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Research on Technology-function Matrix Construction for Patent Layout

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Abstract

Technology-function matrix (TFM) is one of the most important methods of patent layout. The establishment of the TFM can help enterprise managers to make technology layout and market decision. In order to realize the information visualization and automatic construction of TFM, most of the researches focus on sematic annotation technology. The data for the construction of TFM are published patents. But research on the relationship between patents and TFM is insufficient. Considering the deficiency of current research, based on customer requirements and technology life cycle method, a TFM method is proposed. Firstly, customer requirements are accessed by Kano model, and then TFM is established by narrowing the technology domain through technology life cycle diagram. An engineering case is provided to verify the feasibility of the approach.

Keywords: customer requirements, patent layout, technology-function matrix, technology life cycle

1. Introduction

Patent text is the carrier of detailed design information to the public, and it is the most effective way to obtain technical information. How to query the target technical field in large number of patent texts are the issues faced by technicians at present. Patent technology-function matrixes are widely used by technicians among all technical management and analysis tools. It is a kind of patent map, which has advantages in information visualization.

Technicians annotate the patent text. The "technology" and "function" involved in the indexing patent instructions. Merging the similar technical efficacy of different patents, and finally draw the TFM. The matrix statistical tables or diagrams is used to analyze the technical skill and achieving efficacy. The rule of making a matrix is achieving efficacy as the vertical axis, and the technical skill as the horizontal axis. The number of patents or patent number is generally used in tables or diagrams.

Enterprise managers use matrix diagrams to make patent layout, discover technological opportunities, evade minefields, and discover core patents in the specific technical field. Many of the experts and scholars have studied how to improve and perfect the TFM. Kim et al. (2008) had put forward a new method of patent map visualization, established a keyword semantic network without considering filing date, took into account both structured and unstructured items of patent documents, and summarized patent information in a more understandable way. Liu (2013) had proposed a faster method to construct the TFM, and it is easier to update and expand the details. Cheng et al. (2013) had construct IPC and USPC as technical words and functional words respectively, it can help designers to quickly construct the TFM without the help of experts. Nanba et al. (2008) had put forward extracting the technology and function in papers and patents at the same time. Tseng et al. (2007) considered the efficiency and effectiveness of creating patent maps, he researched many methods such as: text segmentation, summary extraction, feature selection, term association, cluster generation, topic identification and information mapping. The above experts and scholars pay more attention to the efficiency and visualization of results in the construction of the TFM. The ultimate goal of constructing the TFM is to help managers make decisions on the next

technology layout, formulate enterprise development plans, and provide guidance suggestions for winning target customers and occupying the market in advance.

However, the existing methods seldom consider the specific requirement of customers or the specific development status of enterprises when constructing the TFM. Based on the above literature, this paper proposes a method of establishing TFM based on customer requirements and technology life cycle.

2. Customer requirements

In the field of product design, the product expected state means customer requirements. Customer requirements is the starting point and stay-dot of product design. A successful product design is that designers translate customer requirements into product functions accurately, and display the functions to users conveniently in the use process. In order to help technicians design successful products to meet users' needs, it is necessary to understand customer requirements accurately.

Kano model was put forward by Professor Kano (1984) of Tokyo University of Technology in 1984. The model considers that the relationship between user satisfaction and quality attributes is non-linear. It defines three levels of customer requirements: attractive, one-dimensional and must-be. The quality attributes of attractive requirement will not reduce the users satisfaction degree even it is reduced, however, it will significantly increase the users satisfaction degree when it increases; There is a linear correlation between the quality attributes and the users satisfaction degree who belong to the one-dimensional requirement; Users will be very dissatisfied when the quality attributes decreases that belongs to the must-be requirement, and it is not helpful to improve users satisfaction degree even the improvement of quality attributes. Detailed form can be seen Fig. 1.

