Core Technologies Identification of China's New Energy Vehicles Based on Patent Analysis

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Abstract. With the worsening of the global environment, energy conservation and environmental protection have become an inevitable trend in the development of modern vehicles, and new energy vehicles have been widely used in the world. Core technologies identification of new energy vehicles will help to clarify the development trend of new energy vehicles in the future and promote sustainable development. Firstly, Apriori algorithm is used to analyze the support of new energy vehicle technology and find the ones with strong technical relevance. Then, based on the concept of relative technical similarity, the technical distance and technical similarity are measured. Finally, patent portfolio analysis is conducted to identify the core technologies of new energy vehicles.

1 Introduction

Taking the path of sustainable development is the top priority in the world, which is conducive to the development of all mankind. With the concept of sustainable development deeply rooted in the hearts of the people, the new energy automobile industry is also developing, and China attaches more and more importance to the development of new energy. New energy vehicles, which use new energy, new materials, artificial intelligence, Internet and other transformative new technologies, can promote the optimization of energy structure, improve the transportation system and the intelligent operation level of urban infrastructure, which is of great significance to the sustainable development of environmental protection and the construction of a clean city. Developing new energy vehicles is the only way for China to become an automobile power, and it is also a strategic measure to deal with climate change and promote the green development of the automobile industry. The main purpose of the research is to clarify the core technology and future main development direction of the new energy vehicle industry, so as to provide suggestions for the development of new energy vehicles worldwide.

2 Figures and tables

This study takes the patent data of new energy vehicles in China in the past 20 years as the research object. A total of 27,976 patents related to the field of new energy vehicle technology have been screened through data cleaning methods such as the removal of variation data and duplicate data. According to classification rules, IPC classification numbers are classified step by step, including a five-tier system of department, category, sub-category, large group and small group. The higher the level, the greater the degree of cross-field. According to the classification rules, the first four digits of IPC classification number represent the sub-category of this technology, and the analysis of their number can intuitively observe the core technologies in this field, so the first four digits of IPC classification number are selected for research. This paper refers to the research of Xu [1], Zhao [2], Mao [3] and others to identify the core technology of new energy vehicle patents.

2.1 Life cycle analysis of new energy vehicle patent technology

Based on the life cycle theory and the specific development trend, the development of Chinese new energy vehicle technology is divided into three stages: the starting stage, the growing stage and the mature stage, as shown in Figure 1 below.

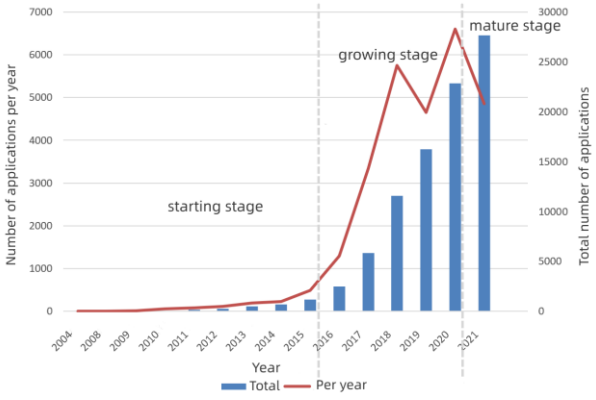

Fig. 1. Life cycle map of China's new energy vehicle patent technology from 2004 to 2021.

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According to the actual analysis, before 2016, the number of patents in the field of new energy showed a small total amount and a low growth rate. By 2016, the total number of patents was only 1188, so the period before 2016 is defined as the starting stage of China's new energy vehicle technology. From 2016 to 2020, the number of related patents in the field of new energy vehicles grew rapidly, from only 2,483 patents in 2016 to the maximum number of applications in a single year of 22,827 in 2020, with an increasing growth rate. Therefore, this period is determined as the growing stage of the life cycle of new energy vehicle technology. From 2020, the number of patents in the field of new energy vehicles is still growing, but the application began to reduce gradually, from 6,597 in 2020 to 4,855 in 2021, the new energy vehicle technology has entered the mature stage of development.

Due to the outbreak of the novel coronavirus epidemic in 2020, the new energy vehicle industry, which has not been fully established, is facing severe problems. At the present stage, the innovative breakthrough of the new energy vehicle industry has become more difficult. Correctly identifying the patented core technology of new energy vehicles and grasping the development prospect of new energy vehicles can re-stimulate the development vitality of the new energy vehicle industry.

