

Analysis of patent innovation evolution and layout characteristics of global new textile materials technologies

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Abstract

Vigorously developing new textile material technology is critical to improving the textile industry's high-tech level, upgrading its transformation, promoting high-quality development of the real economy, and enhancing the country's overall power. This paper analyzes patent technology to explore new textile material technology layout characteristics and evolution trends for the strategic basis of industrial transformation and development on a global scale. The research took new textile material technology patents as the research object, constructed 76,373 invention application patent data pools in China, Europe, Japan, South Korea, and the United States, and analysed new textile material technology structural characteristics and their evolution trend from three aspects of patent structure, layout characteristics and evolutions. As a result, it was found that the development plans and target focuses of textile new material technology vary from country to country. Global enterprises in garments, advanced material production, and chemical materials, represented by DuPont, 3M, and Dow Global Technologies, provide an important guarantee for the United States in maintaining its global leadership position in the development of the new textile material industry. Japan pays more attention to the practicality of new materials and considers the coordinated development of the environment and resources. Europe and South Korea focus on the construction of industrial clusters with their own characteristics, establish and improve the industrial standardization system based on core technology and core manufacturing, and maintain global competitiveness in textile new material technology. After 2009, the number of patent applications for new textile material technology in China exceeded that of Europe, the United States, Japan, and South Korea, becoming a global patent power. However, there is still a huge gap between the quality of patents and the layout of new cutting-edge materials in China and those in developed countries such as the United States and Japan, which is the main problem that needs to be solved urgently in the future innovation and development of China's textile industry, technology planning and layout.

Keywords

textile, new material, patent innovation, layout structure, technology evolution.

1. Introduction

Material is the basic element of all human social life and economic development, and as a key resource input, plays a vital role in promoting the progress of technological revolution [1]. New materials refer to newly emerged materials with excellent properties or special functions, or materials with significantly improved properties or new functions after the improvement of traditional materials. As a basic and pillar strategic industry, new materials are the forerunner and cornerstone of high-tech development. They are also a support and guarantee for the development of advanced manufacturing industry, and play an important role in promoting technological innovation, promoting the optimization and upgrading of manufacturing industry, and ensuring national security [2, 3]. Previous studies have shown that new textile material technology refers to an advanced textile technology that uses advanced technology and new methods to greatly improve raw materials, spinning, weaving, knitting, sewing

and fabric treatment through a series of processes such as physical research, material design and processing, so as to realize that textile materials have a high degree of technicality, manufacturability, functionality and effectiveness [4-6]. Since the 21st century, more and more countries have taken the development of the textile new materials industry as a major national strategic decision, and countries (regions) in the world's leading position in new materials, such as the United States, Japan, Europe and Russia, have further refined the development direction of the new material industry. New textile technology, multi-disciplinarily converged and integrated, has become the main direction to drive the upgrading of the textile industry chain, to enhance the competitive advantage of enterprises and guide the innovation and development of textile science and technology.

Innovation is the soul of the development of new textile materials, and technological breakthroughs in new

materials will greatly make material products intelligent, multi-functional, environmentally friendly, composite, low-cost, among others [7]. These products can have a significant impact on manufacturing, service sectors, and people's lifestyles. With the successive introduction of „carbon neutrality” and „carbon peak” policies, the era of the „carbon neutral” economy has arrived. The development trend of new high-performance, low-cost, and green textile materials has become apparent. In the face of huge pressure on resources, the environment, and population, resource conservation by material recycling is an inevitable choice for the new material industry to meet the sustainable development of the economy and society.

Furthermore, as an important source of competitive advantage and an important guarantee for sustainable development, technological innovation plays an increasingly important role in the textile and clothing industry [8]. More and more

scholars are using patents to analyze the application and research of new textile material technologies in different fields, including the potential of membrane science in developed clothing and protective textiles [9], sustainable textile technology [10], and the structure and evolution of scientific and technological innovation systems in the textile industry [11]. Also attracting attention are the innovative activities and innovative models of enterprises in the textile and clothing industry [12-14].

As a key area of international competition, new textile material technology is a key force in promoting the high-end, intelligent, green, and integrated development of the textile industry, and an important engine to realize the modernization of the textile industrial system. The theoretical significance of this study is to construct the innovation evolution and layout mechanism of new global textile material patent technologies, and to preliminarily explore the patent structure, layout characteristics and technical themes of new textile material technologies in China, the United States, Japan, South Korea and Europe. The practical significance of this paper is that it shows that the development plans and goals of new textile material technology in various countries are different, and the government should relax industrial regulations, strengthen the innovation and R&D of emerging technologies in the industry, and promote cross-regional industrial technology cooperation.

2. Literature Review

2.1. New textile materials

At present, scholars' research on the technological innovation of new textile materials mainly focuses on three aspects: (1) the field of textile raw material technology, such as herbal biomass, natural dyes, and extracted cellulose, which are widely used to develop high-performance, intelligent textiles and multi-functional materials [15-17] to meet the needs of the industry and market, and improve the competitiveness and added value of

textiles; (2) case studies focusing on the impact of technological innovations in new textile materials, such as using eco-friendly technologies to produce textiles with the required physicochemical and mechanical properties [18,19], as well as scalable nanofabrication technologies to customize smart fabrics [20] and natural fabrics [21] to meet various potential application needs, and (3) analysis of the policy mechanism of technological innovation for new textile materials, as well as evaluation of the expected impact of new technologies on the environment and human security [22, 23], and emphasis on the important role of policy guidance and supervision in the sustainable development of technology.