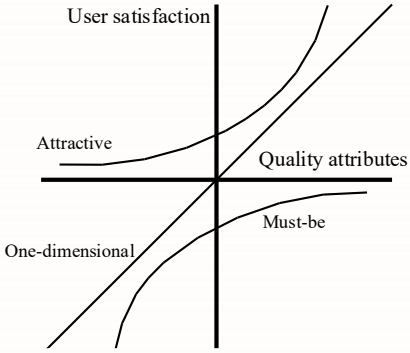


Fig. 1 Kano model's customer requirements

The standard form of Kano model requirements classification table is to set positive and reverse questions. The positive question is the user's feeling when providing this service, and the reverse question is the user's feeling when not providing this service. Both questionnaires have 5 levels: "like", "must-be", "neutral", "live with" and "dislike" for the respondents to choose. Detailed form can be seen Fig. 2.

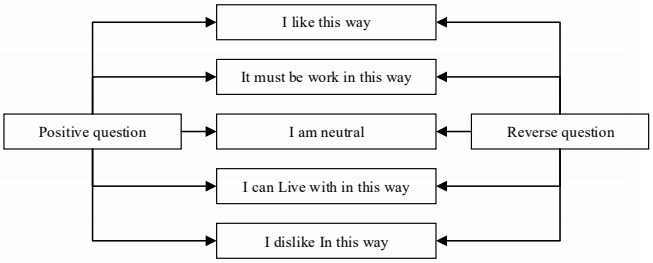


Fig. 2 Positive and reverse questions

The Kano model has some shortcomings, such as low utilization rate of survey data, and it is difficult to categorize requirement types when the number of indicators are the same. In view of these shortcomings, Berger et al. (1993) improved the customer satisfaction index in 1993. On the basis of Kano model, Berger adds an indifferent requirement index. By calculating better-worse index, we can show the impact of a product quality attributes on increasing satisfaction or eliminating dissatisfaction. Berger's formula is as follows:

$$Better=(A+O)/(A+O+M+I) \quad (1)$$

$$Worse=(-1)(O+M)/(A+O+M+I) \quad (2)$$

A=Attractive

M=Must-be

O=One-dimensional

I=Indifferent

The frequency of each type of demand index is determined according to Kano model requirement classification criteria. At the same time, each type of requirement should be determined according to the classification table. R represents reverse requirements. Q represents questions. The Kano model requirements classification table is shown in Table 1.

Table 1 Kano model requirement classification table

		Reverse question				
Positive question	Like	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q
		Like	Must-be	Neutral	Live with	Dislike

By drawing a better-worse quadrant diagram, it can clearly distinguish the type of each requirement. As a basis for the selection of technical blank area in the TFM, technical blank area must be a true reflection of customer requirements. Technical blank areas should not be settled at the point where customers don't care. Clear categorization of customer requirement is an important prerequisite to improve the accuracy of patent layout.

3. Technology life cycle

Tan (2010) have shown that patent technology will generally follow the four stages of technology life cycle development. Four stage life cycle include introduction, growth, maturity, and decline. Each of these four stages has its own development characteristics as shown in Table 2.

Table 2 Stages of technology life cycle

Stage	Feature	Strategy
Introduction	The number of patent applications is small. Technology R&D activities have just started, and the market of product technology is not clear. There are only a few enterprises involved in product production and R&D. Whether the technology can be recognized by the market and whether it is feasible is highly uncertain.	Make full use of the existing components and resources in the system, focus on solving bottleneck technology, and bring products to market as soon as possible.
Growth	With the development of this technology, the product market is constantly expanding. The number of participating enterprises is also increasing, and the number of patent applications is also expanding.	Promote the main products performance to the best and seize the market opportunity.
Maturity	The number of participating enterprises began to decrease gradually. Only a few enterprises were still engaged in relevant researches in this field, and the growth rate of patent applications began to decrease.	Improve product appearance, simplify system. Combining technology with other fields to achieve innovation.
Decline	As the profits of enterprises shrink, enterprises begin to withdraw from the technology market, and the growth of patent applications is negative.	Looking for alternative technologies for new areas and products.

