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Development Concept of New Energy Vehicles Based on Innovative Thinking

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Abstract: New energy vehicles provide an important opportunity for the transformation, upgrade, and high-quality development of China's automobile industry. This study analyzes the three elements required for innovation, namely ideas, talents, and atmosphere, based on the innovative thinking that should be maintained in the development of new energy vehicles. The thinking methods—prospective, differential, global, and circular thinking— required for innovation are also presented. On this basis, this study proposes that the new energy vehicle development be promoted by innovation, policies, and the market. Good products, infrastructure, and business models are crucial for the new energy vehicle development. Moreover, transport, energy, information, and cultural networks should be integrated. This study is expected to provide strategic references for the development of new energy vehicles in China.
Keywords: new energy vehicles; innovative thinking; development concept

1 Introduction

Over the past 40 years of reform and opening up, the automobile industry has become one of the pillars of China's national economy. The automobile manufacturing output accounts for approximately 2% of the total economic output [1]. In 2018, China's automobile sales volume totaled 28.0806 million, ranking first globally for 10 consecutive years [2]. New energy vehicles are an important direction for the future development of automobiles. Along with intelligence-based and interconnection development, new energy vehicles provide an important opportunity for the transformation and upgrade of China's automobile industry and the realization of high-quality development (Fig. 1). The emerging new technologies, models, and forms in the new energy vehicle development bring new challenges and opportunities to the automobile industry. Accordingly, the key points of the new energy vehicle development with innovative thinking must be further clarified.

2 Innovative thinking in new energy vehicle development

The new energy vehicle development in China benefits from a favorable industrial foundation and a broad market, which provide a chance for China to catch up with the rest of the world and realize lane-change overtaking. However, numerous key technologies must be broken through, and shortcomings must be strengthened. Therefore, adhering to innovative thinking and establishing the idea that innovation is the first driving force for development are of great importance. Measures should be taken to attract global innovative talents and support domestic and international cooperation. The cross-industry integration of new energy vehicles, new materials, and information technology should be facilitated. Moreover, a healthy environment of cooperation and competition must be promoted, and the protection of intellectual property rights must be improved to create a good foundation for the

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innovative development of the new energy vehicle industry.

2.1 Prospective thinking

The essence of prospective thinking is to think about the future based on the current situation. It is the key to grasping the future development direction. Relevant policy environment, industrial layout, and key technologies are constantly changing with the rapid development of new energy vehicles. Without prospective thinking, it is impossible to keep pace with the trend of industrial development and master the leading technologies, especially core technologies. Prospective thinking is conducive to the planning of the technological development path, definition of critical and breakthrough points, and strengthening of the technical reserve and scientific research and development. The ultimate goal is to achieve an independent innovation of key technologies.

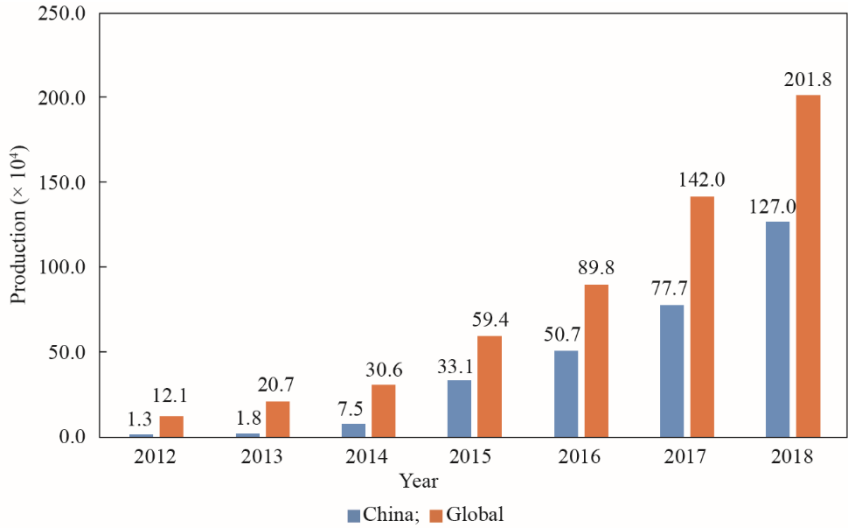

Fig. 1. Comparison of the new energy vehicle production between China and the global market.