2.2. Patent value

The current definition of patent value mainly includes the excess rent earned by the patent in the market and the asset value of the patent [24, 25]. The former reflects the incentive effect of patent protection scope, while the latter emphasizes the profit return obtained by the patentee by utilizing the patent monopoly within the scope of patent protection. A large number of studies have shown that the value of a patent depends on many factors, including the legal, economic, technical, and strategic value of the patent. The number of patent citations (forward citations) is a commonly used an indicator of patent value [26], representing the originality, influence, and versatility of patented technology [27]. More and more scholars have directly measured patent value by the number of patent citations, and used it as the dependent variable of regression analysis, indicating that the number of patent citations has a positive effect on patents' value [28-30].

However, at present, there are few studies on the evolution of the patent innovation of new textile material technology, especially the lack of comparative research on global patent data. Therefore, from the perspective of a micro-technology network, this paper explores the technical layout, development trend,

and evolution characteristics of textile new materials in major countries and regions of the world, providing reference for textile technology innovation and development.

3. Variables and methodology

3.1. Sample selection and data source

The data used in this article are from the PatSnap patent database (<https://analytics.zhihuiya.com/>). As for new textile material technology, according to the research results of Slubik et al. [31], Papaspyrides et al. [32], and Sibiescu et al. [33], it is mainly defined as high-tech fibers, high-tech fabrics, and high-tech industrial textiles produced by adopting high-tech processes and equipment in recent years. Its content involves textiles, clothing, fibers, spinning, weaving and weaving, etc. The International Patent Classification (IPC) includes two categories: D (textile) and A41 (garment). First you select the new material industry in the national strategic emerging industry classification, and combine it with the international patent classification number D01 fiber, D02 yarn, D03 weaving, D04 knitting, D05 sewing, and D06 fabric treatment, etc., The patent status is then selected as „valid”. Since the time period is about 18 months from the invention patent application to publication and grant, the search time is limited to before 2021. Since IP5 (Five Intellectual Property Offices), the world's five major intellectual property offices, handle about 80% of the world's patent applications, (about 95% of all work carried out under the Patent Cooperation Agreement (PCT)), five countries and regions including China, the United States, South Korea, Japan, and Europe were selected as innovation regions for the study. Through the above strategies, the search results were applied for consolidation, and finally 76373 patent data consistent with this study was obtained.

3.2. Patent layout analysis

With the implementation of the economic globalization strategy and the rapid development of textile technology, a large number of multinational enterprises participating in international market competition rely on patents in different countries and regions to improve the competitiveness of products and technologies. Therefore, overseas patent layouts can help enterprises obtain exclusive intellectual property rights, and play a positive role in promoting enterprises to build brand value and enhance technological innovation capabilities [34]. At the same time, based on the recognition and respect for intellectual property rights, products with overseas intellectual property rights protection may gain more recognition in the process of expanding overseas markets. To further analyze the layout of each country in the global market of textile new material technology patents, this paper calculates the overseas export rate (OER) and the acceptance layout rate (ALR) of a country or region according to the following formula.

$$\text{OER}_i = \frac{\sum P_{(i \rightarrow j)}}{P_i} \times \% \quad (1)$$

$$\text{ALR}_i = \frac{\sum P_{(j \rightarrow i)}}{P_i} \times \% \quad (2)$$

Where P_i represents the total number of patents in new textile material technology in a certain country or region; $P_{(i \rightarrow j)}$ indicates the number of new textile material technology patents applied by the country or region i or in the country or region j ; and, in the same way, $P_{(j \rightarrow i)}$ indicates the number of new textile material technology patents applied for by the country or region i that were accepted by the country or region j .

3.3. Patentometrics

Information such as the number of patents, patent types, and patent composition categories reflects the development trend of technological innovation in the industry. By using

the patent measurement method to analyze the technical characteristics of the sample data, the overall trend of the development in this field can be obtained [35-37]. This paper uses global textile new material technology patent application data for textile new material technology to reveal the evolution process and competitive situation of new global textile material technology innovation from the perspectives of patent application development trends, applicant distribution, technology evolution, and technology field distribution, reflecting the textile technology innovation ability and layout characteristics.

4. Empirical results

4.1. Analysis of technological innovation of new textile materials

4.1.1. Trends of innovation and development

Statistical analysis of the annual patent applications of new textile material technology in Europe, China, Japan, the United States, and South Korea was conducted, the results of which are shown in Figure 1. From 2001 to 2008, the United States and Japan have a relatively obvious advantage in the number of new textile material patents; both with advanced manufacturing technology and strong research and development strength, rich achievements were made in the field of textile composite materials [38-40], smart textiles [41, 42], and new fabric-based materials with special functions and properties [43-45]. After 1990, the United States long attached great importance to the development of the new material industry and successively introduced policies such as the Advanced Technology Program (ATP), the Advanced Materials and Process Technology Program (AMPP), and Industrial Materials for the Future (IMF), which laid the foundation for the technological innovation and development of the textile industry and maintained its global leadership position in the field of new materials. Japan pays more attention to the practicability of new textile

materials, considering the coordinated development of the environment and resources. With the gradual deepening of the reform and opening up policy and the rapid development of domestic textile technology, the number of patent applications for new textile materials in China has increased significantly since 2009, surpassing that of America, Europe, Japan, and South Korea, and the number of patents has increased rapidly, making China a patent power. It initially formed the development direction of functional fibers, intelligent textiles and high-performance fiber technology, which has become the focus of national attention.

From 2010 to 2018, the number of patent applications in all countries around the world showed a steady upward trend, in which the growth momentum of Japan and South Korea replaced the United States and Europe, becoming an important development force after China. However, the number of applications of the latter grew by leaps and bounds, reaching 2,130 in 2013, far higher than other countries and regions. As a traditional pillar industry and people's livelihood industry, under the influence of sustainable development and the „Made in China 2025” policy, the government formulated the “10th Five-Year Plan”, “11th Five-Year Plan”, “12th Five-Year Plan”, “13th Five-Year Plan” and the “14th Five-Year Plan” to promote the transformation and upgrading of the textile industry, and proposed to establish a relatively complete industrial system of the textile industry, and flexible, intelligent, and refined production as the main trend of the development of new textile material technology. After 2019, due to the impact of COVID-19, the technological innovation activities of various countries were disrupted to varying degrees, so the annual number of patent applications declined significantly.