Distinguishing the current development stage of this technology is essential for enterprises to enter this field and improve their products. Through the analysis above, we can see that technology in the stage of growth is easier to occupy the market and obtain higher profits than other three development stages. We need to make a clear judgment on the stage of technology development. In order to accurately identify the technology field at the end stage of introduction or the early stage of growth, it is necessary to be more sensitive and discernible than other competitors. Only in this way, it is easier for enterprises to obtain high returns by combining the characteristics of their own development and choosing technology in the stage of growth.

There are many methods to judge technology life cycle, including S curve method, patent index method, relative growth rate method, technology life cycle diagram method, TCT calculation method (Zhong et al. 2012, Cao 2005, Chen et al. 2006, Lou 2011), etc. Each method has its own advantages and disadvantages. In order to facilitate data acquisition and calculation, this paper chooses the technology life cycle diagram method to judge the technology life cycle.

Generally, the number of patent applications reflect the degree of technological development activities, and the number of applicants reflect the

enterprises or individuals involved in technological competition. Using the data of the number of patent applications and the number of patent applicants varying with time, according to the relationship between both, the technology life cycle diagram can be drawn. Detail can be seen in Fig. 3.

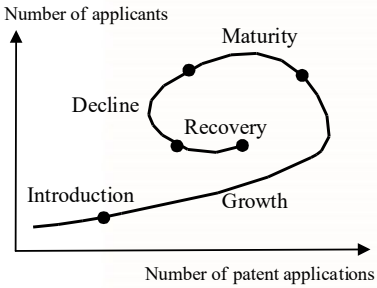


Fig. 3 Technology life cycle diagram

Based on customer requirement acquisition and technology life cycle judgment, a new method to construct the TFM is proposed. The specific process can be seen in Fig. 4.

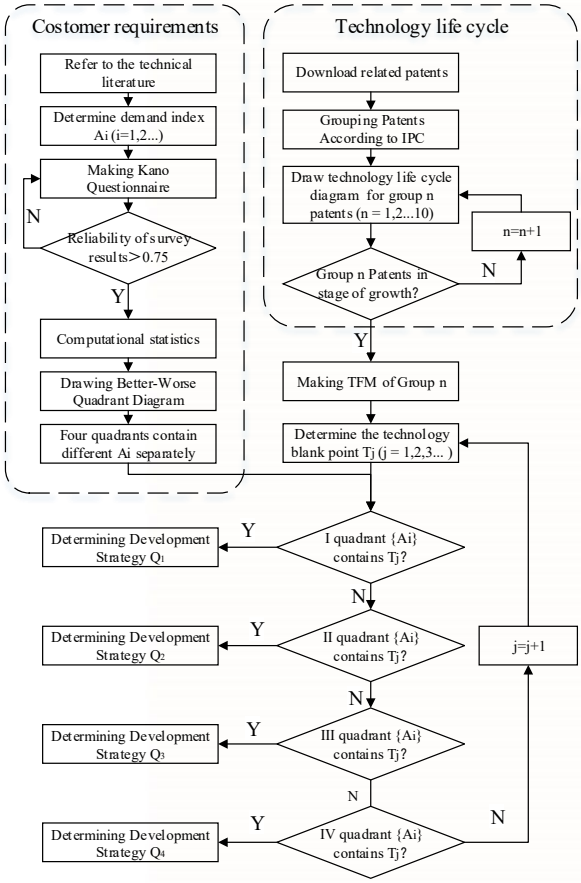


Fig. 4 Establishment of technical - function matrix

Step 1: Acquire customer requirements

Refer to relevant technical literatures and summarize the indexes listed in the literatures describing product performance. According to these indexes, Kano questionnaire was made and the reliability of the survey results was analyzed. The statistical results are calculated, and customer requirements are classified by Berger model. Finally, the quadrant of each requirement index is determined, and each quadrant represents a requirement type.