2.2 Analysis of association rules and Apriori algorithm

Based on the Apriori algorithm, the support degree analysis shows that heat exchange piping system, refrigeration and heating system, power supply system, digital processing and recording carrier, power supply system and power device, ticketing system and traffic control, electricity conduction and power device all appear at the same time in very high proportion, indicating that these technologies have strong technical correlation.

2.3 Formatting the text

To identify core technologies based on technology coclass analysis, it is necessary to measure their technical distance, or technical similarity. In the measurement of technical distance, scholars mostly use the frequency of key times of patent technology as the patent vector, and use Euclidean distance to measure the distance between vectors, such as Yoon [4], Chang [5]. In coclass analysis, scholars mostly use Jaccard coefficient and Salton cosine function [6]. Leydesdorff [7] makes a detailed comparison between Salton cosine function and Jaccard coefficient. And, Li [8] believes that Salton cosine function can describe the degree of correlation between two variables in statistics, but it is not suitable for measuring the relationship between two technical fields. He proposes the concept of "relative technical similarity", so as to measure technical distance more carefully. Assuming that A and B represent two different technology fields, $n_{A\cap B}$ represents the number of patents possessing two classification codes, then the technology similarity $R_{A\to B}$ of technology A relative to B can be expressed as:

$$R_{A\to B}=\frac{n_{A\cap B}}{n_A}\times 100\% \tag{1}$$

where, $n_{A\cap B}$ represents the number of patents appearing together with the patent class numbers of technology field A and B, and n_A represents the number of patents in technology field A. The calculation result is between 0 and 1. The closer the result is to 1, the more similar technical field A is to technical field B; otherwise, the smaller it is. After calculating the similarity of each corresponding technology, a technology correlation matrix can be constructed, as shown below:

$$\begin{pmatrix} 1 & R_{A\to B} & R_{A\to C} & R_{A\to D} \\ R_{B\to A} & 1 & R_{B\to C} & R_{B\to D} \\ R_{C\to A} & R_{C\to B} & 1 & R_{C\to D} \\ R_{D\to A} & R_{D\to B} & R_{D\to C} & 1 \end{pmatrix} \tag{2}$$

This matrix is an asymmetric matrix, where the sum of each row of the matrix corresponds to the technology similarity, which can reflect the overall similarity ability of this technology field. The value is directly proportional to the importance and similarity of this technology, which can reflect the similarity strength of this technology to other technologies. The sum of each column of the matrix corresponds to the technology richness [9], and the higher the value, the more it reflects the promoting effect of this technology on other technology fields. After obtaining the technical similarity and technical richness of each technology, these two data characteristics are used for analysis, and then the identification of core technologies under this model dimension is realized.

This paper draws on the patent portfolio analysis method proposed by Ernst [10] in 1998, and identifies the core technologies of new energy vehicles according to the "technology similarity" and "technology richness" of patented technologies. As shown in Figure 2 below, the horizontal axis represents the technological similarity of new energy vehicles, and the vertical axis represents the technological richness of new energy vehicles.

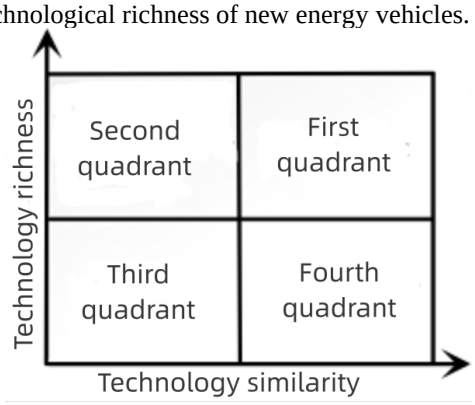

Fig. 2. Core technology identification quadrant diagram.

The first quadrant is characterized by high technology similarity and high technology richness, which is the

current research hotspot and mainstream technology. Technology in the second quadrant is characterized by low technology similarity and high technology richness. The technology in this region is generally the power source to promote the development of technology in this field and usually needs to be focused on, so it is called potential technology in this paper. The third quadrant is characterized by low technology similarity and low technology richness. The technologies in this region may be non-core technologies that can be ignored, or they may just emerge and be developed into potential technologies and core technologies in the future. The technologies in this region need to be identified according to the development trend of technologies. The technology characteristics of the fourth quadrant are high technology similarity and low technology richness, indicating that the technology has a certain degree of importance, but it does not show the characteristics of supporting the development of other research fields. The technologies that exist in this quadrant need to be carefully identified in light of their trends, as some of them are likely to evolve into core technologies in the future.