4.1.2. Patent quality analysis

Patent citation reflects the law of technological development in the field of technology, and reflects the continuity and succession of science and technology, as well as the cross-integration between

Citations of patents	China		USA		Japan		South Korea		Europe	
	No. of patents	ratio	No. of patents	ratio	No. of patents	ratio	No. of patents	ratio	No. of patents	ratio
0	31275	90.91%	5535	16.09%	11943	34.71%	7003	20.36%	6158	17.90%
1-5	3006	8.74%	3655	31.80%	1254	9.40%	2692	26.18%	643	9.39%
6-10	93	0.27%	934	8.13%	99	0.74%	403	3.92%	36	0.53%
11-50	28	0.08%	1192	10.37%	43	0.32%	181	1.76%	13	0.19%
51-100	0	0.00%	127	1.11%	0	0.00%	4	0.04%	0	0.00%
>100	2	0.01%	50	0.44%	0	0.00%	1	0.01%	0	0.00%

Table 1. Number and proportion of citations of global patents for new textile material technologies

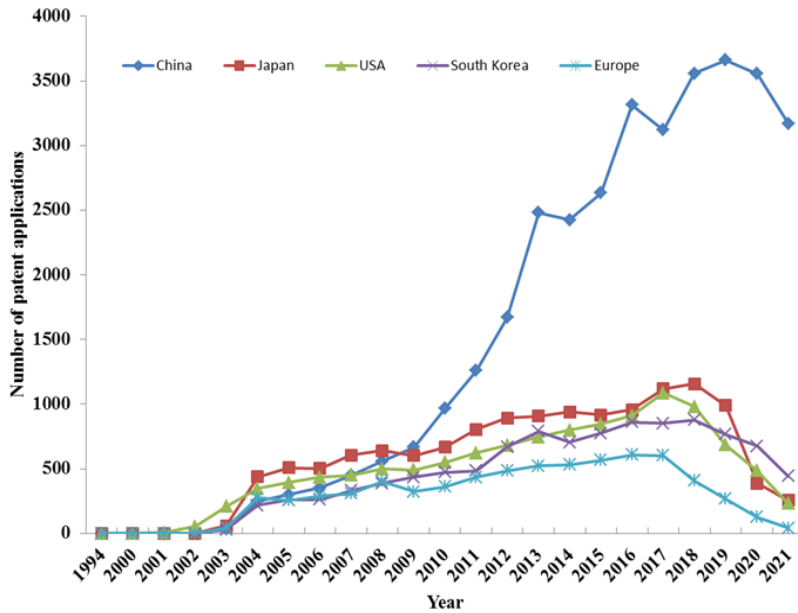


Fig. 1. Application Trends of New Global Textile Material Technology Patents

different disciplines. The academic community pays attention to the citation value of patents by analyzing their citation frequency because it not only reflects the external performance of patents that are expansive and groundbreaking, but also shows the positive relationship between a higher number of citations of patents and the greater technical influence of the patented [11] from the perspective of technology accumulation and innovation. Table 1 presents the number and proportion of new global textile material technology patents cited, among which the quality of patents in the United States is the most prominent, with the number of patents cited with 11-50 times, 51-100 times and more than 100 times accounting for 10.37%, 1.11% and 0.44% respectively, with a total of 11.92%, far higher than China's 0.09%, Japan's 0.32%, South Korea's 1.81% and Europe's 0.19%, showing a

„standout” state. Although China has the largest number of patents in the world, the number of patents cited with 0 times accounts for 90.91%, which is much higher than other countries and regions, reflecting the contradiction of „big but not strong, many but not excellent” in the field of new textile material technology. This has an important warning effect on China's innovation and development, technical planning, and layout in the textile industry.

Although some studies have proposed to use the number of patent citations as an index to judge the value of patents, it is difficult to objectively reflect the value of patents, but it cannot be denied that the United States holds a large number of core patents in new textile material technology, reflecting its global leadership and competitiveness in the development of new material industry.

4.1.3. Patent layout analysis

In order to protect the main markets or future potential markets of existing technologies and products, innovative entities carry out overseas patent layouts by applying for patents. Therefore, analysis of the overseas layout of patents in different countries or regions is helpful to discover the layout characteristics of new textile material technology. Table 2 shows the matrix of the global patent layout of new textile material technology, indicating the number of patents developed in China (CN), the United States (US), South Korea (KR), Japan (JP), and Europe (EP), and the ratio of patent families in the countries' overseas layout, as shown in the last column.

Although the number of patent applications for China's new textile material technology ranks first in the world, only 3.57% of the patents are applied for overseas with a high value of the acceptance layout rate at the same time. The main source countries are Japan (45.81%), the United States (26.78%) and Europe (19.65%), indicating that the Chinese market has a huge external attraction, forming a strong control over China's new textile material market through the patent layout strategy. In contrast, China's innovation institutions are seriously lagging behind in their awareness and action of the international patent layout, causing the weak position to seize the international market. It is hoped that under the promotion of „Made in China 2025” and the „14th Five-Year Plan”, Chinese enterprises will attach importance to patent layout and technological innovation, and enhance the value of intangible assets and enterprise competitiveness by actively participating in international competition.

