The application of product innovation design based on Tacit Knowledge

Zhang Jianmin, Zhou Jun

College of Mechanical Engineering, Shanghai University of Engineering Science, Shanghai 201620,China

ABSTRACT: With the advent of the era of knowledge economy, the knowledge of the traditional product design cannot meet the needs of the users for the product. Improving the quality of product design is the primary way to maximize the benefits, however, product innovation design is the main way to improve the core competitiveness of enterprises and tacit knowledge is the source of product innovation design. Therefore, this paper proposes a application of tacit knowledge in product innovation design. Under the premise of understanding the concept of tacit knowledge, attain tacit knowledge in the mind of the user access from the product, and transform the tacit knowledge through improved Kano model and analytic hierarchy process method to the user's functional requirements to the product, so as to obtain a product of the specific function and function structure chart, completing product innovation design. Finally, the method is applied to the product innovation design of the small advertising cleaning machine to prove the feasibility of the method.

Keywords: product innovation design; tacit knowledge; the improved Kano model; analytic hierarchy process

I. INTRODUCTION

With the continuous development of technology, the focus of researching and developing products not only depends on technology or principles to realize product innovation, but drives product innovation from the knowledge. Service object of product is the users, we only fully exploit the users' emotional and experience (tacit knowledge) so as to make the product meet the users further.

At present, domestic and foreign experts have begun to focus on the users' tacit knowledge, and it is widely used in product design, for example: Japanese knowledge management expert Ikujiro Nonaka introduced the SECI process of the conversion between explicit knowledge and tacit knowledge and solved the conversion problem between explicit knowledge and tacit knowledge; OSGOOD put forwards a semantic difference method that made consumers' mental responses performanced in the Likert scale and then used the relevant mathematical methods to process and analysis by learning object's semantics (including the color of product, the shape of product, etc.), and provided a reliable method for the product conceptual design[1]; Luo Shijian, Pan Yunhe, Zhu Shang shang proposed that in product design, knowledge representation based on tacit knowledge of thinking illustrations provided an important way for externalization of tacit knowledge [2]; Liu Zheng, LU Na, Sun Lingyun, put forward tacit knowledge acquisition method for the process of concept design, which expressed the tacit knowledge with the method of oral report and sketch explanation[3];Chen Youling, Xiao Yingjiao proposed tacit knowledge acquisition of product-oriented design, and the concept of "knowledge cells",at the same time, they completed efficient acquisition of tacit knowledge by means of artificial neural networks[4]. At present, domestic and foreign scholars' research on the tacit knowledge primarily in tacit knowledge acquisition method and tacit knowledge applied to product modeling design. The nature of the product design is its functional improvements which leading to an improved structure. And now, the application

of tacit knowledge on product innovation design is not yet mature.

Therefore, this paper presents the application of product innovation design on tacit knowledge, it mainly solves the function and structure innovation of product. First selecting the adjectives of emotional evaluation related with Product function semantics by consultants and designers, and using the improved Kano model and AHP(analytic hierarchy process) with questionnaires to make the users' tacit Knowledge transform into the users' demand for the product function and make functional design of the product, and finally the establish product function - structure chart to get the final program . At the same time, this study can be used as   a reference of the peers of knowledge management, product design.

II.   TACIT KNOWLEDGE AND PRODUCT DESIGN

2.1 The concept of tacit knowledge

Tacit knowledge is the concept which is proposed by Michael • Polanyi in 1958 from the philosophy proposed [5,6]. He believes that, in a particular situation, tacit knowledge is people-carrier and exists in the human brain and it is the knowledge which is difficult to express in words .It is an important part of the knowledge innovation, mainly originates from the individual's emotion, cognitive or experience.

2.2 Tacit knowledge in product design

Product design services for users, the user's demand, awareness and evaluation for the product is very important, and these are the tacit knowledge which, at the beginning, must be understood by every designer to design products, which we called users' tacit knowledge. Before the users know the product, "impression" will appear in the brain based on past experience and knowledge such as "what functions it should have,""what does it looks like " and other such the problem of 4W1H (what, when, who, where, how); when receiving product information, users typically make use of a certain adjectives, such as "normal", "delicate", "lightweight", "simple" to describe it [7]. Perceptual evaluation of these adjectives is composed to user tacit knowledge. At the same time, users have expressed tacit knowledge for product which is often the experience or ability of using product, it is particularly important for product innovation design.