Step 2: Establish the technology life cycle diagram

Download related patents. Extract keywords for the technology to be analyzed through the analysis of the technology in the stage of growth industry. The key words of technology are input into the patent search software. In this paper, PatSnap are used as the search platform. The extracted keywords are input into the patent search software, and the International Patent Classification (IPC) classification numbers corresponding to the patents are used to screen out the other classification numbers related to the target technology. According to these patent classification numbers, the keywords are expanded, and finally the patent retrieval form is constructed. Only in this way can we ensure that all patents in this technical field can be found out absolutely. At the same time, removal of patents unrelated to the target domain. The specific process can be seen in Fig. 5.

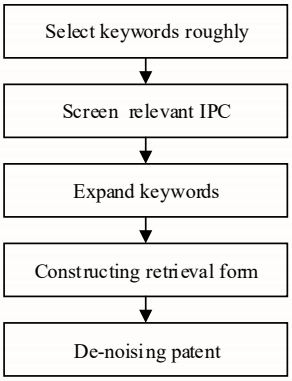


Fig. 5 Patent acquisition process

The key words and IPC classification numbers need to be connected by boolean logic operators in the construction of retrieval form. The specific process can be seen in Fig. 6. The rules for using boolean logical operators are as follows:

(1)The same kind of keywords are connected with each other by the logical relation of "or",

which indicates the expansion of keywords with the same meaning.

(2)Different kind of keywords are connected with each other by the logical relation of "and", which means that two types of keywords should appear in a patent at the same time.

(3)The purpose of limiting IPC classification is to remove some patents. It should be connected with the logical relation of "and".

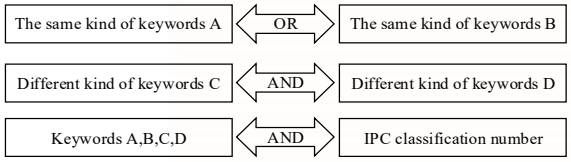


Fig. 6 Boolean logic operators

The downloaded patents are classified according to the subcategory level of IPC classification number. Drawing each subcategory's technology life cycle diagram according to the data of the number of applications and the number of patent applicants varying with time. Patents at the stage of growth are selected as sample patents to construct the TFM.

Step 3: Construct the TFM

The patent texts are labeled "technology" and "function". Technology and function are used as abscissa and ordinate respectively when drawing TFM. Fill in the matrix with the number of patents. Finally, analyses the technical blank area in the TFM.

Step 4: Identifying development strategies

Comparing demand indexes belonging to different categories with technical blank area. Determine the development strategy of all technical blank areas in the TFM.

There are four different development strategies, the meaning of each development strategies can be seen Table 3.

Table 3 The meaning of development strategies

Symbol	Meaning
Q_1	These demand indexes can effectively improve customer satisfaction. There should be at least one such technology in the product.
Q_2	This kind of demand has little effect on the improvement of satisfaction and the decrease of dissatisfaction. Users do not care much about these requirements. When enterprises have limited capacity, they can appropriately reduce their investment in these services.
Q_3	This kind of demand can effectively reduce users' dissatisfaction. This technology belongs to the basic performance of products. When enterprises do not want to expand new markets and adopt a conservative development strategy, they should first meet these indexes.
Q_4	These demands directly affect the improvement of users' satisfaction and the reduction of users' dissatisfaction. Enterprises should pay enough attention to these demands.

4. Case study

Abrasive cutting machine is also called abrasive-disk cutter. Abrasive-disk cutter is suitable for construction, hardware, petrochemical industry, mechanical metallurgy, hydropower installation and other fields. It can cut metal square flat pipe, square flat steel, I-beam, channel steel, carbon steel, circular pipe and other materials. It is a basic and important processing tool in the field of machine processing. The traditional abrasive-disk cutter has the advantages of simple structure, easy assembly, easy portability and low price. Meanwhile, it has some shortcomings, such as heavy weight, high noise and so on. In order to improve the performance of abrasive-disk cutter, many enterprises are committed to the improvement of existing products, it is a key issue how to accurately locate improvement points.

