Present situation and prospect of new energy vehicle industry in China

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Abstract. As the global energy and ecological environment are facing severe challenges, the promotion of new energy vehicles is becoming more and more extensive. This paper introduces the concept and development history of new energy vehicles, summarizes the development status of pure electric vehicles, plug-in hybrid vehicles and fuel cell vehicles in China, further analyzes the development opportunities of new energy vehicle industry, and looks forward to its development prospect based on GM (1,1) grayscale prediction model. Finally, the development suggestions are put forward according to the problems existing in power battery technology, safety, market competition and infrastructure construction of new energy vehicles.

1. Introduction

Adhering to the advantages of environment-friendly and technology-intensive, new energy vehicles have been widely supported and favored by people. The development of new energy vehicles is an effective solution to solve the problems of traditional fuel vehicles, such as environmental pollution, lack of resources[1]. China has attached importance to the development of new energy vehicles since the 1990s. Nowadays, pure electric vehicles, plug-in hybrid vehicles and fuel cell vehicles have become the targets of vigorous development. The sales of new energy vehicles in China from 2013 to 2020 were 1.8, 7.5, 33.1, 50.7, 77.7, 125.6, 120.6 and 136.7 ten thousand vehicles respectively. China's new energy vehicle market accounted for 41% of the global new energy vehicle sales in 2020. Although China has introduced advanced technology and invested more funds to improve the development level of the new energy vehicle industry in recent years and has made certain achievements in the actual development process, power battery technology is still its main technical bottleneck[2].

Using the grayscale mathematical model to predict the sales volume of new energy vehicles in the next five years is helpful to grasp the development process and formulate the development vision as a whole. Under the current situation of great changes in international finance that has not happened in a century, Chinese new energy automobile enterprises need to recognize the current situation of development, tackle key battery technologies, improve infrastructure construction and service system, actively face the pressure of market competition, and realize the green and sustainable development of the industry.

2. New energy vehicles

New energy vehicles appear relative to traditional internal combustion engine vehicles. Traditional vehicles mainly use gasoline and diesel as the main raw materials, and polluting gases such as sulfur oxides and carbon dioxide will be emitted during driving, which will have a bad impact on the ecological
environment. The new energy vehicle is a new structure vehicle which integrates the drive control technology of the traditional fuel vehicle and is improved on the basis of it. Environmentally friendly is a prominent feature of the new energy vehicle. The first practical new energy vehicle was an electric vehicle invented by Robert Davidson in 1873. The emergence of electric vehicles opened the development of new energy vehicles, the initial development was good. As the development of technology lags behind that of internal combustion engine vehicles, although new energy vehicles started early, there was no substantial development in the middle and later stages of the 20th century. With the global shortage of oil resources and increasingly serious environmental pollution, new energy vehicles have entered a period of rapid development in recent years[3].

3. Development status of new energy vehicle industry

3.1. Pure electric vehicles
The pure electric vehicle is completely powered by the on-board power supply. It has the advantages of zero emission, low noise and easy maintenance, etc. It is the main development model of electric vehicles in China. According to the China Association of Automobile Manufacturers[4], sales of pure electric vehicles in China were 1.115 million in 2020, an increase of 12.17 percent over the same period. The fastest growth rate was 663.73% from 2014 to 2015. Due to the transformation of China's economic development model from high-speed growth to medium-to-high-speed growth, the growth rate of pure electric vehicles has slowed down since 2015, but overall sales have increased year by year, as shown in figure 1.

Although pure electric vehicles have made rapid development, they also face some problems such as long charging time and short mileage[5]. Battery and its management system, motor drive and its control technology, vehicle technology, lightweight technology and safety protection system are the core technologies to be solved and improved for pure electric vehicles[6]. China still has a long way to go to achieve the goal that pure electric vehicles will become the mainstream of new sales vehicles and fully automate the use of vehicles in the public domain by 2035.

![Figure 1. Sales and growth rate of pure electric vehicles in China.](image)

3.2. Plug-in hybrid electric vehicles
Plug-in hybrid electric vehicle contains not only the components of traditional vehicle such as engine, transmission system, fuel tank, but also the battery, motor and control circuit of pure electric vehicle, and is equipped with charging interface. It has the advantages of large battery capacity, long mileage and zero emission driven by pure electric power, so it is the best model to solve the problem of short mileage of new energy vehicles[7]. According to the China Association of Automobile Manufacturers[4], sales of plug-in hybrid vehicles in China were 25.1 ten thousand in 2020, an increase of 6.36% over the
same period, with a maximum growth rate of 878.11% in 2014. Overall car sales are on the rise, as shown in figure 2.