III.   TACIT KNOWLEDGE'S ACQUISITION AND DOMINANCE

This paper, firstly, selects the tacit knowledge factor (adjectives) related with product function semantics with the way of consulting experts and product designers. For the acquisition of tacit knowledge factor, it must be explicit by a tool, in order to apply it to product innovation design. Therefore, we introduced an improved Kano model and AHP.

3.1 Acquisition and expression of tacit knowledge based on improved Kano model and AHP
3.1.1 Kano model

Kano model was proposed by the Japanese Quality Management experts Kano, which was a model of customer satisfaction related with product performance. Using this model can identify the user's needs, and classify users; requirements [8].Kano model has two important tools: one is a quality characteristic evaluation table; the other is the classification table of evaluation results of   kano model.

3.1.2 Improved kano model

In order to meet the needs of the users' tacit knowledge becomes dominant better, and express the users' deeper functional requirements of the product, we will change the positive issues and negative issues related with product quality characteristics in quality characteristic evaluation table into product functional semantics

expressed by a positive adjective and a negative adjective which consists of product quality characteristic evaluation table, as shown in table 1, where a1 is positive adjective, a1' is the reverse; the traditional classification table of evaluation results of kano model is merely a tool to distinguish users' needs, but it does not clearly express the extent of the users' demand of product. and the users' demands of product are actually a variety of product functional demands, according to primary and secondary order of product, product function can be divided into the basic function and additional functions[9]. Since any product has its basic functions, such as: the basic function of the bicycle is a means of transport, the basic function of mobile phones is make a phone call and so on, and this basic function will not be changed in a certain period of time, so we should focus on consideration for additional function. The additional function of the product is the core of product innovation design. So, we will make a assignment to six demands which are divided in kano model: A shows exciting demand, O shows expected demand, M shows basic demand, I shows irrelevant demand, R shows opposite demand, Q shows problem demand, their values are in turn: 2, 1, 0, -1, -2, -3, in the actual operation, if its value is -3 and -2, then it is an unreasonable demand which can not be considered. As shown in Table 2.

Table 1: Product function demand evaluation table

Positive issue	Having a1's function, how do you evaluate?
	□I like it □It must be so □Indifferent
	□I can bear it □I don't like it
Negative issue	Not having a1's function, how do you evaluate?
	□I like it □It must be so □Indifferent
	□I can bear it □I don't like it

Table 2: Kano Model Product Extrademands score table

Additional functional requirements		Product does not have a1'sfunctional attributes				
		I like it	It must be so	Indifferent	I can bear it	Idon't like it
Products with a1's functional attributes	I like it	-3	2	2	2	1
	It must be so	-2	-1	-1	-1	0
	Indifferent	-2	-1	-1	-1	0
	I can bear it	-2	-1	-1	-1	0
	I don't like it	-2	-1	-1	-1	-3

The users' demand for additional function of product is based on the use of the adjectives (a1 and a1') to evaluate, so only one kind of functional requirements will exist. The results in Table 1 and Table 2: users think the score of products with a1 (positive adjective) functional requirements is 0 to 2, then a1 '(reverse adjective) functional requirements do not need to be tested; if the results are -1 to 0, then a1 '(reverse adjective) functional requirements need to be retested to determine their specific scores.

Using improved Kano model to make explicit tacit knowledge can quantify user' additional function demand for products, but for several additional functions, if their scores are the same ,it is difficult to determine which additional function is more important, then we need to calculate the weight, so we introduce AHP.

3.1.3 Analytic Hierarchy Process

After analysis[10], AHP (Analytic Hierarchy Process) is more accurate and persuasive than the other algorithms, so we unanimously decided to use AHP to calculate the weight of each feature item in the case.①

Identify the characteristics items to be determined--the number of properties of each case, the same to the above is n; ②the relative importance of identify the pairwise important degree between the two feature items, and measure it with the number in table 3;③Analysis experimental data, according to the satisfaction consistency test of judgment matrix ,we can determine that the required feature weight is available or not.

Table 3 1~9 scale method and its meaning

Important degree	Numerical Scale
As important	1
A little important	3
Obviously important	5
Much more important	7
Extremely important	9
Intermediate values of two adjacent odd-scale	2,4,6,8

(1) Get the coefficient matrix of the important degree of the feature items

Each case has j feature items. Comparing with every two feature items which can get the coefficient matrix A of the important degree of the feature items:

$$A = \left(a_{kh}\right)_{n \times n} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & \dots & \dots & a_{nn} \end{bmatrix} \tag{1}$$

a_{kh} represents the first k case feature items which is relative to the importance of the first h cases feature items, and it meets $a_{hk} = 1/a_{kh}$, the value is a certain value in Table 1, while at the same time,if $h = k$,then $a_{kh} = a_{hk} = 1$.