4.1 Customer Requirement Analysis

Data were collected after consulting a large number of literatures about abrasive-disk cutter and visiting consumers and retail customers. A Kano questionnaire with 25 indexes was designed through group discussion and expert consultation, the 25 questions are set up as positive and negative questions according to the standard form of Kano questionnaire. Ask users how they feel when they offered this service or not. Questionnaire design form is shown in Table 4. Fifty questionnaires were sent out and 48 were recovered. 46 questionnaires were valid after screening.

Table 4 Abrasive-disk cutter questionnaire

	Questionnaire	Like	Must-be	Neutral	Live with	Dislike
Positive question	Beautiful display		⊙			
Reverse question	Ugly display					⊙

The reliability analysis was carried out by SPSS software. The result showed that the value of Cronbach's alpha was 0.893. The results of the survey have high reliability, which shows that the questionnaire is reliable. The results of SPSS analysis are shown in Table 5.

Table 5 Reliability analysis

Cronbach's Alpha	Item number
0.893	25

46 questionnaires were collected for statistical analysis. The Better and Worse values are calculated according to formula (1) and formula (2), and the better-worse quadrant diagram is drawn according to the statistical results. The statistical results of the questionnaire are shown in Table 6, and the better-worse quadrant diagram is shown in Fig. 7.

Table 6 Statistical results of the questionnaire

Number	Requirements	A	I	M	O	Better	Worse
1	Beautiful display	8	32	1	5	0.283	0.130
2	Many Product models	2	29	6	9	0.239	0.326
3	Adequate stock	12	23	9	2	0.304	0.239
4	Provide home delivery service	24	13	4	5	0.630	0.196
5	Free installation and maintenance	1	26	11	8	0.196	0.413
6	Payment on arrival	16	25	1	4	0.435	0.109
7	Good service with patience	25	13	7	1	0.565	0.174
8	Familiar with products	7	19	14	6	0.283	0.435
9	Open price	2	16	7	21	0.500	0.609
10	Provide feedback channels	7	31	3	5	0.261	0.174
11	Real-time online consultation	11	29	2	4	0.326	0.130
12	Parts are easy to replace	5	20	9	12	0.370	0.457
13	Easy maintenance	4	23	10	9	0.283	0.413
14	Long service life	21	1	3	21	0.913	0.522
15	Feed controllability of steel pipe	15	22	2	7	0.478	0.196
16	Clamp firmly	8	11	2	25	0.717	0.587
17	Easy to learn and use	13	26	1	6	0.413	0.152
18	Cutting speed is controllable	9	19	4	14	0.500	0.391
19	Easy to replace grinding wheel	7	13	11	15	0.478	0.565
20	Grinding wheel stability	2	1	25	18	0.435	0.935
21	Holistic non-tremor	4	9	18	15	0.413	0.717
22	Operational safety	1	1	16	28	0.630	0.957
23	Beautiful appearance	6	33	2	5	0.239	0.152
24	Cutting a variety of materials	9	22	6	9	0.391	0.326
25	High cutting quality	15	7	18	6	0.457	0.522

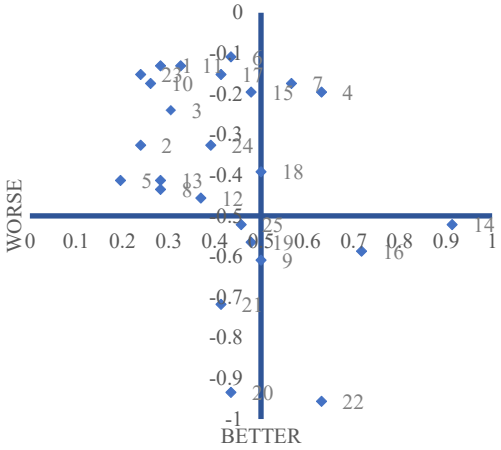


Fig. 7 Better-worse quadrant diagram

Each point in Fig. 7 represents a customer requirement. Better values closer to 1 in quadrant, It indicates that the improvement of this demand index is very effective in improving user satisfaction; Worse values closer to -1 in quadrant, It indicates that the improvement of this demand index is more effective in reducing user dissatisfaction. The name and meaning of each quadrant are shown in Table 7.