The main problems of plug-in hybrid electric vehicles are to improve the specific power and life of batteries, to develop more advanced and effective electronic control and detection systems, and to lighten the weight of electronic devices in China at present[8].

3.3. Fuel cell vehicles

Hydrogen and methanol produce electric current through chemical reactions, which become the power source of fuel cell vehicles, which has the characteristics of no noise, zero pollution, short fuel filling time[9], etc. According to the data of China Association of Automobile Manufacturers[4], 2737 fuel cell vehicles were sold in 2019, 6165 fuel cell vehicles were retained, and the installed capacity of hydrogen fuel cell was 128MW. Its sales were only 1177 in 2020, down 57% from the same period last year mainly due to the impact of the epidemic, but ranked second in the global market after South Korea. The sales of fuel cell vehicles in China in the past five years are shown in figure 3.

Judging from the current development situation, fuel cell vehicles in China have realized industrialization and commercialization, and have great potential for development. However, the working temperature and energy density of the battery, the power grade of the engine, the acceleration performance of the whole vehicle, and the preparation and storage of hydrogen are still the technical problems faced by China in the fuel cell field[10].

Figure 2. Sales and growth rate of plug-in hybrid electric vehicles in China.

Figure 3. Sales of fuel cell vehicles in China.

Figure 4. The proportion of new energy vehicles in total car sales.
4. Development opportunities and sales forecast of new energy vehicles

4.1. Development opportunities

4.1.1. The continuous expansion of industrial scale
With the continuous improvement of people's living standards, cars have become a means of travel for more and more people, the automobile market is showing prosperity. China's road transportation industry is developing rapidly, and the demand for commercial vehicles continues to grow. China's automobile industry has made remarkable achievements, and the scale of the automobile market is constantly expanding. At the same time, new energy vehicle industry is expanding year by year, and the market is developing rapidly[11]. The proportion of new energy vehicle sales in total vehicle sales in China is increasing from 2014 to 2020, as shown in figure 4.

4.1.2. Policy guidance
2021 is the first year of The Fourteenth Five-Year Plan, government departments continue to consolidate and expand the achievements of epidemic prevention and control, economic and social development, and scientifically implement macro policies. China's economic operation will remain within a reasonable range[12]. At the same time, China has issued a series of policies to promote the development of new energy vehicles. The latest Development Plan of New Energy Vehicle Industry (2021-2035) sets the goal for the industry and points out the way. New energy vehicles will continue to upgrade in the direction of electrification, intelligence, networking and digitalization, from policy-driven to market-driven.

4.1.3. Continuous improvement of national environmental protection awareness
Today, the world is facing serious trends such as shortage of oil resources, natural environment deterioration, and governments have given certain attention to environmental protection. China's ecological protection work, advocated environmental protection concepts and environmental policies are deeply rooted. More and more people's environmental awareness is continuously improved and has created a good prerequisite for the promotion of new energy vehicles.

4.2. Sales forecast of new energy vehicles based on grey model
The grey model is the core prediction model in the grey system, which accumulates the irregular original data into a regular exponential series, establishes a differential equation for the generated sequence, and then solves the equation. It can achieve high-precision prediction, simple operation and easy to test. Using GM model to forecast the sales volume of new energy vehicles in the next 5 years has important reference value for analyzing the market prospect of new energy vehicles in China and making development suggestions. The modeling process is as follows[13-14]:

(1) Generating cumulative sequence
With original sequence \( X^{(0)} \):
\[
X^{(0)} = \{X_1^{(0)}, X_2^{(0)}, X_3^{(0)}, \ldots, X_n^{(0)} \}
\]
Accumulating \( X^{(0)} \) to generate sequence \( X^{(1)} \):
\[
X^{(1)} = \{X_1^{(1)}, X_2^{(1)}, X_3^{(1)}, \ldots, X_n^{(1)} \}
\]
Where \( X_k^{(1)} = \sum_{i=1}^{k} X_i^{(0)} \), \( k = 1, 2, 3, \ldots, n \).

(2) Mean generating sequence \( Z^{(1)} \):
\[
Z^{(1)} = \{Z_1^{(1)}, Z_2^{(1)}, \ldots, Z_n^{(1)} \}
\]
Where \( Z_k^{(1)} = \frac{1}{2} (X_{k+1}^{(1)} + X_k^{(1)}) \), \( k = 2, 3, 4, \ldots, n \).