Country/Region	CN	US	JP	KR	EP	Total	Overseas proportion
CN	33177	670	293	107	158	34404	3.57%
US	1409	6195	1495	778	1618	11495	46.11%
JP	2410	2113	6224	1261	1331	13339	53.34%
KR	408	593	408	8630	245	10284	16.08%
EP	1034	1290	1175	768	2583	6850	62.29%

Table 2. Patent layout matrix of new global textile material technology

CN		US		JP		KR		EP	
patentees	NO. of patents	patentees	NO. of patents	patentees	NO. of patents	patentees	NO. of patents	patentees	NO. of patents
Donghua University	918	P&G	377	Toray	801	Kolon Industries, Ltd	521	P&G	191
Jiangsu Hengli Chemical Fiber Co., Ltd	405	Toray	214	Kao Corporation	480	Toray Advanced Materials Co.	399	Toray	189
Wuhan Textile University	388	DuPont Safety & Construction	166	Mitsubishi Chemical	412	Toray	197	Kimberly Clark	92
Sinopec	379	Kimberly Clark	139	Kuraray	312	LG Chem Co.	152	Dow Global Technologies	90
Toray	314	3M	127	Asahi Kasei	300	Kimberly Clark	115	3M	77
P&G	129	Seiko Epson Corporation	117	Teijin Limited	254	DuPont Safety & Construction	81	Kuraray	64
DuPont Safety & Construction	125	Dow Global Technologies	104	P&G	209	Kuraray	58	Kolon Industries, Ltd	62
Asahi Kasei	101	Mitsubishi Chemical	71	Seiko Epson Corporation	150	Mitsui Chemicals	57	Seiko Epson Corporation	61
Kao Corporation	97	LG Chem Co.	67	Mitsui Chemicals	144	Dow Global Technologies	36	Mitsubishi Chemical	59
Kuraray	96	Kuraray	65	Dow Global Technologies	80	Mitsubishi Chemical	35	Mitsui Chemicals	56

Table 3. Distribution of major patentees of new textile material technology in the world

4.1.4. Distribution of patentees

The main patentees of new textile material patent technologies in China, the United States, Japan, South Korea, and Europe were selected for analysis, and the distribution data of the top 10 patentees, shown in Table 3, was obtained. The types of applicants are mainly composed of internationally renowned multinational companies, of which Japanese companies are particularly prominent, including Toray Corporation, Kuraray Co., Ltd., Mitsubishi Chemical Corporation, and Mitsui Chemicals. As a world-renowned high-tech multinational enterprise with organic synthesis, polymer chemistry, and biochemistry as its core technologies,

Toray Corporation has a large number of patent applications in China, the United States, South Korea, and Europe, reflecting its pivotal international position in the field of fibers, functional chemicals, carbon fiber composites, and other cutting-edge materials. P&G and Dow Global Technologies in the United States also demonstrate strong competitiveness in the chemical industry.

Comparatively, the distribution of patentees in China, South Korea, and Europe is similar, and the competitiveness of domestic enterprises in the international market is limited, which is unable to influence the monopoly of the United States and Japan. Chinese

universities occupy an important share of the main patentees, among which Donghua University and Wuhan Textile University rank top, both of which have a textile discipline background. The former is a key university under „Project 211” of the state, with government support and resource integration. The university has deeply integrated with local governments and enterprises in industry-academia-research activities, which has produced a large number of scientific research results in textile new material research.

From the viewpoint of applicant types, enterprises are not only the main body of national and industrial technological innovation, but also the core force of

Country/ Region	Type of patentees	Number of patents	ratio
CN	Company	26605	77.32%
	Colleges/institutes	8405	24.43%
	Personnel	545	1.58%
US	Company	10049	87.44%
	Colleges/institutes	1184	10.30%
	Personnel	392	3.41%
JP	Company	12906	96.75%
	Colleges/institutes	540	4.05%
	Personnel	190	1.42%
KR	Company	7903	76.83%
	Colleges/institutes	1375	13.37%
	Personnel	1449	14.09%
EP	Company	6493	94.68%
	Colleges/institutes	266	3.88%
	Personnel	165	2.41%

Table 4. Distribution of major patentees of new textile material technology in the world

scientific research. Table 4 shows the distribution of major patentee types. Among them, Japan and Europe are particularly prominent, with companies accounting for 96.75% and 94.68% of the total number of patentees respectively; the former being largely due to the fact that Japan attaches great importance to the growth and development of enterprises in technological creation, and is guided by policies such as the Basic Law on Small and Medium-sized Enterprises, the Basic Law on Science and Technology, the Basic Plan for Science and Technology, and the Comprehensive Strategy for Science and Technology [10]. Stimulating the company's independent innovation vitality played a positive role in promoting the emergence of many well-known multinational companies later.

4.2. Analysis of the evolution of new textile material technology

The theme of patent technology can reflect the process of patent technology aggregation and evolution in a particular field, and is the basis for predicting technology development trends and discovering emerging technologies [9]. Based on the IPC number of new textile material technology patents and the use of Loglet Lab software to fit the S-curve of the technology life cycle, the results

show that the number of new global textile material technology patents before 2005 was relatively small and belongs to the embryonic stage. From 2005 to 2009, with the rapid development of textile technology and the deepening of the process of economic globalization, the cumulative number of applications reached 2,518, and the development entered a growth period, where the United States and Japan were in a dominant position in new textile material technology innovation. Meanwhile, China had also begun to enter the fast lane of technology patent applications, and became the country with the largest number of patents for new textile material technology in the world. From 2010 to 2018, the number of patent applications in Europe, the United States and developed countries tended to stabilize, and technological development entered a mature period. However, after 2019, due to the impact of the COVID-19 around the world, the technological innovation activities of enterprises and scientific research institutions were affected to varying degrees, so the annual number of patent applications declined significantly. Then, combined with the number and year of IPC, the evolution process and evolution characteristics of new textile material technology in different countries at different stages and different periods were analyzed through a bubble chart, in which the size of the bubble represents the number of patent applications.