Source: China Association of Automobile Manufacturers, Marklines and Evsales.

2.2 Differential thinking

Innovation differentiation means that the new energy vehicle development in China should consider the economic and social development levels as well as the current situation of the automobile industry and identify the focus and strategy for the development roadmap different from that adopted by foreign countries. In this way, China's new energy automobile industry can achieve a differentiated and unique development. The independent research and development capacity of China's automobile industry significantly improved after decades of efforts, especially the rapid development since the reform and opening up. However, a certain gap still exists compared to the advanced technologies of foreign countries. Pure electric and plug-in hybrid vehicles have been rapidly developed in China in the past decade. In addition, China has kept pace with the development of the intelligent connection technology and even achieved the leading position in certain areas in the recent years. These favorable factors provide a rare opportunity for China's new energy vehicle industry to adopt a roadmap different from that of foreign countries and realize lane-change overtaking.

2.3 Global thinking

Global thinking is a way of thinking involving the perception of things in a comprehensive, systematic, and connected manner rather than in a one-sided, scattered, and isolated way. The automobile industry features high relevance, wide coverage, high technical requirements, and strong comprehensiveness. Meanwhile, the new energy vehicle industry is going through different development stages. Pure electric and plug-in hybrid vehicles are in a transition period from the introductory to the development stage. Hydrogen fuel cell vehicles are evolving from the research and development to the introductory stage. Adhering to global thinking and strengthening top-level design are greatly significant in achieving the overall planning of the following three relationships: 1) relationship between new energy vehicles and the whole automobile industry; 2) relationship between different development strategies of

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pure electric, plug-in hybrid, and hydrogen fuel cell vehicles; and 3) cross-border integration of new energy and intelligent connected vehicles.

2.4 Circular thinking

The core of circular thinking is the efficient use and recycling of resources. Its principles are reuse and resource recovery. Circular thinking is also characterized by low emission, low consumption, and high efficiency and carries the belief that the new energy vehicle development should conform to the sustainable development concept. After decommissioning, the automobile power battery can be used for a long time in many energy storage scenarios; therefore, its service life has two cycles. Power battery recycling must be strengthened with circular thinking, including technology research and development, pilot operation and industrialization of echelon utilization, and recycling. From the perspective of low-carbon energy conservation, the carbon footprint of a new energy vehicle during its life cycle from production, use, and decommissioning must be comprehensively considered, and carbon emissions must be systematically assessed by establishing the life cycle database. Simply stacking batteries for endurance mileage improvement, which might lead to higher carbon emissions than traditional cars, is deemed inappropriate.

3 China's development concept of new energy vehicles

China's new energy vehicle industry is in a period of transition from rapid growth to high-quality development. The scale of the pure electric and plug-in hybrid vehicle industry is rapidly growing, and the overall technical level is significantly uplifted. Hydrogen fuel cell vehicles are in the stage of fundamental research and small-scale pilot operation. The pilot commercial operation of hydrogen refueling stations is being gradually promoted. New energy vehicles are currently in the critical period of transformation and upgrade. The development concept proposed herein aims to provide guidance and reference for new energy vehicle development.

3.1 Innovation driven

Scientific and technological innovation has always played a leading and supporting role in the new energy vehicle development. The core technologies of new energy vehicles must be continuously improved, and basic research and technological innovation in power batteries and drive motors must be strengthened.

High-energy density power batteries are urgently needed for new energy vehicle development. According to the goal of the battery research project, which is part of the priority plan of the Chinese Academy of Sciences, the energy density of a cell should be more than 300 Wh/kg by 2020 (Fig. 2). Currently, next-generation power batteries with a research focus are solid-state batteries, lithium–sulfur batteries, metal–air batteries, fuel cells, etc. However, the realization of industrialization within 5 to 10 years has little chance. Lithium-ion power batteries are expected to achieve the goal of 300 Wh/kg by 2020. Domestic teams have used a high-nickel ternary anode and a Si/C cathode to develop flexible packaging lithium-ion batteries with a specific energy of up to 300 Wh/kg. The technical performance of some samples was close to the application requirements, but the safety cannot meet all the international standards. Hence, a breakthrough in technological innovation is still needed.

