International patent analysis of water source heat pump based on orbit database

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Abstract. Using orbit database, this paper analysed the international patents of water source heat pump (WSHP) industry with patent analysis methods such as analysis of publication tendency, geographical distribution, technology leaders and top assignees. It is found that the beginning of the 21st century is a period of rapid growth of the patent application of WSHP. Germany and the United States had done researches and development of WSHP in an early time, but now Japan and China have become important countries of patent applications. China has been developing faster and faster in recent years, but the patents are concentrated in universities and urgent to be transferred. Through an objective analysis, this paper aims to provide appropriate decision references for the development of domestic WSHP industry.

1. Introduction
Patent data is an important indicator to measure the ability of technological innovation. Patent analysis is a unique measure for predicting technology trends, analyzing the main competitors, and providing appropriate decision making references for the state and enterprises [1-4]. The analysis on patent information of water source heat pump (WSHP) has important strategic significance in accelerating the development of domestic WSHP industry.

As an applicable method for renewable energy utilization, WSHP is one of the frontier topics of the international air-conditioning and refrigeration industry. Driven by some amount of external power, WSHP uses flowing water as low grade source to accomplish the work of transferring energy from the heat source to the heat sink [5]. Since the main heat source is natural renewable energy or industrial waste heat, WSHP is a technology with great potentialities due to its high efficiency and low energy consumption characteristics [6].

The research of WSHP began in the 1950s. United States designed heat pumps for heating by absorbing heat from groundwater or river water. However, their reliability was questioned because of corrosion problems [7-9]. Since the world energy crisis broke out in the 1970s, various countries all have paid more attentions to WSHP. After continuous improvement, the technologies of WSHP have been becoming mature, and the products have been increasingly commercialized. In recent years, numerous studies have been conducted to describe the development, characteristics and performance of WSHP [10-15]. However, the analysis on patent information has not been reported widely. Based on patent analysis, this paper analyzes several aspects of WSHP such as patent publication tendency, geographical distribution, technology leaders and top assignees to provide appropriate decision references for the development of domestic WSHP industry.
2. Patent analysis
The international patent data of WSHP comes from the orbit database. The orbit database is an intellectual property portal developed by Questel that can search more than 90 patent authorities worldwide. By the time of December 10, 2016, 2742 international patents of WSHP had been published (Considering the time lag between the publication and the point in time at which the invention was completed, this paper presents results on the basic analysis of international patents with publication years ranging from 1960 to 2014).

2.1. Development tendency analysis

As is shown by figure 1, the technologies of WSHP have been developed for over fifty years with an increasing trend since 1960s. Some significant achievements have been attained ever since, so that the development of WSHP is being boosted greatly. It can be seen that there are four stages of WSHP development:

1) Seed stage (1960-1984): In this stage, the number of patent publication rose from 1 in 1960 to 22 in 1984. The rapid development of industrial economy led to imperative demand of heating, and promoted the development of underground WSHP. Since the world energy crisis broke out in 1973, various countries had set their sights on heat pump energy-saving technology. They had invested funds and human resources to conduct research, production and installation of heat pumps.

2) Decline stage (1985-1993): The amount of patent publication started to shrink in this stage. Europe was the relatively mature area of WSHP, but there were many installation projects failed because of the lack of communication between experts and installation workers. In addition, the high price of units hindered the development of WSHP. The above mentioned reasons led to the decline of patent application and publication.

3) Bottleneck stage (1994-1999): The annual patent quantity fluctuated in the range of 2 to 9. Some countries focused on theoretical researches and tests of key technologies such as corrosion, heat absorption and heat conduction efficiency, and some countries committed to solve energy problem with solar energy. Therefore, the patent publication of WSHP kept low.

4) Rapid growth stage (2000-): The number of patent publication has explosive growth from 2000 and comes to a summit in 2014. Along with the energy crisis and environmental pollution, the concept of sustainable development made the world turn to heat pumps again. The vigorous extension of WSHP triggered a new upsurge of patent application.

Figure 1. International patent publication tendency of WSHP.
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2.2. Geographical distribution analysis

Figure 2 shows the annual distribution of the leading countries of WSHP, and the size of the bubbles represents the number of patent application. It can be seen that the United States, France, and Germany are the countries who have a head start. Japanese patent application on WSHP started relatively later, but it has surpassed the United States and European countries in recent years. There were few patents of WSHP in China before 2000. At the end of 1990s, theoretical studies in all aspects of WSHP were carried out. The beginning of the 21st century is a period of explosive growth of Chinese patents of WSHP.

According to the four stages of patent development, different technology leaders have appeared.

1) During the seed stage of 1960 to 1984, the Siemens, Kulmbacher Klimageraete, Fichtel & Sachs from Germany, and Snyder General, Citicorp, American Air Filter from United States had technical superiority. The technical pushers are German companies. Several different forms of heat pump were successfully developed and tested in Germany, and the average heating performance coefficient under European climatic conditions was 1.3 to 1.6.