4.3. The evolution process and characteristics of new textile material technology in China

Before 2009, China's research on textile new material technology was in its infancy, so the size of the bubbles was not obvious (the results as shown in Figure 4). After 2010, technologies such as D01F (equipment for making man-made filament fibers with chemical characteristics or carbon fibers), D06M (biochemical treatment of fiber products made from fiber, yarn, and thread raw materials) and D01D (mechanical methods or equipment for making chemical filaments, threads, and fibers) developed rapidly, becoming an important force in promoting domestic textile technological innovation and upgrading of the industrial chain. At the same time, China's accession to the WTO obtained the most favored nation treatment, effectively improving the economic and trade market, under the influence of low-cost labor, population and market dividends, which laid a good foundation for further opening-up of China's textile industry development to the outside world. In 2001, China's textile and garment exports amounted to 54.32 billion US dollars, accounting for 13% of the world's total textile and garment trade. By 2010, China's textile and garment exports were worth 212.0 billion US dollars, accounting for 34% of the world's total textile and garment trade, and the export scale ranked first in the world. Driven by the concept of global sustainable development and the upgrading of the industrial chain, the Chinese government issued policies such as the „13th Five-Year Plan for the Development of National Strategic Emerging Industries”, the „Guidelines for the Development of New Materials Industry” and the „Made in China 2025”, proposing the goal of developing from a „major textile country” to a „powerful textile country”. Since 2013, technologies such as D04H (textile manufacturing), D06P (dyeing or printing), C08G (polymer compounds), and D02G (fiber) have injected new vitality into the innovation and development of new textile materials.

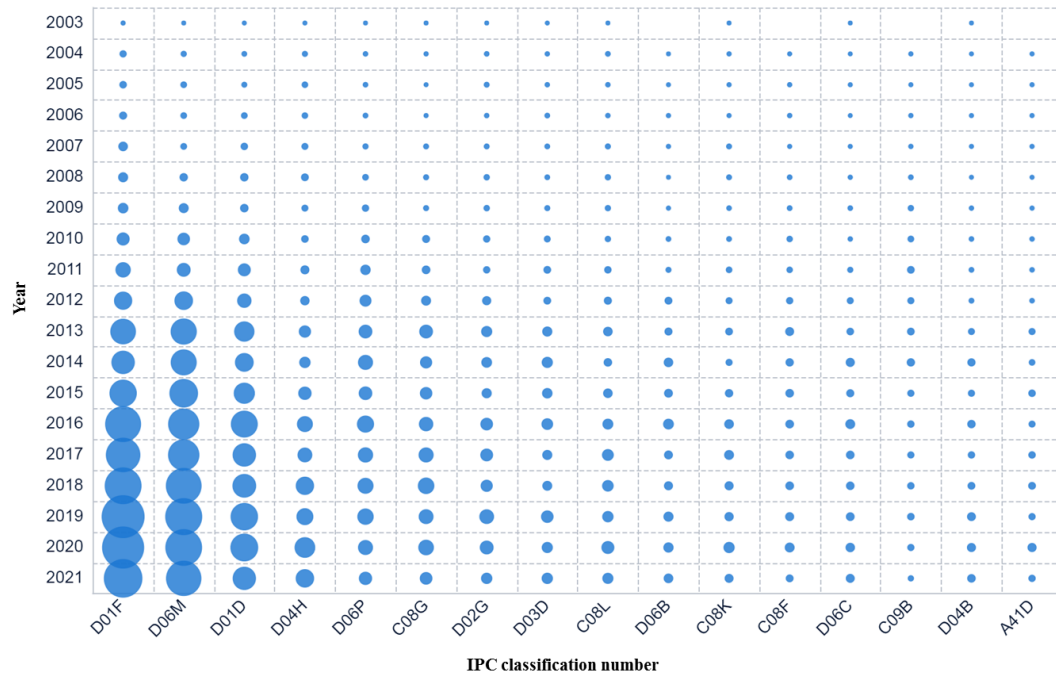


Fig. 2. Evolution mapping of new textile material technology in China

4.4. The evolution process and characteristics of new textile material technology in Japan

As mentioned above, the innovation strength of new textile materials in Japan is at the forefront the world, and since 2004, it has been particularly prominent in technologies such as D06M, D01F, and D04H (the results as shown in Figure 5), with a more pronounced bubble presentation. This is mainly due to the country's early policy support for new materials. As early as the 1980s and 1990s, the Japanese government began to take a series of measures to promote the development of new materials, proposing the development goal of „focusing on the practicality of new materials, taking into account the coordinated development of the environment and resources,” and so in the global market for carbon fiber technology, new chemical materials and man-made fibers as well as other market positions began to play a significant role. After 2016, the government strengthened business alliances, such as Nihon Keidanren, highlighting its own advantages and emphasizing innovative models such as international cooperation with the United States and the European

Union. Therefore, D03D (woven fabrics; weaving methods; looms), C08L (polymer compound composition), D01D and D02G, and other technologies also showed strong market competitiveness.

4.5. The evolution process and characteristics of new textile material technology in the USA

To maintain its global leadership in the field of new materials science and technology, the United States has formulated a series of development goals for comprehensive strategic planning, including the National Nanotechnology Initiative (NNI) [8], which was launched in 2000, the Materials Genome Initiative [46, 47] for Global Competitiveness, launched in 2011, and the National Network for Manufacturing Innovation (now known as Manufacturing USA) [48, 49] in 2012, which took the lead in completing the layout for the integration and development of patented technologies in the world. Therefore, from 2001 to 2010, D01F, D04H, D02G, and D03D technology had obvious advantages, with DuPont, 3M and Dow Global Technology Company, and other representatives

of the garment and advanced material production and chemical material enterprises, providing an important guarantee for the United States in the development of the new textile material industry to maintain the global leadership position. After 2010, the digital revolution and the rapid development of Internet of Things technology, the United States re-recognized and positioned the development trend of the textile industry, especially multi-material and multi-structure smart fibers and revolutionary fibers & textiles that integrate multiple functions, giving birth to the important industry of „Smart Fabrics”. Consequently, technologies such as D01D, D06M, C08L, C08K (using inorganic or non-polymeric organic substances as ingredients), and D06P (dyeing or printing of textiles) became the focus of research and development.

