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Analysis of core patent technology of high-tech industry based on computer complex network science

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Abstract. In the era of big data, data has become a national strategic resource, in which patent data represents core technology and core competitiveness. Identifying and mining core patent data is helpful to analyze the technical layout and development trend of an industry and an enterprise. From the perspective of complex network science, a patent citation network is constructed and visualized, a core patent data identification method is proposed, and empirical analysis is conducted on the high-temperature alloy industry in China. The study found that visualizing the research results using computer complex network methods can better analyze the development and technological innovation trends of the industry.

Keywords: Complex networks; Computer science; Big data; Network science; Core patent; Reference network; Superalloy.

1. Introduction

Patent literature contains a large number of technical information and economic information. Through the measurement of patent information, it can effectively identify the important technology and technological development status in this field, but also can effectively identify competitors and their technological innovation ability, and judge the industrial competition situation [1]. Core patents represent the key core technologies with more value in the industry and can support the core competitiveness of the industry. For enterprises, mastering the core technology can grasp the initiative of competition. For the industry, mastering the core technology is to master the driving force of innovation and development. For the country, mastering the core technology represents the improvement of comprehensive national strength. So identifying the core technologies of the industry can drive innovation to a large extent.

2. Core patent identification method

With the development of economy and the intensification of scientific and technological competition, how to excavate and identify the core patents has become the focus of academia and industry. At present, a large number of scholars have carried out relevant research, mainly forming three types of methods to judge the core patents: the first category is the single index judgment method, such as the patent citation index [2][3]Number of patents of the same clan [3] Point degree centrality [4] And so on; the second type is the multi-index combination judgment method, generally through the construction of patent index system. Different scholars construct the index system from different perspectives. Yang Wu uses the number of scientific correlation, the number of backward references, the number of claims, and the number of patents of the same family from the perspective of characteristic analysis [5] Wait and so on. Scholars' empowerment of the index system is mainly divided into the subjective empowerment method, such as the expert judgment method [6][7], Objective empowerment method, such as the hypervolume index function [8], regression model [9], TOPSIS algorithm [10]Correlation coefficient method [11]And objective combination, such as fuzzy hierarchy analysis and entropy weight [12]There are two main other judgment methods. One is to directly use foreign commercial databases to judge the core patents. For example, Liu Qin used the Innography database to determine the core patents [13], The second is to build a model to judge. For

example, Ma Ruimin and others build the patent similarity matrix, and use the Louvain community discovery algorithm to build the core patent prediction model [14]. On the whole, many models and theories are introduced into the core patent identification, most of which are comprehensive measurement of multiple patent indicators, and the core patents are calculated. Later, the technical or layout analysis of the core patents is conducted, and good results are achieved, but there are still some limitations, such as the lack of single index judgment method and subjective method; the objective method is too complicated and complicated; the availability of foreign commercial databases is a great defect, and the analysis of domestic related industries and enterprises is not comprehensive and objective. The most prominent flaw of the various methods is that there are basically no patents of high commercial value.

3. The empirical study protocol design

3.1. Study subjects and data sources

Superalloy, also known as "superalloy", is widely used in aviation, aerospace, petroleum, chemical industry, ships of an important material, its development has been the national attention and support, in recent years, the relevant state departments have introduced a series of related policies, support and encourage the development of superalloy industry in China, provides a good policy environment for the industry. In this paper, it is necessary to study the core patent.

The wisdom bud patent database was used to search the related patents of the superalloy industry in China. Select area is China, search type: Title / Abstract: (superalloy) AND (TA: (superalloy) NOT LEGAL_STATUS: (cancel OR failure)) yielded 7216 search results. After data cleaning, weight removal and processing, a total of 6,236 patents were obtained.

3.2. Selection of core patent indicators

In network science sum up, the reference relationship between patent and patent (availability), can constitute a patent node patent reference network, also can reflect the technology evolution process, for a patent, the importance of the patent not only depends on itself, also affected by the importance of its neighbor node (reference relationship). In the patent reference network, the degree center performance of the node measures the importance of the node, and the eigenvector centrality (EC) can characterize the importance of its neighbor nodes. Non-patent literature can measure the flow and diffusion of knowledge between scientific knowledge and technology, and can supplement the technical attributes of patents.

The two indexes of patent transfer and patent litigation can measure the economic value and competitiveness of the patent. Simple with patent representative have common priority, and published by different countries or subject, basically the same patent family, for a patent enterprise, the layout of simple with patent need higher patent cost, so often represents the patent has a high commercial value, the specific evaluation index used in this paper as shown in Table 1.