For drive motors, improving power density without sacrificing efficiency is the mainstream research direction recognized internationally. High-speed drive motors are an important factor in achieving this goal. The volume and the weight of high-speed motors with the same power are much smaller than those of low-speed motors. The material cost in the mass production of motors mainly comes from the conductor, silicon steel stamping sheet, and neodymium magnet. Therefore, the power density of a motor is also closely related to the cost. A high-speed motor design is quite difficult; however, once finalized, mass production will have an obvious cost advantage. At present, the power density of advanced high-voltage drive motors in the world can reach 5–8 kW/kg, while that of some military motors can reach 9–10 kW/kg. The power density of drive motors on sale in China is generally 0.6–4 kW/kg, which is far behind the international standards. Research and development must further be strengthened to overcome the challenges in core technologies, basic materials, and key components.

3.2 Two-wheel drive

Over the years, comprehensive competitive advantages in the industry, market, infrastructure, policies, and regulations have been created in China's new energy vehicle industry, reflecting the positive incentive effect of the

two wheel-drive of policy and market. In the future, the two-wheel drive must be fully used according to different stages, levels, and situations of new energy vehicle development.

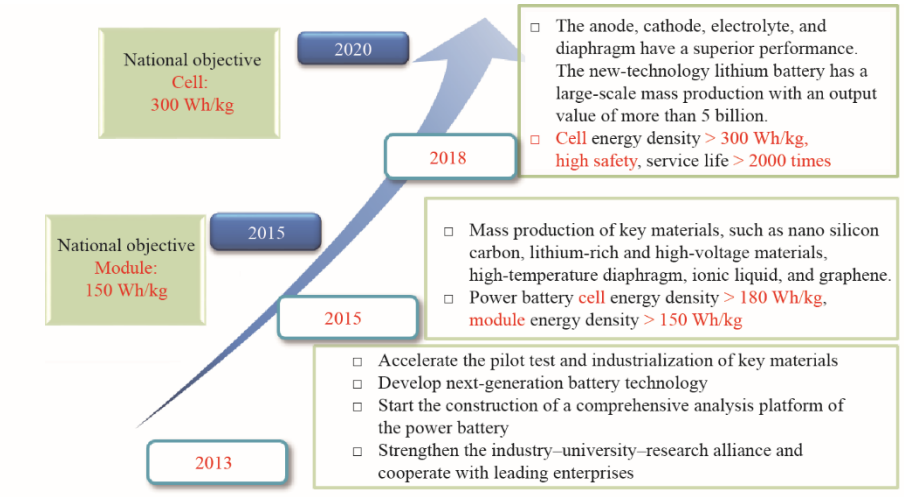

Fig. 2. Battery research objectives.

Note: The picture is drawn according to the objectives of the battery research project of the priority plan of the Chinese Academy of Sciences

The production cost of pure electric and plug-in hybrid electric vehicles is gradually reducing with the rapid market growth. The application advantages are gradually emerging, and the conditions for the withdrawal of financial subsidies by 2020 are being satisfied. The transition from simple financial subsidies to a comprehensive policy support, which can be reflected in tax relief, carbon trading, right of way support, and other aspects, must be considered. After the withdrawal of subsidies for pure electric and plug-in new energy vehicles, tax incentives, such as vehicle purchase tax reduction and exemption, should be maintained. Industrial policies, including fuel consumption standards and double credits, which can be transformed into the carbon trading mechanism at the appropriate time, should be strictly implemented. New energy vehicles should be promoted as an important means of urban atmospheric environment protection. New energy vehicle users should be given more right to purchase and road use. More customers will be guided by policies to purchase and use new energy vehicles. Meanwhile, making full use of the functions of market entities is important. At the policy level, specific requirements for parameters like energy density and endurance mileage should be gradually removed. Furthermore, the choice of technologies should be transferred to the enterprises and the market themselves. Market competition will forge a number of new energy vehicle enterprises and products with strong competitiveness and influence in the global market.