(3) Establishing differential equation
Supposing the sequence \( X^{(1)} \) satisfies the first order linear differential equation:
\[
\frac{dX^{(t)}}{dt} + aX^{(t)} = b
\]  \hspace{1cm} (4)

The equation (4) is discretized and the grey differential equation is obtained:

\[
X^{(0)}_k + aZ^{(1)}_k = b
\]  \hspace{1cm} (5)

Where \( a \) is the coefficient of development, \( b \) is the grey action.

(4) Finding the optimal solution of parameter \( a \) and parameter \( b \) by least square method.

(5) Establishing a prediction model \( \hat{X}_{k+1}^{(i)} \):

\[
\hat{X}_{k+1}^{(i)} = [X^{(0)}_1 - \frac{b}{a}] e^{-ak} + \frac{b}{a}
\]  \hspace{1cm} (6)

Where \( k = 0, 1, 2, \cdots, n - 1 \).

The prediction model of the original sequence is obtained by reducing the sequence \( \hat{X}_{k+1}^{(i)} \):

\[
\hat{X}^{(0)}_{k+1} = \hat{X}^{(i)}_{k+1} - \hat{X}^{(i)}_k = (1 - e^a)[X^{(0)}_1 - \frac{b}{a}] e^{-ak}
\]  \hspace{1cm} (7)

Where \( k = 1, 2, 3, \cdots, n \).

In the case of considering only the data, using the sales of new energy vehicles in China from 2014 to 2020, the above model is programmed in MATLAB to get the forecast data as shown in Table 1.

| Year | 2021 | 2022 | 2023 | 2024 | 2025 |
|------|------|------|------|------|------|
| Projected sales | 1897444 | 2371249 | 2963367 | 3703342 | 4628093 |

![Table 1. Gray forecast sales of new energy vehicles in China](image)

Figure 5. Forecast curve of sales volume of new energy vehicles in China.

Figure 5 shows the curve of the predicted result. As can be seen from the changing trend of the curve, although the sales volume of new energy vehicles in 2019 has declined somewhat, the overall sales volume is developing in a good direction. The relative residual of the model is \( Q = 0.1540 \), the ratio of variance is \( C = 0.3042 < 0.5 \), the probability of small error is \( P = 1 > 0.95 \), therefore the accuracy of prediction is excellent.
5. Existing problems and development suggestions

5.1. Existing problems

5.1.1. Shortcomings of power battery technology

As the power source of new energy vehicles, battery is the main technical bottleneck facing China at present. New energy vehicle power batteries mainly include lead-acid batteries, lithium batteries and hydrogen fuel cells. Energy density is the core technical index of them.

① The development of lead-acid batteries is slow. The specific energy of lead-acid batteries in China has increased from 20Wh/kg in the early stage to 40Wh/kg, but breakthrough technologies such as colloidal batteries, coil-type lead-acid batteries and lead-carbon super batteries were all developed abroad. In addition, the environmental pollution of lead-acid batteries is obvious, so there are few cases of their commercialization in the field of new energy vehicles.

② There is no substantial breakthrough in lithium battery technology. Lithium batteries mainly include ternary lithium batteries, LiFePO₄ batteries, LiMn₂O₄ batteries and solid-state batteries. The positive and negative electrode materials have the greatest influence on the mass energy density of them[15]. Chinese researchers have prepared electrode materials with high discharge specific capacity by means of high temperature solid phase reduction, spray drying combined with low temperature microwave hydrothermal method, mechanical grinding fluid mixing method, sol-gel method and oxygen-enriched sintering treatment, which have made contributions to the development of high energy density batteries. However, countries such as the United States, South Korea and Germany hold most of the patents in the lithium battery industry. Most of the research in China is based on existing technology without substantial breakthroughs.

③ The key material technology of fuel cell gets stuck. Japan, South Korea and other developed countries master the key material technologies such as fuel cell proton exchange membrane, catalyst, gas diffusion layer. China's perfluorosulfonic acid membrane proton exchange membrane has achieved 15 μm, which has good chemical and mechanical durability, but there is still a big gap compared with Nafion membrane and Dow membrane and Gore-selectTM composite membrane (America), Aquivion membrane (Belgium), Aciplex membrane and Flemion membrane (Japan) [16], etc. Although Chinese fuel cells have conducted in-depth research on platinum carbon, platinum alloying, core-shell, non-precious metal and other catalysts, the products do not have market competitiveness; China's gas diffusion layer supply has always been monopolized. Its core carbon fiber technology is mastered by Toray of Japan, so it is difficult for China to achieve mass production of high-quality carbon fiber raw materials and key equipment in the short term.