Table 1. Core patent evaluation index

Secondary indicators	formula	meaning
linear measure	$DC=\frac{N_{degree}}{V-1}$ [15] Where V represents the number of nodes. For a graph G= (V, E) with n nodes, the degree centrality DC of a node v is the entry degree that returns this node.	In a network, if a node is directly associated with many other nodes, then the node is at the center. In this paper, we is used to represent degree centrality.
Eigenvector centrality (EC)	$EC(i)=x_i=c\sum_{j=1}^{n}a_{ij}x_{ij}$ [16] Where c is a proportional constant, remember x= [x1, x2, x3,..., xn] T.	The more important the neighbor node connected to it is, the more important the node is.
Non-patent citations of f		Can be used to measure the flow of knowledge between scientific research and technology
transfer of paten		Can be used to measure the commercial value of the patent
Patent litigation		It can be used to measure the competitiveness of the patent and reflect the legal attribute of the patent
Simple ethnic patent		More so than so on the technology stickiness and market value of patents
State of patent law		The current status of the patents reflects the value of the patent

3.3. Core patent identification method

Specific method is divided into four steps, Step 1 to build a patent reference network, Calculate degree centrality (by degree) and eigenvector centrality (by EC) of network nodes, Using generic cited literature indicators to measure technology flow between research and technology, Based on the three indicators, the important nodes in the process of technology evolution; The second step is to make the statistics of the legal status, patent transfer and patent litigation of all the patents retrieved, The value of the expiration of the term is 1. the value of the unpaid annual fee is 0; The value of the transfer, pledge and preservation of the patent is 1, and the rest is 0; If the value of patent is 1, the other is 0, Combine the legal status of patent, patent transfer and patent litigation index, At the same time, use simple same clan patent index to improve; The third step uses the entropy method to calculate the weight of each index. Entropy method is a commonly used objective empowerment method, which can determine the weight of indicators from an objective perspective by analyzing the degree of connection between the indexes and the amount of information provided by them. Generally speaking, the greater the weight obtained, the greater the impact on the evaluation results. According to the results of the entropy method, all the high technical and high commercial patents are sorted separately. The fourth step, according to Pareto's law, 20% is the classification standard, obtain the patents with high technical and high commercial indexes in the top 20% respectively. Cross-compare the two, get the final patent collection, and assume these patents as the core patents.17

4. Results and the analysis

4.1. Results

(1) The entropy method is used to calculate the weight of each patent index, and the calculation results are shown in Table 2.

Table 2. Weights of each indicator

Level 1 indicators	Secondary indicators	Level 3 indicators	weight
Core patent indicators	High technical indicators	linear measure	0.962870686
		Eigenvector centrality (EC)	0.938634905
		Non-patent citations of f	0.827448523
	High commercial indicators	Simple ethnic patent	0.907234193
		State of patent law	
		Patent litigation	0.954838453
		transfer of paten	

(2) Calculate the technical indicators and commercial indicators of each patent respectively, rank and screen the duplicate items. A total of 262 patents were screened, and the 262 patents were assumed to be the core patents, as shown in Table 3. Relevant studies show that the average value of patents is quite small, and the value distribution is highly skewness. 5%~10% of patents represent half of the overall value of patents [18]. The ratio of patents selected this time to the total number of all retrieved patents is about 4.2%, which meets the requirements from the perspective of data. At the same time, the analysis results have been verified by the qualitative evaluation of relevant superalloy research experts, combined with the research results of other scholars [19] and the industry think tank report [20]. From the perspective of technical field, the empirical research results are in line with the current research status of superalloy field in China.

Table 3. Rantable of core patents and various indicators

Public disclosure (announcement) No	High commercial	High technical	amount to
CN101279346A	0.651981924	1.314341449	1.966323373
CN105483448A	0.988875361	0.884318494	1.873193855
CN102443721A	0.970151901	0.819230369	1.78938227
CN1916493A	0.970151901	0.788527612	1.758679514
CN1490425A	0.506197055	1.19372137	1.699918425
CN102706920A	0.970151901	0.709013227	1.679165128
CN103088275A	0.911832678	0.697861881	1.609694559
CN106636759A	0.970151901	0.567217555	1.537369457
CN102500952A	0.40276599	1.129960512	1.532726502
CN105806878A	0.858844055	0.632373688	1.491217742
.....	.....	.....	.....
CN112746231A	0.40276599	0.298843507	0.701609497