Hydrogen fuel cell vehicles are currently in the key stage of pilot commercial operation with a significant progress in technology research and development. Major global automobile companies have basically solved the core technical challenges of hydrogen fuel cell vehicles, and performance has reached the level of traditional vehicles. Meanwhile, research teams in China are also focusing on key technologies, and breakthroughs have been made in the catalyst and bipolar plate technologies. However, a gap between China and leading countries still exists in terms of fuel cell durability, key materials, core components, and hydrogen storage. Therefore, making full use of the collaborative advantages of the two-wheel drive and attaching importance to the policy introduction and market cultivation and development are essential. At the policy level, major national science and technology projects have been established to encourage domestic research and development teams to continuously tackle the key technical problems and focus on the key technologies of hydrogen fuel cells. The policy continuity must be maintained, and the financial subsidies for hydrogen fuel cell vehicles must be kept to encourage enterprises' continuous investment in hydrogen fuel cell vehicles. When new situations emerge, the corresponding technical standards and regulations on hydrogen energy management should be studied and issued on time. In terms of market promotion, priority should be placed in areas with favorable conditions for hydrogen energy development and utilization as well as new energy vehicle development. The pilot commercial operation of hydrogen energy production, storage, and transportation, hydrogen refueling infrastructure, and hydrogen fuel cell vehicles must be accelerated. The scale of

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hydrogen fuel cell vehicle use should be gradually expanded, and a complete industrial chain of materials, components, and systems should be cultivated and established.

3.3 Good products, infrastructure, and business model

The new energy vehicle development will ultimately be tested by the market and the consumers. Good products, infrastructure, and business models are important benchmarks for the high-quality development of new energy vehicles. The fundamental purpose of developing new energy vehicles is to provide good products, which are affordable and reliable for general consumers. An extensive, convenient, and secure infrastructure is the basis for eliminating the user experience gap between traditional and new energy vehicles. A good business model comes with innovation that integrates the electrification, intelligence, and interconnection of vehicles and drives the innovation and reform of the new energy vehicle industry.

The iteration cycle of new energy vehicle technologies and products is faster than that of traditional vehicles and getting shorter. With the rapid iteration, consumers have higher expectations for good products. In the future, with the accelerated retreat of subsidies and the full entry of foreign new energy vehicles into China, the new energy vehicle market will face a fiercer competition. The original phenomenon of relying on financial subsidies and designing products based on policies to obtain a certain market share will no longer exist. Enterprises should create competitive products and attract consumers by mastering the core technology and understanding customer needs. Meanwhile, more attention should be paid to the increasingly prominent safety issues of new energy vehicles. Enterprises have the primary responsibility for safety, which should have a higher priority than technical parameters like energy density, driving mileage, and charging convenience. The safety level should be improved in different stages of research and development, design, manufacturing, and service. Meanwhile, enterprises in power battery and automobile manufacturing and charging operation should strengthen cooperation, improve data connectivity, and form a platform and a mechanism for the cooperative analysis of accident causes and safety improvement.

The increase of infrastructure construction and the improvement of user convenience and satisfaction are the keys to promoting the wide application of new energy vehicles. China's electric vehicle charging stations have rapidly developed in the recent years. As of December 2018, China had already deployed 299 752 public charging stations with a year-on-year increase of 40.1% [3]. Although the charging infrastructure is rapidly developing, the industry is still confronted with problems, such as weak foundation and unbalanced development. More importantly, with the rapid growth in the number of electric vehicles, the disordered charging of vehicles during the peak demand may affect the power grid and increase the charging cost of users. Therefore, a charging network system that can link and control many charging stations must be built (Fig. 3). The charging network should be able to couple and interact with the power distribution network to realize a coordinated dispatching of both networks. The orderly charging of electric vehicles and the peak load shifting of the power grid operation can be realized through charging by off-peak power at night, charging directly by solar and wind energy, or charging indirectly by corresponding energy storage equipment. The solar and wind energy that cannot be absorbed by the power grid can be used for hydrogen production and storage, thereby providing refueling services for hydrogen fuel cell vehicles. Business model innovation plays an increasingly important role with the rapid development of the new energy vehicle industry. New energy vehicles are the best carrier of intelligence, interconnection, and sharing, which will inevitably accelerate the industry integration of information technology, finance, and new materials and promote the continuous innovation of a business model [4]. In the future, both product-oriented business models of vehicle sales and service and use-oriented business models, including car sharing, freight or passenger transport, and public transport, will exist in the new energy vehicle industry. Accordingly, the development of new energy vehicles must be promoted with more diversified and sophisticated business models: 1) the innovation of the financial insurance service must be further strengthened, and the financial incentives for car purchase and usage should be increased; 2) the popularization and the application of short-time car rental and intelligent connection should be promoted; and 3) the deep participation of vehicle enterprises in charging services should be encouraged, and vehicle enterprises should be supported in purchasing services from charging service operators.

