demand for clean energy. This makes the use of clean energy, which is the main force to replace the traditional fuel vehicles of new energy vehicles to its environmentally friendly energy-saving characteristics of the widespread attention. So far, high-efficiency motors serve as the core components of new energy vehicles. Its performance and technology development directly affect the energy efficiency of new energy vehicles and product competitiveness, which further affects its market competitiveness. This paper discusses in depth the development status of new energy vehicles, including the benefits of fitting high-efficiency motors to new energy vehicles, analyzes its development trend, looks forward to the future innovation direction and application prospect of high-efficiency motor technology, and describes the author's research contribution in this field.

Keywords: Electric motor; New energy vehicles; Environmental protection; Automobile industry.

1. Introduction

With the progress of science and technology and the improvement of environmental protection consciousness, as well as the shortage of traditional petrochemical energy, clean energy is becoming more and more the key development direction of all countries. New energy vehicles, as the main application scenario of clean energy, have become an important direction for the development of the automobile industry. In the early 19th century, the world's first direct current motor was invented by the German scientist Werner, when the research mainly focused on how to convert electrical energy into mechanical energy. With the progress of development and technology, Tesla invented the AC motor in the late 19th century, which marked the electric motor entered a period of rapid development. At the end of the 20th century, the highest use rate is the standard efficiency of the motor. However, in the 21st century, under the framework of energy conservation and emission reduction, energy-saving motor has become the inevitable direction of the development of the motor industry. It replaced the traditional motor and has become the mainstream, and the proportion of use is as high as 41%.

Taking the passenger car market sales in January 2024 as an example, the passenger car market sales in January were 2,223,000 units, up 71.8% year-on-year; the new energy market sales month was 664,000 units, up 126.3% year-on-year, an increase of significantly higher than the passenger car market [1]. As the core component of all kinds of new energy vehicles driven by electric energy, high-efficiency motors are widely used in pure electric vehicles and hybrid vehicles. Their performance improvement, control refinement, and overall technological innovation are of great significance in enhancing the energy efficiency of new energy vehicles and promoting the development of the industry.

The purpose of this paper is to systematically sort out and analyze the development of high-efficiency motors, as well as the current status and development trend of their application in new energy vehicles. It initially discusses the support provided by high-efficiency motors to the sustainable development of new energy vehicle industry, as well as the possible direction of future development.

2. New Energy Vehicle Motors

2.1. Current Status

2.1.1 Overview of High-Efficiency Motor Technology

This section will introduce the basic principle, classification, and performance characteristics of high-efficiency electric motors to provide a theoretical basis for the subsequent application analysis. Like regular electric motors, high-efficiency electric motors operate on the same fundamental ideas, which are mostly derived from the electromagnetic induction laws. The motor's primary components are a revolving armature, or rotor, and an electromagnet winding, also known as a distributed stator winding, which is used to create a magnetic field. The working concept involves creating a rotating magnetic field with an electrified coil, which then acts on the rotor to produce a spinning torque of magnetoelectric power [2].

Most electric motors in the power system are AC motors, which can be either synchronous or asynchronous internal motors. Electric motors are classified as either DC or AC motors based on the power sources they employ. Asynchronous, synchronous, and DC motors are the three categories into which motors can be classified based on their structure and operating principle. Reluctance synchronous motors, hysteresis motors, and permanent magnet synchronous motors are further classifications for synchronous motors. Induction motors and AC commutator motors are the two categories under which asynchronous motors fall. Asynchronous motors in three phases are one subset of induction motors, and so on. The various types of cooling methods are classified based on ventilation, including fan-cooled, closed-circuit gas cooling, self-cooled, and others. This paper mainly analyzes and discusses the high-efficiency motors used in new energy vehicles. An example of classifying electric motors is shown in Fig. 1, with the division between AC and DC motors coming first [3].

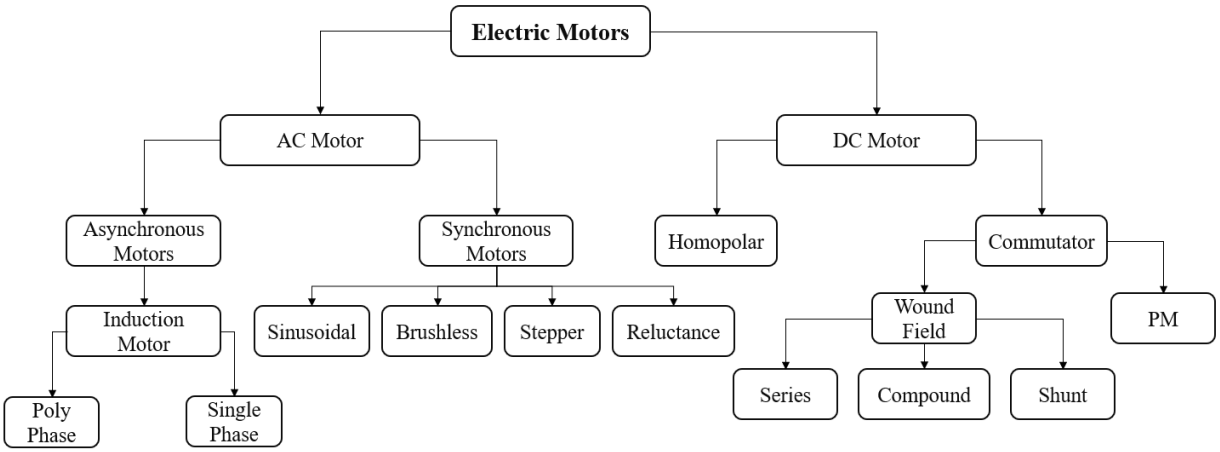


Fig. 1 Classification of Electric Motors [3].