4.2. Analysis of the overall status of the core patents

The core patent reference network was constructed, and the modular index of the network was calculated, and the result was 0.885. The closer the index is to 1, the more obvious the partition is. Therefore, according to the modular results and the color, the size of the nodes is adjusted according to the size of EC and degree respectively. At the same time, the nodes are filtered to make the picture see more clearly, as shown in Figure 1 and Figure 2. In Figure 1, a larger node means a larger EC, that is, the node has more important neighbor nodes. In Figure 2, a larger node means that the node has more reference relationships, and a larger probability represents the core point of technology evolution in this field. Analysis of figure 1, the improvement of the preparation method, various accessories and application of forming method technology topics such as node have higher EC, such as CN102962567A, CN102212720B, CN1490425A, the three not only have higher EC, and the surrounding node also have higher EC, which shows that these patents representative technology in the field by the industry, has become a technology gathering center represented by these patents. Patent such as CN103100620B and CN110487788B, despite having higher EC, But it has not yet formed a central technology gathering center, So the technologies represented by these patents have a high

development potential, It is more possible to become an important technical support in the field; Reanalysis of Figure 2, High-degree patents are more dispersed than patents with high EC, Rarely forming technical clusters, CN101279346A,CN11235434A, CN102120292A and other patents, The high number of height patents of the same module is more, Show that these technical directions are more widely used in the field of superalloy, It is a current research hotspot in this field.

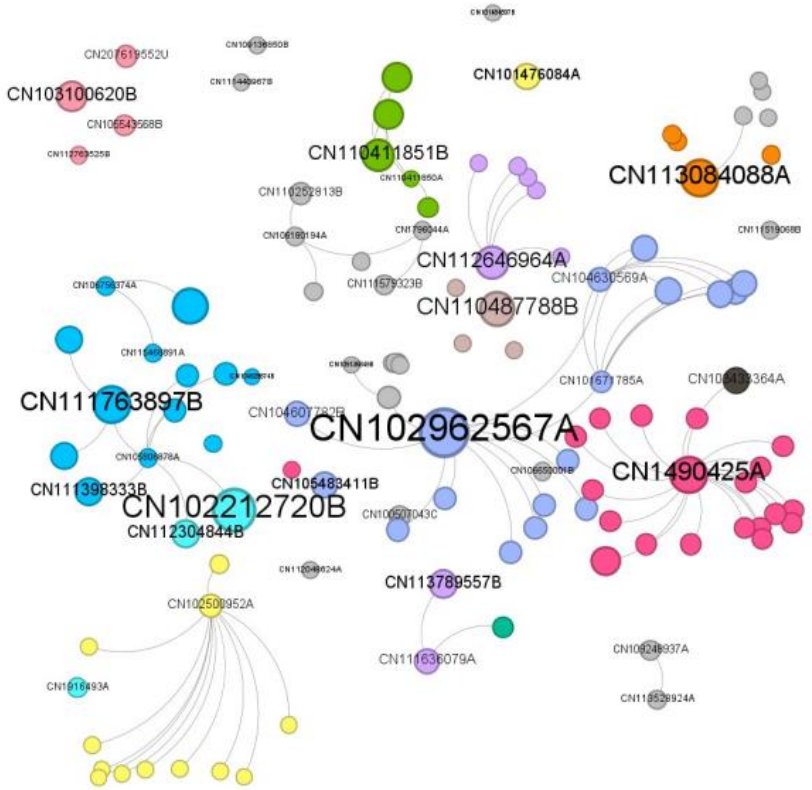

Figure 1. Core Patent Reference Network (node size reference EC)

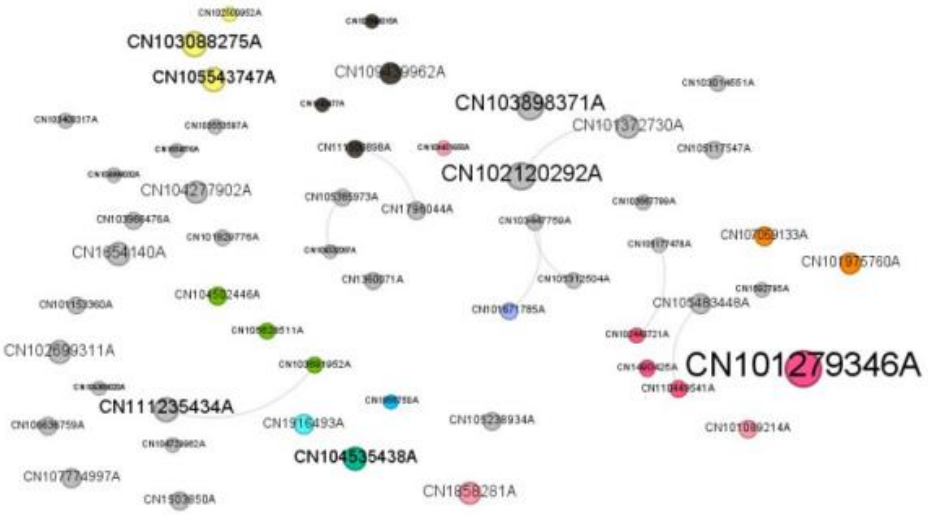

Figure 2. Core Patent Reference Network (node size reference)

The top 10 core patents are shown in Table 4. Among the first ten patents, C22C19 is the main IPC classification number, and it can be seen that nickel or cobalt-based superalloy is the mainstream product in the field of superalloy in China. Superalloy is usually manufactured by rolling method; in terms of main applicants, 9 (90%) of the top 10 core patents are developed and patented by enterprises, which reflects the strength of high-tech enterprises in superalloy industry, and two patents are domestic market and patent layout.