3.4 Four-network and four-flow integration

The emergence of cars has not only changed the way people travel, but has also changed the world. However, automobile development has also brought various problems to the human society, such as air pollution, traffic jams,

and unsustainable energy. Therefore, automobile development needs revolution, the core of which is electrification, autonomous driving, and interconnection. The secondary energy used by new energy vehicles, such as electric or hydrogen energy, can be coupled with and optimize the primary energy. In this way, energy use and management can be improved in terms of informatization, digitalization, and interconnection. The combination of energy and automobile revolutions should be promoted to form the integration of transportation, energy, information, and human networks built for new energy vehicles and the energy flow, information flow, material flow, and value flow, namely, the combined four-network and four-flow integration.

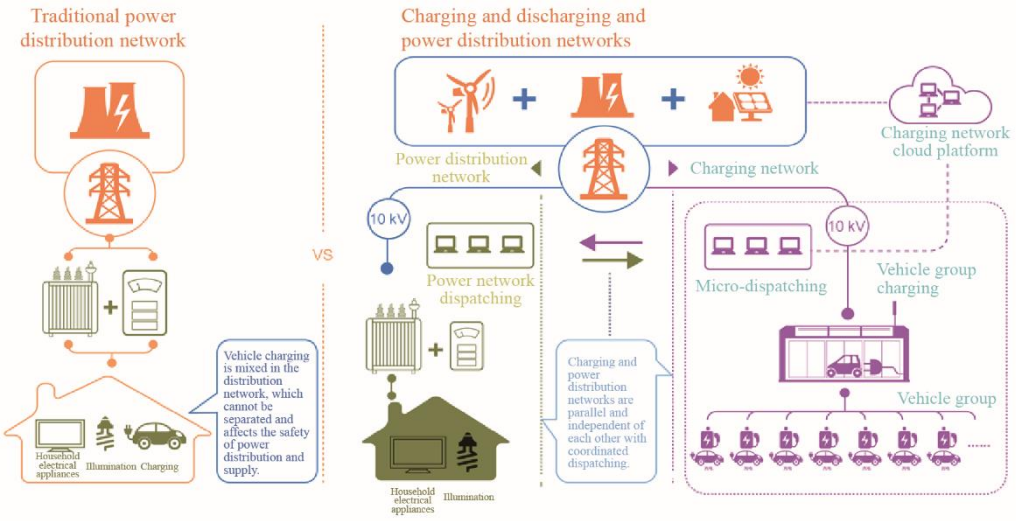

Fig. 3. Schematic diagram of the charging network.

Guided by the four-network and four-flow integration, the new energy vehicle development in the future should be based on humanized needs and rely on humanized wisdom. The vehicle development should involve a comprehensive consideration of the three dimensions, namely vehicle, road, and city, and adhere to the innovative design concept "owned by people, built for people, and enjoyed by people." Building a human-oriented architecture (HOA) is essential in realizing the coordination of perception, computation, and intelligence. The HOA is composed of three open architectures: vehicle electronic architecture (VEA), road sensing architecture (RSA), and city data architecture (CDA). In architecture design, vehicle, transportation, and city are regarded as a unified system, and the Internet of Things and the Internet are integrated (Fig. 4).

The VEA is a new vehicle electronic architecture that constructs an open system environment. In the VEA, each sensor can be freely called, and each software module can be freely reorganized. Therefore, developers, including third parties, can construct abundant functional categories with unlimited imagination at any time. In such a car, people can have access to various types of services, from food, music, information, to health care.

