Analysis of the BEV Technology Progress of America, Europe, Japan and Korea Based on Patent Map

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Abstract: The paper analyzed the Battery Electric Vehicle patent application trend, major country distribution, main technology layout and patentee of America, Europe, Japan and Korea based on patent information from 2006 to 2016 by using patent map method, and visualized the Battery Electric Vehicle technology progress conditions of the four countries and regions in the last decade.

1. Introduction
America, Europe, Japan and Korea are the four most fast developed countries and regions in the field of global electric vehicle except for China, and their technology R&D are always leading the main direction of global electric vehicle progress in the world. Patent is the best way of technology protecting, and it also is the most important achievement manifestation of technology R&D, and contains rich technology information, economic information and legal information. Patent is an important symbol of technology market and industrialization, and the enterprise technical innovation decision-making important basis and guideline of imitation innovation. The paper analyzed the Battery Electric Vehicle (BEV) patent application trend, major country distribution, main technology layout and patentee of the four countries and regions based on patent information, and can provide references for the BEV strategic layout and technology research in China.

2. Data Sources and Analysis
All the BEV patent data comes from the Derwent Patent Database: Thomson Innovation(TI), and search strategy is edited by combining IPC codes, key words and Derwent Manual Codes together, and obtained 16393 American patents, 6994 European patents, 25079 Japanese patents and 6908 Korean patents from 2006 to 2016 totally, and searched on January 1, 2017. Then the patent data is processed and analyzed by using the patent analyzing software, such as TDA, TI and Innography, etc comprehensively, thus the BEV technology R&D progress of America, Japan, Europe and Korea since 2006 are obtained.

2. Development Trend Analysis
2.1. Patent Application Trend Analysis
Figure1 is the BEV patent application and publicity of America, Europe, Japan and Korea since 2006, and it shows that patent application and publicity in America are both rise year by year, especially the patent application increases rapidly since 2008; the patent publicity increases continuously and steadily in Europe, and the application increased steadily before 2012; Japanese patent application had
a slight decrease in 2007, then started to increase steadily after that, and the application reached to the peak in 2011, later started to decrease constantly, the patent publicity increased steadily year by year, and reached to the peak in 2014, while it had a slight decrease in 2015 and 2016; Korean patent application increased continuously and rapidly from 2006 to 2011, the publicity basically increases constantly and steadily, and started to increase in 2016 after a slight decrease in 2015.

![Figure 1. BEV patent application and publicity trend](image)

As it needs 18 months to 3 years from the patent application to the publicity, so the patent application data in recent three years is not complete, the development trend of the recent three years can refer to the patent publicity.

### 2.2. Researchers Trend Analysis

It can be seen from the researchers changing tendency in Figure 2 that the researchers changing trend of America, Europe, Japan and Korea are basically similar, there are many researchers enter into the BEV field every year, and also some researchers have quit this field. The total number of researchers increases steadily after it had a slight decrease in 2008 in America, and increases steadily since 2006 in Europe, and increased steadily from 2006 to 2011 in Japan, the number of researchers in Korea basically presents a steady increase trend except for two slight decrease in 2009 and 2013.
3. Main Patent Application Countries Analysis

3.1. Main Countries Distribution
In addition to the local patent applying, many other countries also have applied for BEV technology patents in America, Europe, Japan and Korea, Figure 3 shows that America, Japan and Korea all have the most local patent applications; the patent number of America, Japan, Korea, Germany and France applying in the big four markets rank top five in turn; Japan has an absolute leading position in the big four markets, and its local patent application even has reached to 91.72%, the number of patent application in Europe market reaches to 48.2%, which is well above America, whose patent number ranks second, and the number of patent application in America and Korea have highly reached to 38.31% and 26.51% respectively. China also has applied BEV patents in the big four markets, while the patent number are all quite less.

Figure 3. Main Application Countries Distribution
3.2. Main Countries Technology Layout
Table 1 is the top ten IPC codes of the four markets, and it shows that the technology mainly concentrates on the BEV core technology fields, for battery technology, traction motor and motor control system, etc. Battery is the heart of electric vehicles, so the relative IPC codes H01M has the most patent layouts in every market.

| No. | America | Europe | Japan | Korea |
|-----|---------|--------|-------|-------|
|     | IPC     | Number | IPC   | Number | IPC     | Number | IPC   | Number |
| 1   | H01M    | 6870   | H01M  | 3580   | H01M    | 14089  | H01M  | 4188   |
| 2   | H02J    | 2544   | B60L  | 1923   | B60L    | 6361   | B60L  | 1480   |
| 3   | B60L    | 2503   | H02J  | 1281   | H02J    | 4230   | H02J  | 906    |
| 4   | H02P    | 1098   | G01R  | 560    | B60K    | 2287   | G01R  | 422    |
| 5   | G01R    | 856    | B60K  | 532    | B60W    | 1792   | B60W  | 308    |
| 6   | B60K    | 829    | B60W  | 458    | H02P    | 1700   | B60K  | 292    |
| 7   | H02K    | 737    | H02P  | 394    | H02M    | 1408   | H01G  | 289    |
| 8   | B60W    | 730    | H02K  | 314    | G01R    | 1350   | H02P  | 214    |
| 9   | G06F    | 718    | H02M  | 312    | H01G    | 1319   | H02K  | 209    |
| 10  | H01G    | 535    | H01G  | 233    | H02K    | 1243   | C01B  | 139    |

4. Main Patentee Analysis

4.1. Main Patentee Distribution
Figure 4 shows the top ten patentees of BEV technology in the four markets, Toyota Motor Corporation technology R&D holds leading Status, and ranks first in America, Europe and Japan patentees, ranks third in Korea patentees. Among the top ten patentees of America, there are two local enterprises, five Japanese enterprises, two Korean enterprises, the two local enterprises are General Motors Corporation(1011 patents, ranks 2) and Tesla Motors Corporation(275 patents, ranks 10); Among the top ten European patentees, there are five Japanese enterprises, two Korean enterprises, and German Bosch, French Renault, and SB LiMotive. Japanese top ten patentees are all local enterprises. Among the top ten Korean patentees, there are five local organizations.
4.2. Main Patentees’ Technology Layout

Figure 5 is the main patentees’ technology layout, it shows that different enterprises pay attention to different technology fields in different markets, for in America, Toyota concerns more about the active materials and Energy Storage Device, while GM pays more attention to Battery Cells; In Europe, Toyota concerns more about Energy Storage Device, Bosch mainly concerns about Battery Cells, and LG Chem concerns more about the Secondary Battery; In Korea, LG Chem concerns more about Secondary Battery, Toyota pays more attention to Negative Electrode. Hitachi concerns more about Secondary Battery.
5. Conclusions
The paper analyzed the BEV technology R&D status of America, Europe, Japan and Korea based on patents information, we can see the BEV technology R&D of four countries and regions present the following features:
(1) The BEV technology R&D trends of the four markets are basically similar, and all have developed rapidly since 2006, the number of researchers keeps increasing as well.
(2) The BEV patents of the four markets mostly are applied for by the organizations coming from America, Japan, Korea, Germany, France and China.
(3) Japan occupies the leading position in the four markets, and the number of patent application occupies quite high proportion both in local and European markets, and ranks second both in American and Korean markets.
(4) The technology patent distribution of the four markets mainly concentrates on the core technology fields of BEV, for battery technology, traction electric motor technology and motor control system, etc.
(5) The BEV technology R&D of Toyota Motor Corporation account for absolute leading position, ranks first among Japanese, American and European patentee distributions, and ranks third in Korea.

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