4.6. The evolution process and characteristics of new textile material technology in South Korea

In the mid-1990s, the technological level of South Korea's spinning, weaving, dyeing and printing, garment production,

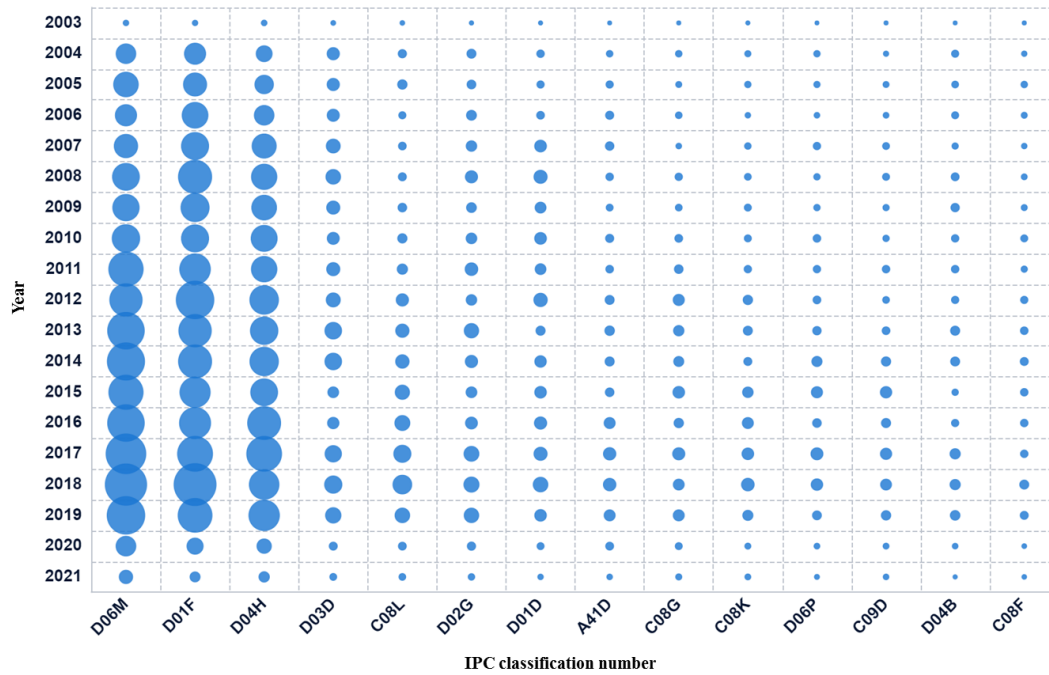


Fig. 3. Evolution mapping of new textile material technology in Japan

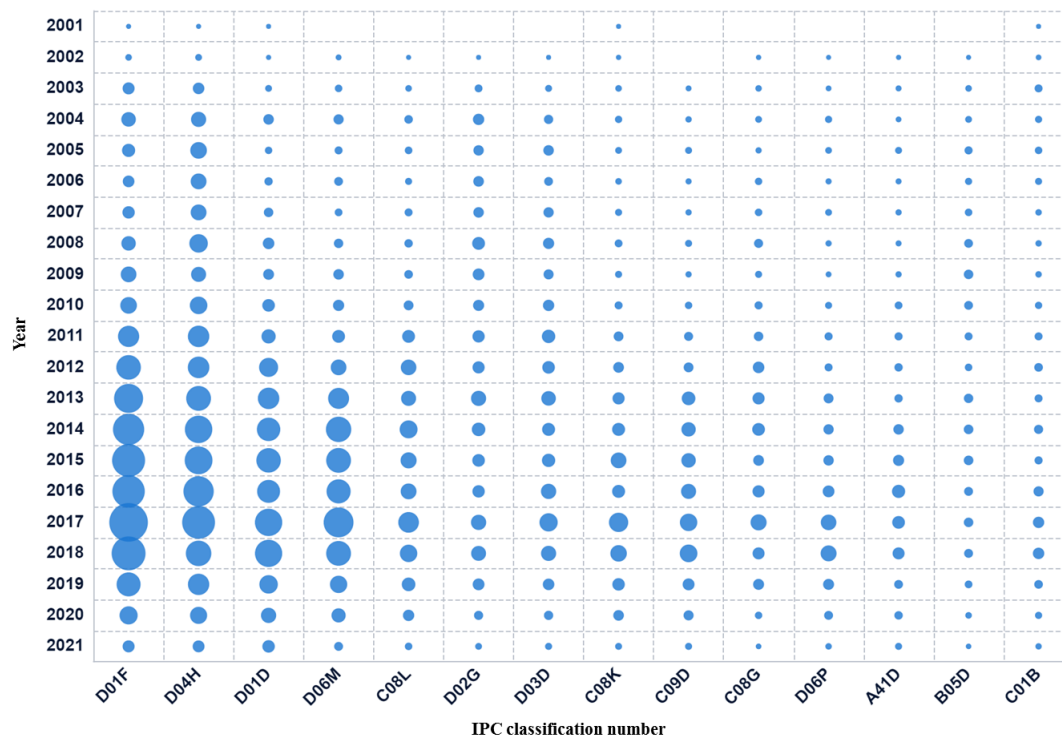


Fig. 4. Evolution mapping of new textile material technology in the USA

and textile machinery manufacturing was recognized worldwide, with D01F, D01D, D06M, and D04H becoming the focus of its new textile material technology development. After 2012, policies and plans such as the „Nanofusion