Table 7 The name and meaning of each quadrant

Quadrant	Name	Feature
I	Attractive	Better absolute value is high and worse absolute value is low. These indexes have a great impact on improving satisfaction but less impact on reducing dissatisfaction.
II	Indifferent	Better and worse have low absolute values. These indexes have little impact on improving satisfaction and reducing dissatisfaction.
III	Must-be	Better absolute value is low and worse absolute value is high. These indexes have little impact on improving satisfaction but have great impact on reducing dissatisfaction.

IV	One-dimensional	Better and worse have high absolute values. These indexes have a great impact on improving satisfaction and reducing dissatisfaction.

4.2 Product life cycle analysis

The main function of abrasive-disk cutter is to cut cylindrical steel pipe, so the searching key words are "cutting" and "steel pipe". After entering the keywords into the PatSnap Website. Finding synonyms and the same expressions for the initial keywords from the "IPC Classification Number" column. The keywords with the same meaning as "cutting" is grinding; The keywords with the same meaning as "steel pipe" are hard pipe, alloy pipe, thin-walled pipe, metal pipe and rigid pipe. According to IPC classification information, the most relevant IPC classification numbers including "cutting machine" can be obtained: B23K26/38, B23D21/00, B26D7/00, B24B27/00. The final retrieval form is determined as follows through the expansion of above keywords and the de-noising of the IPC classification:

(TAC: (steel pipe or metal pipe or thin-walled pipe or hard pipe or rigid pipe) and ((TAC: (cutting or grinding) and (IPC: (B23K26/38 or B23D21/00 or B26D7/00 or B24B27/00))

The time limit for patent application is 1987-2018. A total of 1085 patents were obtained by retrieval. A further de-noising method is per application only display one open text. Thus, 1001 patents were obtained. These patents are classified according to IPC small group classification. Arrange and analyze the top ten groups according to the number of patents. The technology life cycle diagrams are established respectively based on these patent groups. Classification Number and number of top ten patent applications are shown in Table 8.

Table 8 Classification number and number of top ten patent applications

	Classification Number	Meaning	Number
1	B23D21/00	Machines or devices for shearing or cutting tubes	811
2	B23D33/02	Arrangements for holding, guiding, or feeding Work during the operation	289
3	B23K26/38	Removing material by boring or cutting	143
4	B23D33/00	Accessories for shearing machines or shearing devices	132
5	B23D33/04	For making circular cuts	100
6	B23K26/70	Working by laser beam, Auxiliary operations or equipment	96
7	B23Q11/00	Accessories fitted to machine tools for keeping tools or parts of the machine in good working condition or for cooling work; Safety devices specially combined with or arranged in, or specially adapted for use in connection with, machine tools	70
8	B23D19/00	Shearing machines or shearing devices cutting by rotary discs	58
9	B23Q3/06	For mounting on a work-table, tool-slide, or analogous part.Work-clamping means	45
10	B23Q7/00	Arrangements for handling work specially combined with or arranged in, or specially adapted for use in connection with, machine tools, e.g. for conveying, loading, positioning, discharging, sorting	40

The number of applicants and the number of patent applications are arranged according to the time. And establish the coordinate diagram of the relationship between them. Compare with the technology life cycle diagram standard form in Fig. 3. Determine which stage of the technology belongs to the life cycle. Taking 58 patents under B23D19/00 as an example, the technology life cycle diagram is established. The drawing results are shown in Fig. 8. It can be clearly seen that the curve in Fig. 8 turned backwards in 2018. It shows that the technology of "Shearing machines or shearing devices cutting by rotary discs" is at the end of its growth stage. Even it has entered the early stage of maturity.