Table 4. Top 10 core patents

Open number	IPC class number	The main applicant	area	amount to
CN101279346A	B21H1/06 、B21J1/04	Guizhou Anda Aviation Forging Co., LTD	Guizhou	1.966323373
CN105483448A	C22C19/05、C22F1/10	Steel Research Institute Co. Ltd	Beijing	1.873193855
CN102443721A	C22C19/05 、 C22C30/00	Liaoning Red & Silver Metal Co., Ltd	Liaoning	1.78938227
CN1916493A	F23D1/00 、C10J3/20	Gas Products & Chemical, Inc	America	1.758679514
CN1490425A	C22C33/04	Baosteel Special Steel Co., Ltd	Shanghai	1.699918425
CN102706920A	G01N25/02	Liaoning Red & Silver Metal Co., Ltd	Liaoning	1.679165128
CN103088275A	C22F1/10 、 C22F1/00 、 C21D6/00 、 B22F3/105 、 B22F7/02	Ansaldo Energy UK Intellectual Property Company Limited	Britain	1.609694559
CN106636759A	C22C19/05 、C22F1/10 、 C30B29/52、 C30B11/00	Liaoning Red & Silver Metal Co., Ltd	Liaoning	1.537369457
CN102500952A	B23K35/30	Zhejiang Yatong New Material Co., Ltd	Zhejiang	1.532726502
CN105806878A	G01N25/04	Suzhou Gaojing New Material Technology Co., LTD	Jiangsu	1.491217742

4.3. Technical topic analysis

The IPC statistics of the core patents in the field of superalloy in China can intuitively analyze the distribution of technical themes in this field. In this paper, the IPC classification numbers of the core patents are clustered in a large to small order according to the frequency, and the results are shown in Table 5. The technical themes in the field of superalloys are mainly distributed in various alloys, such as C22C19 / 05, C22F1 / 10, C22C1 / 02; casting modeling, such as B22D27 / 04, B22C9 / 04, B22F3 / 105; additive manufacturing technology, such as B33Y10 / 00.

Table 5. The IPC classification numbers of the top 10 core patents

IPC, class number	Technology theme areas	frequency
C22C19/05	Chrome-containing	57
C22F1/10	Nickel or cobalt or alloys where they are based	53
C22C1/02	With melting method	25
C22C30/00	The weight of each component is less than 50 for an alloy of 2	18
C22C1/03	Use the parent (middle) alloy	17
C30B29/52	alloy	13
B22C9/04	Using the melt mode method	11
C30B11/00	Single crystal growth by normal coagulation or temperature gradient coagulation.	11
B22D27/04	Affect the metal temperature, such as casting with heating or cooling	11
C22C19/03	nickel-base alloy	10
C22F1/00	Alter the physical structure of non-ferrous metals or alloys by heat treatment or by heat or cold processing	10

The titles of these core patents were processed, the more specific technical topics were analyzed, and the occurrence frequency of the subject words of each core patent was counted. The top 20 subject words are shown in Table 6. According to Table 6, on the whole, single crystal superalloy, deformed superalloy, preparation process, turbine blade are the main core technologies mastered in China's superalloy industry; in terms of specific technical direction, heat treatment technology, electron beam laser, vacuum treatment and other methods are commonly used in the industry.

Table 6. Top 20 subject words for core patents

key word	frequency	key word	frequency
high-temperature alloy	178	foundry goods	9
preparation method	55	repair	9
single crystal	37	installation	9
paint-coat	17	heat treatment	8
take shape	13	laser	8
turbine	12	be out of shape	7
blade	12	prediction technique	7
directional	11	spread	6
powder	10	recrystallization	5
thin-wall	10	gradient	5

5. Conclusion

Core patents represent the more valuable key core technologies of the industry, so they can support the core competitiveness of the industry. Starting from the concept of core patent, combining with the two dimensions of high technology and high commercial, this paper puts forward a new method of judging the core patent of the industry. Taking China's superalloy industry as the object of empirical analysis, analyzing the overall situation and technical theme of the core patent of China's superalloy industry in detail. It is believed that the overall development trend of China's superalloy industry is good and in a period of rapid development. It can be predicted that China will have a stronger technological competitiveness in this industry in the future.

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