EV electric motors come in a range of forms. High-efficiency motors are distinguished from ordinary motors by several aspects of their following performance characteristics. First, they usually have high torque and power factor, which enables them to maintain efficient operation under various operating conditions. Secondly, high-efficiency motors have a wide speed range, which can meet the needs of different application scenarios. Furthermore, they have good starting performance and can quickly reach a stable working condition. In addition, high-efficiency motors have high operating efficiency, low noise, high reliability, long service life, and are small in size and light in weight, making them easy to install and maintain. The above features make high-efficiency motors very suitable for the application scenarios of new energy vehicles. Minimum efficiency values are specified by the IEC for various motor classes; it is expected that other parts will be rated using a similar system:IE1 denotes poor efficiency and lE5 denotes maximum efficiency [4]. At the same time, the IEC specifies that motors with an energy efficiency rating of IE2 or higher are considered high-efficiency motors.

2.1.2 New Energy Vehicle Development Status

As a hot spot in today's automobile industry, new energy vehicles are ushering in a golden period of rapid development. With the enhancement of environmental protection awareness, the transformation of energy structure and the support of government policies, the new energy vehicle market shows a booming trend [5]. First, from the perspective of market demand, new energy vehicles are gradually favored by consumers. On the one hand, with technological advances, the performance and range of new energy vehicles have been significantly improved, making the gap between them and traditional fuel vehicles in the use of experience gradually narrowed. On the other hand, with the government's increased support for new energy vehicles, including purchase subsidies, purchase tax exemptions, free parking, and other preferential policies, further stimulating the enthusiasm of consumers to buy. For sustainable transportation to continue in the future, electric car technology is essential. Many automakers have boosted their electric car manufacturing. For instance, EV sales increased by 54% between 2016 and 2017 [6]. By 2030, more than 200 million EVs are expected to be sold [7].

Additionally, governmental encouragement influences the market demand for new energy vehicles. To address climate change and minimize carbon emissions, governments have implemented several environmental regulations, including the promotion of new energy vehicles. These regulations not only create a favorable external environment for the development of new energy vehicles, but also ensure their market expansion.

2.2. Issues and Solutions for Existing New Energy Vehicle Motors

This section will outline the development status and market demand of new energy vehicles and analyze the importance and application potential of high-efficiency motors in new energy vehicles. There are two types of permanent magnet synchronous motors (PMSMs), which are internal and surface mounted. They both operate on sinusoidal current. While the internal PM topology is characterized by an internal PM topology with a reluctance torque, which can be employed to reduce the size of the permanent magnets and hence lower cost, the surface-mounted PM topology is easier to build. PMSMs are currently used by most EV manufacturers, including Toyota, Nissan, Zotye, BMW, etc. Currently, PMSM are found in about 26 EV vehicles [8]. PM motors are IE3 energy efficient. Fig. 2 shows that in 2020, the share of the lowest efficiency motors in the lE1 class will still be as high as 22%, and the share of the highest efficiency motors in the IE4 class will only be 2% [9]. The high-efficiency motors need to be popularized and applied in more products.

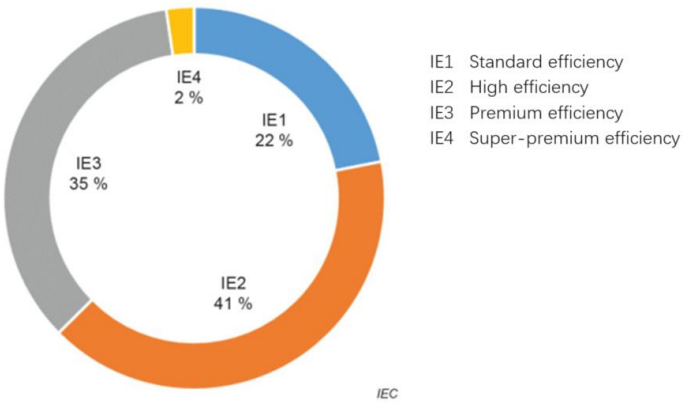


Fig. 2 Share of motor efficiency classes [9].