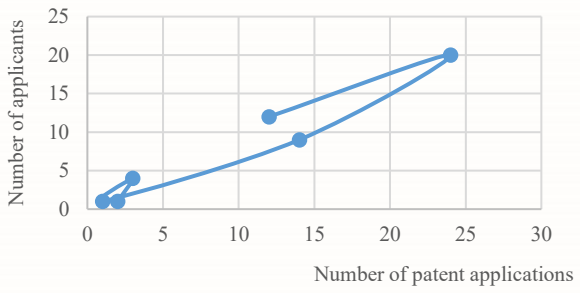


Fig. 8 Technology life cycle of B23D19/00 group

According to the above method, the technology life cycle diagrams of ten technical

fields are established one by one. At the same time, the life cycle stage of each technology is analyzed. Finally, it is found that only technical field "For mounting on a work-table, tool-slide, or analogous part. Work-clamping means" is in the early stage of growth of technology life cycle. The technology life cycle diagram is shown in Fig. 9.

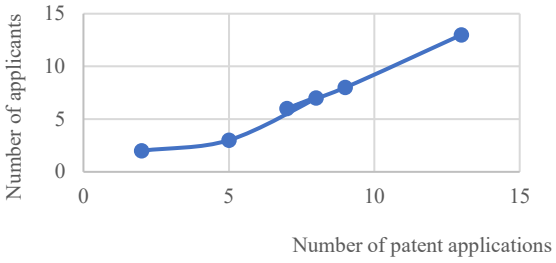
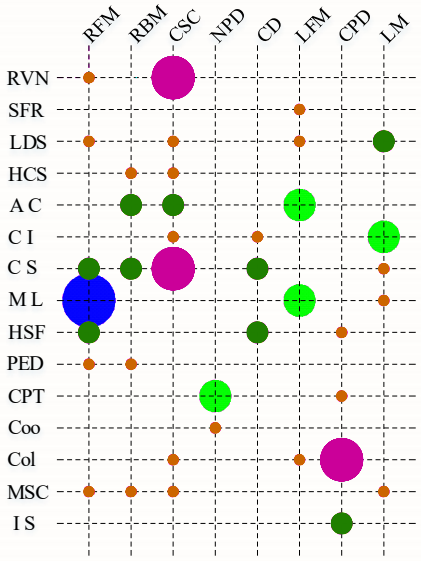


Fig. 9 Technology life cycle of B23Q3/06 group

4.3 Technology-function matrix

According to the analysis in the previous section, 45 patents under B23Q3/06 group are in the early stage of growth of technology life cycle. Choosing the technology in the early stage of growth as the starting point is more conducive to SMEs to improve and develop this technology. Locate the right direction of technology development, push the main performance of products to the best, and seize the market opportunities. By carefully reading the 45 patents under the B23Q3/06 group, we can extract the effects achieved in the patent documents and find the technical means to achieve these effects. Marking the achieved function and corresponding technology, and classify similar technology into a unified expression. Statistics of the number of the same technology to achieve the same function. The technology-function matrix of B23Q3/06 group can be seen in Fig. 10.



RVN: Reduce vibration and noise	RFM: Rotary feed mechanism
SFR: Stable feed rate	RBM: Return baffle mechanism
LDS: Large Diameter Steel Pipe	CSC: Curved surfaces clamping device
HCS: High compressive strength of base	NPD: Negative pressure device
AC: Automatic clamping	CD: Casing device
CI: Clamping invariance	LFM: Linear feed mechanism
CS: Clamping stably	CPD: Collect protective devices
ML: Measuring length	LM: Limit mechanism
HSF: High straightness, Flatness	CPT: Clean processing table
PED: Pipe is easy to displacement	Coo: Cooling and organize
Col: Collect and organize	MSC: Multiple simultaneous cutting
IS: Improve safety	