2.4 Technical similarity analysis

The pre-processed initial data is used in the data. Since this model mainly reflects the similarity between the two technologies in the way of numerical value and matrix, it has certain requirements for selecting the initial technology to be processed. In order to quickly identify core technologies in multiple dimensions and more comprehensively, this model identifies core technologies in China's new energy field in recent years from two perspectives of "technology similarity" and "technology richness". After the Top20 similarity matrix is obtained, the thermal map visualization analysis is carried out on it. Secondly, the technology richness and technology similarity of 20 technologies are calculated through the model. According to the model theory, the technologies with the larger technology richness and technology similarity occupy the main influence in the main fields. Therefore, the technology similarity and technology richness are used as the standard to analyze the patent portfolio of all popular technologies, draw the lattice diagram of technology richness and technology similarity, and preliminarily identify the core technologies in the field of new energy vehicle research.

The results of the first ten IPC combinations of technical similarities calculated from the first Apriori model are shown in Table 1 below:

Table 1. The result of Apriori model.

IPC1	IPC2	Technical similarity
B33Y	B22C	0.5454545
F28G	F25B	0.5454545
G07F	B60L	0.5426829
F24H	B60H	0.5416667
H01R	B60L	0.5347044
A01M	B60L	0.5294111
F16M	B60L	0.5172413
C09K	C08K	0.5102045
C09K	C08L	0.5102043
F21W	F21Y	0.5102041

According to the technical similarity formula, the matrix is obtained and the results are analyzed visually, the heat map is as follows in Figure 3:

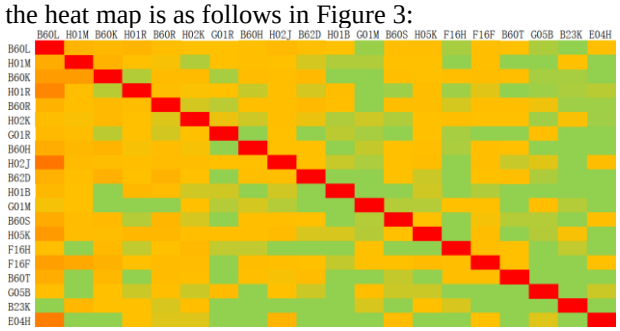

Fig. 3. IPC technical similarity matrix.

Through the patent portfolio analysis method, a line with technology similarity equal to 0.14 and a line with technology richness equal to 0.23 are selected for the horizontal and vertical axes of the quadrant, and the twenty technologies are divided into four parts. The two-dimensional quadrants are obtained as follows in Figure 4:

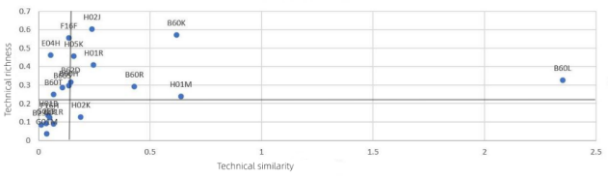

Fig. 4. Key techniques identify two-dimensional quadrants.

2.5 Technical distance and patent portfolio analysis results

In the heat map, red represents 1 and green represents 0, and the closer you get to red, the larger the value of the cell. Since the ranking of technology names in columns and rows is based on the number of times that a single technology appears in all patents, it can be seen from a macro perspective that the value of the upper left part is generally larger, while the value of the lower right part is generally smaller.

In the analysis of patent portfolio, a line with technology similarity equal to or equal to 0.14 and a line with technology richness equal to or equal to 0.23 are selected for the horizontal and vertical axes of the quadrant, and 20 technologies are divided into four parts. Electric vehicle power plant (B60L), method or device for direct conversion of chemical energy to electric energy (H01M), arrangement or installation of vehicle power plant or transmission device (B60K), vehicles, vehicle accessories or vehicle components not included in other categories (B60R), electrical device or system for power supply or distribution (H02J), Motor vehicle

trailer (B62D) and other technologies show high technical similarity and high technical richness, which is the current research hotspot and mainstream technology.