Based on the IEC motor energy efficiency standard, many countries have launched their own national motor energy efficiency standards. For example, China in May 2020 officially released the latest version of the mandatory national standard GB 18613-2020 "Motor Energy Efficiency Limit Values and Energy Efficiency Classes", which will be formally implemented on June 1, 2021, onwards [10]. From the date of implementation of the standard, the IE3 energy-efficiency class will

become the lowest three-phase asynchronous motor energy-efficiency limit value (Level 3 energy-efficiency) in China, and three-phase asynchronous motors with an energy-efficiency limit value lower than that of the IE3 energy-efficiency limit value will be disallowed to produce and sell again. This will provide policy support for the popularization and application of high efficiency motors and will gradually increase the market share of motors with energy efficiency above IE3.

2.3. Impact of High-Efficiency Motors

The energy consumption and greenhouse gas emissions can be greatly decreased by using more efficient electric motors in future energy cars. The example below illustrates the potential energy savings and associated CO2, emissions reductions when using electric motors with rated efficiency according to lE3 class instead of lE2 class for 4-pole direct-on-line operated motors with rated powers of 1,1 kW, 11 kW and110 kW.

The combined coal weight saving over their lifetime by selecting the three lE3 motors instead of the lE2 motors is more than 69 tons, corresponding to more than 166 tons of CO2, emissions which is equivalent to the annual emissions of 49 petrol cars driving 15 000 km per year with an average consumption of 0,80 | per 10 km. The combined extra weight of the three lE3 motors is 54 kg higher than the lE2 motors, which is based on the average weight of cast iron electric motors from catalogue data for the global market leading manufacturers. The development status of high-efficiency motors and new energy vehicles is understood through a review of the literature, and the direction of high-efficiency motor applications is made clear.

3. Applications

The application of high-efficiency motors in new energy vehicles will bring the following enhancements. The first is the enhancement of power output. High-efficiency electric motors are characterized by high power densities and torque densities, which enable them to deliver substantial power in brief bursts, satisfying the acceleration and ascent demands of fully electric cars [10]. Conversely, the wide speed range of high-efficiency electric motors may allow for a greater range of driving speeds.

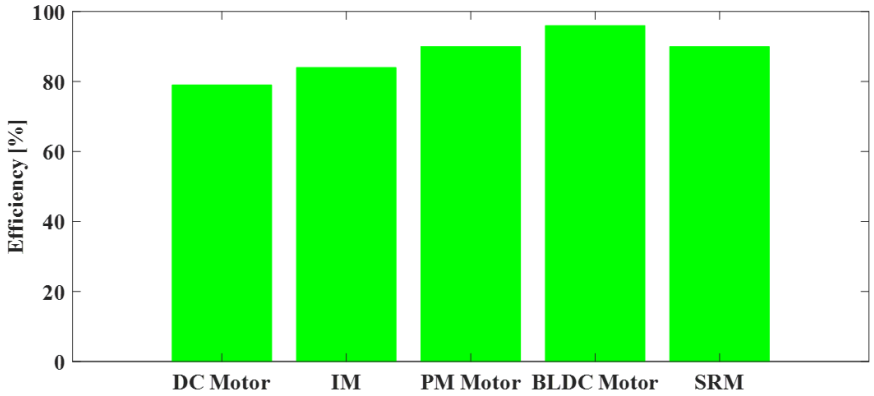


Fig. 3 Efficiency Cumulative Correlations of different topologies [11]

The second is the energy efficiency optimization. By utilizing cutting-edge cooling, material, and electromagnetic design, the high-efficiency motor attains a high energy conversion efficiency. The reduction of motor losses from lE1 to lE4 is typically around 45% [11]. The high-efficiency motor can run for a longer distance with the same battery capacity, which cuts down on the number of recharges and charging time. The third is the control of noise and vibration. During the design and production phases, high-efficiency motors consider the management of noise and vibration. It efficiently lowers the noise and vibration produced by the motor when it is operating, which improves driving comfort and the car's overall quality. It does this by optimizing the electromagnetic field distribution, strengthening the rotor construction, and using vibration-damping techniques [12].

Different types of motors have different performances in efficiency, see Fig. 3. Taken together, permanent magnet motors and induction motors are the more suitable motors for new energy vehicles.

4. Conclusion

This study examines the current literature and research findings to provide a summary of the current state of new energy vehicles, new energy applications, high-efficiency motors, and high-efficiency motors in the application of new energy vehicles. It also compares the performance and other indicators of various motors and shows the trend of high-efficiency motors in the application of new energy vehicles. Furthermore, this analysis categorized the existing state and the current state of development for new energy vehicles, as well as the status of motor development and motor application in these vehicles, are evaluated. This includes an examination of the various motor types, efficiency characteristics, and the distribution of motors with varying levels of energy efficiency. The energy-saving effect of IE4 high energy efficiency grade motors is preliminarily studied compared with IE1 energy efficiency motors, and the development trend of new energy vehicles and high efficiency motors is forecast. And the broad prospects for the future application of high energy efficiency motors in new energy vehicles. The paper has also looked forward to the way of the future application of high-efficiency motor technology in new energy vehicles by combining the development trend of science and technology with the market demand, to provide useful explorations and reflections for the sustainable development of new energy vehicle industry.

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