Fig. 10 Technology-function matrix of B23Q3/06 group

Through the analysis of Fig. 10, it is found that most of the benefits of abrasive-disk cutter patents lie in improving the cutting efficiency and processing quality of steel pipes. To improve the stability of clamping, rotary feed mechanism, return baffle mechanism, curved surface clamping device, casing device and limit mechanism are adopted. The patent layout of this function has been perfected. The abrasive-disk cutter relies on the friction force of the grinding wheel to remove the materials from the steel pipe, and then realizes the steel pipe cutting. In the process of cutting, a lot of heat will be generated, which will cause the burns on the cutting section and inner wall of steel pipe. So it is necessary to reduce the heat generated in the cutting process and improve the cooling effect in order to improve the cutting quality. However, there are few technologies corresponding to improving the cooling effect, which should be the research emphasis in the future.

Through the analysis of the previous section, it is known that the requirement of easy control of feeding belongs to the attractive requirement. Improving attractive requirement can effectively improve customer satisfaction, but as can be seen from Fig. 10, there are few technical means to achieve the effect of "stable feed rate". The technology of improving feed device control has not yet formed an effective patent layout. Technical means to achieve this effect should be focused on.

Operational safety belongs to the one-dimensional requirement, which directly affects the improvement of customer satisfaction and the reduction of customer dissatisfaction. Enhancement of operational safety performance can effectively prevent customer from being unsatisfied, so we should pay enough attention to it. As can be seen from Fig. 10, the intersection point of the function of improving safety and the technology of linear feed mechanism is the technical blank area. The straight-line feeding mechanism moves rapidly, and the workers contact with the steel pipe on the straight-line feeding mechanism directly. It is necessary to further improve this technology in order to achieve the effect of improving safety.

The holistic non-tremor belongs to must-be requirement. Satisfying must-be requirement can effectively reduce the customer dissatisfaction. These demand indexes belong to the basic performance of products. When enterprises do not want to expand new markets and adopt a conservative development strategy, they should first meet these indicators. It can be seen from Fig. 10, the intersection point of the function of reduce vibration/noise and the technology of negative pressure device is the technical blank area. However, it will produce greater vibration and noise when the negative pressure device is running. Therefore, the improvement of negative pressure device to reduce vibration and noise can be regarded as the next research emphasis.

It can be seen from Fig. 10, the intersection point of the function of pipe is easy to handle and the technology of negative pressure device is the technical blank area. The function of rapid positioning of steel pipe by using limit mechanism is remarkable. Although, this effect is easy to achieve from a technical point of view, it is found that automatic steel pipe feeding is an indifferent requirement from the survey of customers. The indifferent requirement has little effect on the improvement of satisfaction and the decrease of dissatisfaction. Users do not care much about these requirements. Therefore, the improvement of the function of easy displacement of pipes can not be the emphasis of research and development. For the 14 indifferent requirements listed in Fig. 7, enterprises with insufficient funds for the production of cutting machines can appropriately reduce their investment in these services.

5. Conclusions

Through questionnaires and customer interviews, the first-hand information of customer requirements is obtained, and these requirements are classified according to the improved Kano model. The classified customer requirements are used to judge whether the direction of patent technology layout is correct.

For small and medium-sized enterprises with weak innovation ability, it is particularly important to choose the technical field in which innovative solutions can be obtained without cross-domain knowledge. According to the characteristics of technology life cycle, technology in the stage of growth is selected as the data for drawing technology-function matrix. After drawing the technology-function matrix, we focus on the technical blank areas, screen these technical blank areas with customer requirements, and further determine the next technology research and development direction.

According to the patent analysis of abrasive-disk cutter, different function improvement methods are adopted for four different requirement types. Finally, the next research emphasis and development direction is determined as follows: easy to control feed, improve safety, and increase holistic non-tremor.

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