5.1.2. Insufficient security performance.

① Frequent accidents. In the early stage of the development of new energy vehicles, enterprises focus on the development of industrial scale and quantity, while ignoring the quality and safety of automobile products. In recent years, new energy vehicles have frequent safety and quality problems, including 53 accidents in 2018 and at least 187 accidents in 2019, including spontaneous combustion in driving, charging equipment failure, spontaneous combustion in parking, collision fire, etc.

② Low level of safety management technology development. The safety of lithium battery is not only the core of realizing automobile system safety, but also the fundamental bottleneck of battery safety technology in China[17]. Foreign researchers mostly start from the battery itself, using more advanced technology, through the development of new electrolytic liquid system, the introduction of new high pressure negative electrode, etc., to provide unprecedented high safety and high energy density cycle performance. Chinese researchers still need to redouble their efforts in this area.
5.1.3. Great pressure of competition in the external market

① The competition in the global new energy vehicle market is fierce. As early as during the Clinton and Bush administrations, the United States proposed policies to support the development of new energy vehicles. The American market has a high acceptance of new energy vehicles, and the subsidy policies are generally stable[18]. Tesla has become one of the most popular pure electric vehicles in the global market, and its popularity has not decreased for many years. Japan's lithium technology is the weather vane of the whole industry. It made plans in 2018 to sell only electric vehicles by 2050 to reduce greenhouse gas emissions by 90%. Japan's hybrid vehicles are the first in the world, while the focus on hydrogen energy use is fuel cell vehicles. The research and industrialization of products are also better than those of other countries. Toyota sold 1770 Mirai vehicles worldwide in 2020. Major European car companies have also increased their investment in new energy vehicles recently. The sales of new energy vehicles in the European market accounted for about 8% of the total car sales in 2020[19-20].

② Stabilizing global market positions by volume alone won't work. Developed countries such as the United States, Japan, South Korea and Europe master the core technology of new energy vehicles and attach great importance to the development of them, so it is difficult for China to maintain its market position only by sales.

5.1.4. Imperfect laying of basic service facilities

① A large infrastructure gap. A total of 1.681 million charging infrastructure had been built by the end of 2020, including 807000 public charging infrastructure, 874000 charging facilities equipped with cars and 25 large-scale operators with more than 100 charging stations. Charging piles cover AC, DC and AC / DC types. A total of 118 hydrogenation stations have been built, of which 101 have been put into operation and 17 have been waiting for operation. China's charging infrastructure basically supports the development of new energy vehicles on the whole, but it is still lower than the expected plan of "one vehicle, one project", and the gap is still huge.

② Uneven regional distribution. The uneven distribution of charging facilities will hinder the travel of new energy vehicles, making it difficult to travel across cities and provinces. The public charging infrastructure of Beijing, Guangdong, Shanghai, Jiangsu, Zhejiang, Shandong, Anhui, Hubei, Henan and Hebei ranks in the top 10, accounting for 72.3% of the national total, and most of them are coastal areas. The development of the region is extremely uneven.

5.2. Development proposals

① Increase investment in basic research and development. With the deepening of the transformation of China's new energy vehicle industry from policy-driven to market-driven, technology has become an important driving force to achieve this process. It is necessary to strengthen investment and seize the commanding heights in the field of new energy vehicles.

② Innovate production technology. Improve the level of technical capability, enhance the power and life of batteries, reduce the cost of batteries constantly, optimize the quality of electronic devices.

③ Enhance safety performance. Develop safer electrode materials, electrolytes, high-strength diaphragms, etc. Research and development of rapid power outage, fault prevention and control, battery health intelligent supervision and other advanced technologies, attach great importance to vehicle safety, and do a good job of prevention.

④ Improve supporting facilities and services. Accelerate the infrastructure construction of charging piles and charging stations for new energy vehicles. Create a networked, digital and intelligent charging system based on artificial intelligence technology. Build a humanized, personalized and intelligent service platform. Realize cross-regional cooperation and balance regional development.

6. Conclusion

In order to maintain the stable development of social economy, China must attach great importance to the problems of energy shortage and ecological environment pollution. The steady and green
development of automobile industry is an indispensable part of China's sustainable economic development. The data predicted by the grey model show that the sales of new energy vehicles will keep increasing in the next five years. China's new energy automobile industry needs to recognize the current situation of development, sum up development experience, grasp the opportunities of industrial development, face the pressure of market competition with a positive attitude, overcome difficulties in key technologies such as power batteries, and persist in innovation-driven development.

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