2) During the decline stage of 1985 to 1993, there had been changes of the top applicants. Japan launched the super heat pump program, and the Japanese enterprises such as Hitachi, Mitsubishi and Panasonic crowded into the top. Although the number of patent application declined, the new force entered the field of WSHP and the main technology leaders were transferred.

3) During the bottleneck stage of 1994 to 1999, the number of patent application of the 22 applicants was all 1. This period was the preparation period for the new rapid development from 2000.

4) During the rapid growth stage, Japanese enterprises ranked in the front of WSHP field. But it is worth noting that many Chinese institutions have also entered the forefront. Along with the serious environmental challenges such as energy shortage and climate change, the heat pump technologies have already drawn a fair amount of attention in Asian countries.

2.3. Assignee analysis

The main competitors in the field of WSHP can be seen from the analysis of assignees. There are 19 assignees that hold more than 10 patent families of WSHP. It can be seen from table 1 that the top 19 assignees are all Chinese institutions or Japanese institutions except Stiebel Eltron in the 14th place that is from German. This indicates that China and Japan attach great importance to WSHP technique.
field and have prominent advantages in R&D. Among the Chinese institutions, Tsinghua University, Shanghai University, Hunan University, Chongqing University, Harbin Institute of Technology and Southeast University are all universities that focus more on theoretical analysis and are not operated for making profits, which forms a sharp contrast with foreign institutions. Japanese WSHP industry has advanced technologies and their invention patents are more closely to industry. Their main patent applicants are enterprises.

Table 1. The main assignees of WSHP.

| NO. | Assignee                                         | Country | Number of patent families |
|-----|-------------------------------------------------|---------|--------------------------|
| 1   | MITSUBISHI                                      | Japan   | 28                       |
| 2   | TSINGHUA UNIVERSITY                             | China   | 25                       |
| 3   | SHANGHAI UNIVERSITY                             | China   | 21                       |
| 4   | HUNAN UNIVERSITY                                | China   | 19                       |
| 5   | NANJING NEWLIXON ELECTRIC                       | China   | 19                       |
| 6   | HITACHI                                         | Japan   | 18                       |
| 7   | CHONGQING UNIVERSITY                            | China   | 17                       |
| 8   | DALIAN BAOGUANG ENERGY SAVING AIR CONDITIONING EQUIPMENT FACTORY | China | 17 |
| 9   | PANASONIC                                       | Japan   | 16                       |
| 10  | KIMURA KOHKI                                    | Japan   | 16                       |
| 11  | MIDEA                                           | China   | 15                       |
| 12  | ANHUI RIYUAN ENVIRONMENTAL PROTECTION ENERGY TECHNOLOGY | China | 15 |
| 13  | CORONA                                          | Japan   | 14                       |
| 14  | STIEBEL ELTRON                                  | German  | 13                       |
| 15  | SANYO                                           | Japan   | 12                       |
| 16  | DAIKIN INDUSTRIES                               | Japan   | 11                       |
| 17  | ZHENGZHOU ZHONGNAN KELAI AIR CONDITIONING EQUIPMENT | China | 11 |
| 18  | HARBIN INSTITUTE OF TECHNOLOGY                   | China   | 11                       |
| 19  | SOUTHEAST UNIVERSITY                            | China   | 11                       |

3. Conclusions
The development of WSHP has attracted much attention with its active R&D. The international patent data lead us to the following conclusions:

1) There is a constant development in the international patent application and publication of WSHP, and the growth has been developing in a high speed in the recent years. It indicates that the international WSHP industry has entered into expansion stage, which has a close positive relationship with the recognition degree of energy and environmental challenges. Along with the impact of global energy crisis and the requirement of sustainable development, the research on WSHP is deepened day by day, and the corresponding number of patent application and publication continues to grow.

2) Japan and China are the important source of WSHP patent applications. China should gather innovation resources, enhance international cooperation, and support foreign advanced WSHP enterprises such as Mitsubishi, Hitachi and Panasonic to construct subsidiary companies in China. A fully developed Chinese financial incentive system should be established as soon as possible to promote the R&D and application of key technologies in the field of WSHP. Chinese institutions need
to pay more attention to the development trend of international leading companies of WSHP, apply for peripheral patents surrounding the foreign core technologies, and cover WSHP technology field with their own patents. Relying on patent administration departments, science and technology information research departments, and enterprises, patent early warning institute of WSHP industry should be set up to provide risk reports regularly.

3) Most of the top 19 assignees of WSHP are Japanese institutions or Chinese institutions, but the main patent applicants of Chinese institutions are universities. China should take measures to strengthen the transformation efforts of scientific and technological achievements, to promote the technical cooperation between universities and enterprises. The innovation platform of WSHP industry with enterprise as the main body should be constructed to create R&D, design and construction atmosphere for patent application. The industry-university-research institution cooperation plays an important role in advancing transformation of patent achievements, and promoting the economic and social development.

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