2020 Project”, „Third Basic Plan for Science and Technology”, and „Korea’s Future Growth Power Plan” were formulated to promote the reform and restructuring of large enterprise groups, play a centralized role, and encourage a

„government civilian integration” model of collaborative innovation among all employees. This led to the emergence of global aramid fiber and new chemical material production enterprises represented by Kelon Industrial Co.,

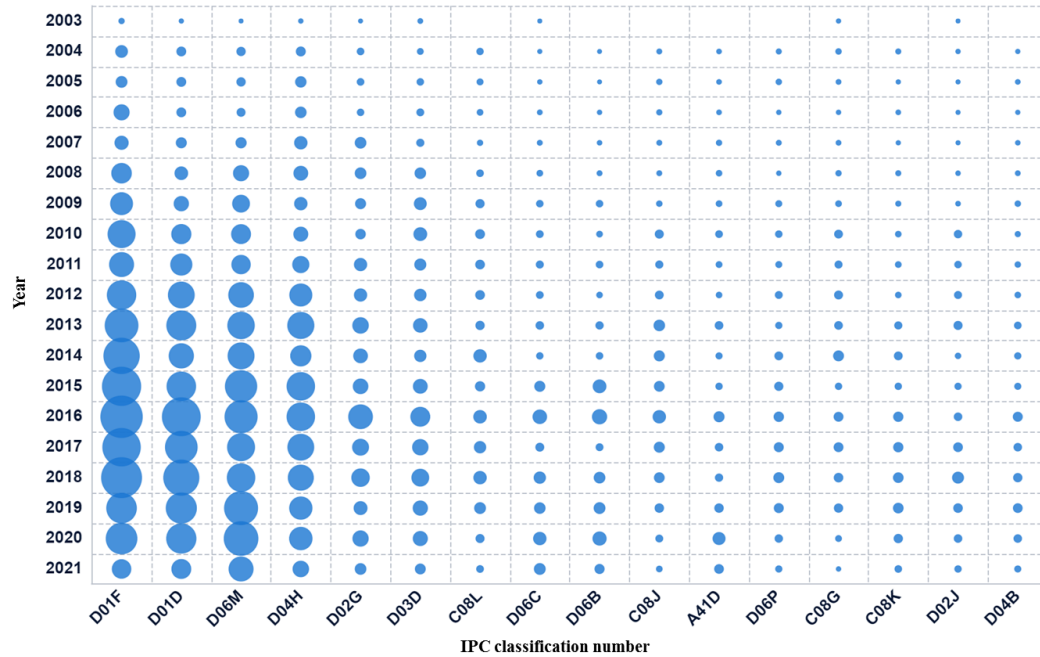


Fig. 5. Evolution mapping of new textile material technology in South Korea

Ltd. and LG Chem. Technologies such as D02G, D03D, C08L, D06C (fabric finishing, sizing, stretching or elongation) and D06B (liquid phase, gas phase or steam treatment of textile materials) were also rapidly developed. This has enabled South Korea to maintain global competitiveness in new textile material technologies.

4.7. The evolution process and characteristics of new textile material technology in Europe

The development of textile new material technology in Europe is similar to that of the United States and Japan, with a strong focus on the construction of industrial clusters with their own characteristics, establishing and improving the industrial standardization system based on core technology and core manufacturing, fostering and promoting strong alliances and high-quality development of basic science and technology-based small and medium-sized enterprises (SMEs). Thus, before 2008, D04H, D01F and D06M had obvious technical advantages. After 2010, with the growing strength of textile technology in Asian countries, its new textile

material innovation model focused on industrial demand, emphasizing the enhancement of the added value of textile materials. In order to maintain the advantages of EU industry and improve its future competitiveness, the European Commission systematically researches the advantages of EU industry and the future development direction. In June 2011, six major technologies, including advanced materials, were identified as Key Enabling Technologies (KETs) [50] for EU industry, with material and nanomaterial technology funding and layout as an important research area. New Textile material technologies became increasingly important in the field of EU science and technology development. After 2014, Germany established a national strategy called the „Textile of the Future” project, which identifies the textile industry as one of the most innovative and dynamic industries in Germany by creating new industries, products, and services based on new materials, energy efficiency, environmental protection, and smart products. Therefore, technologies such as D01D, C08L, D03D, and D02G have gradually become an important part of the field of new textile material technology.

5. Discussion and conclusion

In recent years, developed countries such as the United States and Japan have taken green and sustainable development as an important direction of economic growth, and have introduced a series of relevant scientific and technological policies, as a result of which developed countries occupy a leading position in the new global textile material industry. With the impact of COVID-19 and geopolitics, countries are paying more and more attention to upgrading supply chain security, so they continue to increase national strategic support and investment and begin to promote the reform and restructuring of large enterprises to play a centralized role. In terms of innovation patterns, they also continue to stimulate innovation from the top down, and show a strong policy will. The United States and Japan still have a clear advantage, but the technology gap is narrowing across regions, and competition in key strategic areas has entered a white-hot phase. Although China has independently developed several new textile material technologies that have reached or are close to the international advanced level, there is still a significant gap in the research and application of key common technologies and equipment,