The vehicle power unit (B60L) has the highest occurrence rate among all patents. Compared with other technologies, the support of a single technology is far higher. Nearly 48% of patents contain the technology of vehicle power unit. Nearly 40% of the patents for circuit devices or systems that include power supply or distribution include the technology of vehicle power devices, which shows that the two technologies are highly similar and have a high probability of appearing in the same patent at the same time.

Modern new energy vehicles mostly use electric energy as their energy power. From the perspective of the development of global new energy vehicles, their power sources mainly include lithium-ion batteries, nickel-hydrogen batteries, lead-acid batteries, and supercapacitors, of which most supercapacitors appear in the form of auxiliary power sources. According to the model data, nearly 30% of patents in the past ten years are related to the methods and devices that directly convert chemical energy into electrical energy, and battery packs. Similar to this technology is the vehicle power unit (B60L) and the arrangement or installation of vehicle power unit or transmission unit (B60K). However, because most battery technologies are not fully mature or have obvious shortcomings, there are many gaps compared with traditional vehicles in terms of cost, power and mileage, which is also an important reason and bottleneck restricting the development of new energy vehicles.

The arrangement or installation of vehicle power unit or transmission unit occurred 3308 times in the overall research data, nearly 12%. In the technical similarity model, it can be found that the layout or installation of the vehicle power unit or transmission unit is special because of its high technical richness, which means that it is associated with many technologies, often appears together with other technologies, and its probability of independent occurrence is low. The layout or installation of vehicle power unit or transmission device mostly appears together with other core technologies. In most patents, this technology is not the core problem to be solved, but its high technical richness also makes it occupy a significant position in the field of new energy vehicle technology.

In general, at present, the technical focus and difficulties of new energy vehicles are still concentrated on the power unit and battery technology. However, considering the relevance and similarity of technologies, solving these technical difficulties requires the cooperation and research of talents with multiple technologies to better solve the problems from the overall perspective.

3 Conclusion

Due to the trend of diversification, decentralization and acceleration of technological innovation, global new-energy automobile enterprises can improve their competitiveness by optimizing the technology acquisition strategy of existing technologies and making industrial investment. The identification of the core technologies of new energy vehicles is conducive to the development of the global new energy vehicle industry in the future, and more conducive to the sustainable development of all mankind.

References

1. Xu X. Gui M. Research on Identification and Layout of Core Technologies of New Energy Vehicles Based on Machine Learning. Science and Technology Management Research **41**, 11 (2021)
2. Zhao P. Lin W. Jiang T. Ma T. Research on Identification and Evolution of Core Technologies in Solar Photovoltaic Field in China Based on Patent Analysis. Science and Technology Management Research **42**, 184-191 (2022)
3. Mao J. Du Y. Miao C. Hao C. Constructing and Applying a Key Core Technology Identification Model Based on Patent Co-Occurrence: Taking Lithography Technology as an Example. Journal of Intelligence **41**, 7 (2022)
4. Yoon B. MAGEE C. Exploring technology opportunities by visualizing patent information based on generative topographic mapping and link prediction. Technological Forecasting and Social Change **132**, 105-117 (2018)
5. Chang S. Using patent analysis to establish technological position: two different strategic approaches. Technological Forecasting and Social Change **79**, 3-15 (2012)
6. Wang X. Liu Z. Hou H. Technology development and technology competition of enterprises based on patent co-citation analysis: A study on industrial enterprises of Fortune 500. Science Research Management **31**, 127-138 (2010)
7. Leydesdorff L. On the normalization and visualization of author co-citation data Salton's cosine versus the Jaccard index. Journal of the American Society for Information Science & Technology **59**, 77-85 (2010)
8. Li Y. Relative Technical Correlation Research based on the Field of Technology -- A Case Study on Co-classification Analysis of Derwent Patent Manual Code. Science & Technology Progress and Policy **34**, 146-153 (2017)
9. Liu J. Meng Z. Jiang Z. Analysis on Core Technologies and Cutting-edge Technologies of New Energy Based on Input-output Method. ence & Technology Management Research **174**, 1036-1045 (2017)
10. Ernst H. Patent portfolios for strategic R&D planning. Journal of Engineering and Technology Management **15**, 279-308 (1998)