The RSA is the sensing platform in the HOA. Both in the vehicle and on the road, a large number of sensors are deployed to build a sensing network with a wide coverage. The road sensing system can be a supplement to the intelligent vehicle sensing system, reduce the sensor cost of intelligent vehicles, and provide a surrounding environment model free of blind spots for intelligent vehicles. The vehicle sensors can also provide various real-time dynamic data for the traffic and the city.

As a data-processing platform, the CDA is used to process huge amounts of heterogeneous data generated by the HOA system, that is, data of different formats and sampling frequencies generated by different Internet of Things. With the aid of artificial intelligence, the data are analyzed and reconstructed, and the edge computing capacity deployed on the road and in the vehicle is used for data processing. Hence, the data can be effectively used by different systems.

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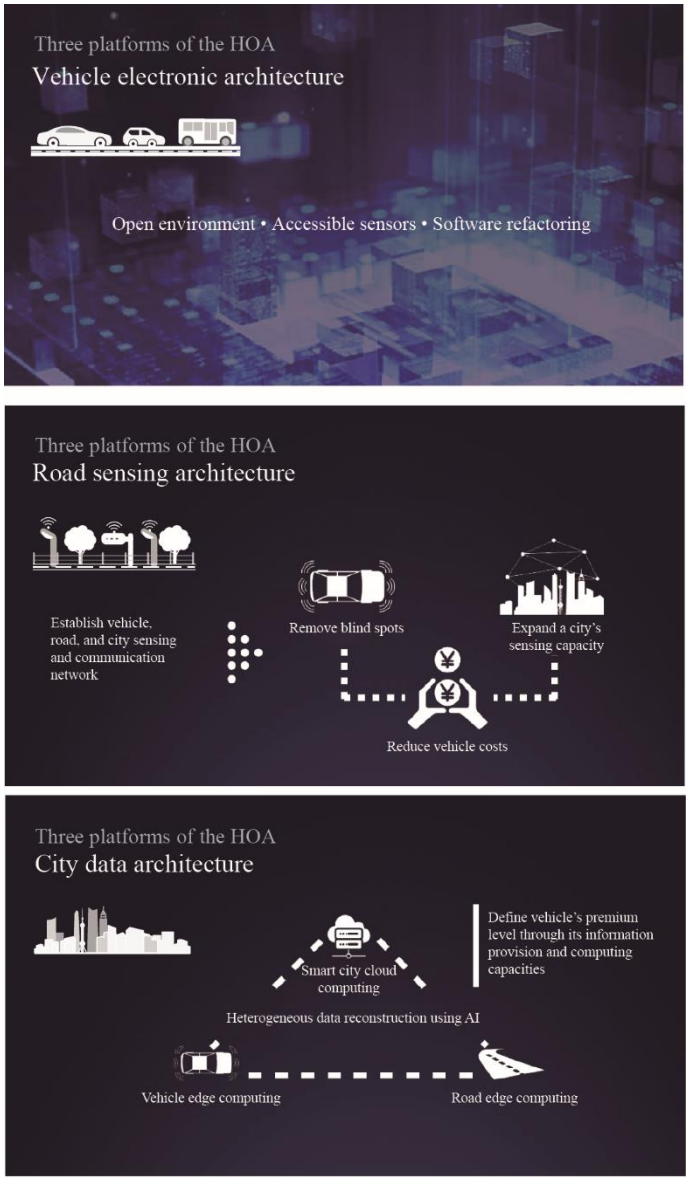

Fig. 4. HOA system architecture.

4 Conclusion

The new energy vehicle industry is a representative strategic emerging industry with a key focus. This industry achieved a leap-forward development in China in the recent years. However, obstructions of numerous technical bottlenecks, high comprehensive cost, and difficult market promotion still exist. Innovative thinking is fundamental to the high-quality development of the new energy vehicle industry, problem solving during industrial development, and prevention of detours and mistakes. The innovation entities of industry, university, and research must be combined. Moreover, the collaborative advantages of policy and market must be fully used. Efforts should also be devoted to developing good products, infrastructure, and business models and promoting the automobile revolution represented by electrification, autonomous driving, and interconnection. In combination with the energy revolution represented by low carbon, intelligence, terminal energy electrification, and hydrogen energy, the transformation and upgrade of China's automobile industry can be promoted, and the goal of becoming an advanced automobile manufacturing power can be achieved faster.

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