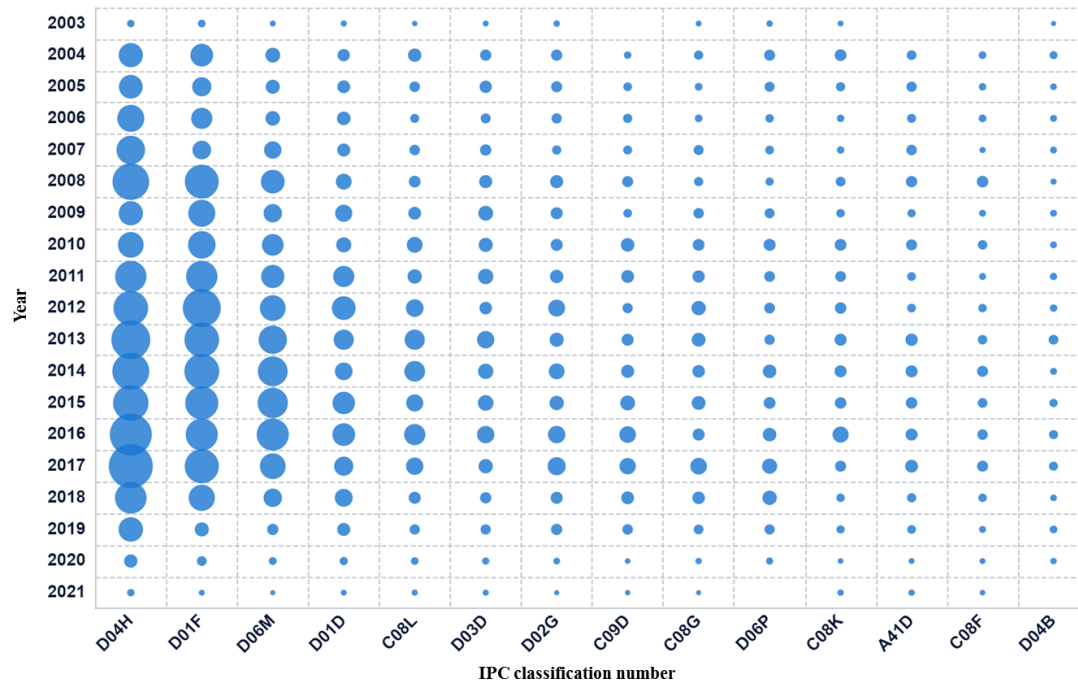


Fig. 6. Evolution mapping of new textile material technology in Europe

such as new fiber materials, advanced textile products, green manufacturing, and intelligent manufacturing, as compared to developed countries such as the United States, Europe, and Japan. The problem of „big but not strong, big but not excellent” is prominent, which requires coherent support and long-term layout of national policies, as well as the strengthening of international innovation cooperation. At present, the intervention role of governments in the economy and industry is gradually strengthening, with the government paying more and more attention to the industrialization of scientific research achievements. Along with the deepening of the concept of sustainable development, intelligent fibers, advanced textile products, green manufacturing, and intelligent manufacturing have risen to be priority strategic goals in the field of new textile materials.

Based on the data pool of 76,373 invention patent applications in Europe, China, Japan, the United States, and South Korea, the study analyses the process of patent innovation evolution, evolutionary characteristics and trends of new global textile material technology. The results are as follows:

Firstly, before 2008, the United States and Japan occupied a global leadership position in the field of new textile materials with advanced manufacturing technology and strong R&D strength. After 2009, the number of patent applications for new textile materials in China increased dramatically, and functionalized fibers, smart textiles, and high-performance fiber technologies became the key focus of development. From 2010 to 2018, the number of patent applications in various countries around the world showed a steady upward trend, and the growth momentum of Japan and South Korea overtook that of the United States and Europe, becoming important development forces after China. However, after 2019, due to the impact of COVID-19, the technological innovation activities of various countries were disrupted to varying degrees, so the annual number of patent applications declined significantly.

Secondly, the quality of patents in the United States is the most prominent, with the number of patents cited more than 11 times accounting for 11.92%, much higher than China, Japan, South Korea, and Europe, reflecting its global leadership in the development of new textile material technology.

Internationally renowned multinational enterprises occupy a pivotal position among the major patentees, especially Japanese and U.S. enterprises such as Toray Corporation, Kuraray Corporation, Mitsubishi Chemical Corporation, and Procter & Gamble Co. perform particularly well, enjoying obvious competitive advantages in a number of cutting-edge material technologies, such as fibers, functional chemical products, and carbon fiber composites.

Thirdly, the development goals and development priorities of new textile material technology in various countries are different, with the United States, Japan, and Europe taking the lead in completing the development of patented technology integration and development, followed by South Korea. With the rapid development of the digital revolution and Internet of Things technology, the United States has focused on the development of D01D, D06M, C08L, C08K, and D06P technologies related to smart fibers, revolutionary fabrics, and fiber industries. Japan pays more attention to the practicality of new materials and considers the harmonious development of the environment and resources, thus it plays a vitally important role in the global market of carbon fiber technology,

new chemical materials, and man-made fibers. Europe and South Korea focus on the construction of industrial clusters and their characteristics, establish and improve the industrial standardization system based on core technology and core manufacturing, and maintain global competitiveness in new textile material technology. China is relatively lagging behind in the layout of new textile material patented technology. After joining the WTO and introducing the advanced technology of foreign enterprises, the country set the goal of developing from a „major textile country” to a „powerful textile country”, and D04H, D06P, C08G, D02G, and other technologies have injected new vitality into its innovation and development in new textile materials.

After 2009, the number of patent applications for China’s new textile material technology exceeded that of Europe, America, Japan, and South Korea, and the number of patents increased rapidly, making it a major global patent country. In 2010, the amount of textile and garment exports reached 212 billion US dollars, accounting for 34% of the world’s total trade in textiles and garments, achieving the top export scale around the world. However, the patent quality and layout of new cutting-edge materials still face great challenges, and how to solve the contradiction of „big but not strong, more but not better” in China’s new textile material technology is a new challenge for China’s innovative development in the textile industry, technology planning and layout.

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Conflicts of Interest

The authors declare no conflicts of interest.

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