(2) To determine the weight of each feature item

$$\omega_k = \frac{1}{n} \sum_{h=1}^{n} \left| \frac{a_{kh}}{\sum_{g=1}^{n} a_{gh}} \right| \qquad k = 1,2,\dots,n \tag{2}$$

(3) To calculate the maximum eigenvalue

All calculated weights consisted of weight vector W , the weight vector met matrix calculation formula:

$$AW^T = \lambda_{\max} W^T \tag{3}$$

Among them, $\lambda_{\max}$ is the largest eigenvalue of matrix A , according to the equation (3),we know that:

$$\lambda_{\max} = \frac{AW^T}{W^T} = \frac{1}{n} \sum_{k=1}^{n} \frac{\left[AW^T\right]_k}{\left[W^T\right]_k} \tag{4}$$

(4) Consistency test

To test the consistency of judgment matrix A, we will establish the consistency index of the judgment matrix:

$$CI = \frac{\lambda_{\max} - 1}{n - 1} \tag{5}$$

When the judgment matrix has full consistency, then $CI = 0$. In order to measure whether n-order judgment matrix has the satisfied consistency, the average random targets RI of the judgment matrix are introduced. The values of RI are shown in Table 4.

Table 4   The values of RI

Order	RI	Order	RI
1	0	6	1.24
2	0	7	1.32
3	0.58	8	1.41
4	0.90	9	1.45
5	1.12	…	…

In accordance with the values of CI and RI, the consistency of judgment matrix A:

$$CR = \frac{CI}{RI} \tag{6}$$

If $CR < 0.1$, then we can think that judgment matrix A has its consistency.

IV.   PRODUCT INNOVATION DESIGN MODEL BASED ON TACIT KNOWLEDGE

This paper used the improved Kano model and AHP with questionnaires to make users' tacit knowledge explicit. Explicit knowledge is users' additional functional requirements for the product and function design is needed, and the product scheme should be expressed by the way of function-structure chart, and then complete the product innovation design, the specific model was shown in Figure 1:
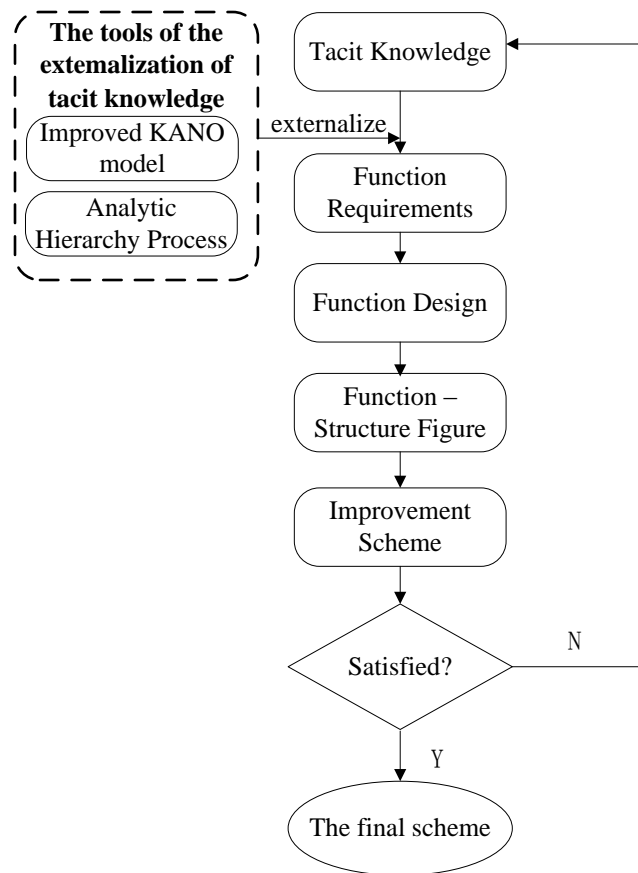
Figure 1 Product innovation design model based on tacit knowledge

Acquisition and expression of users' tacit knowledge: This paper selected n couple of tacit knowledge factors (adjectives) related to the product functional semantics by consulting experts and product designers. For the acquired tacit knowledge factors, we use the improved Kano model and AHP to make them explicit. Externalized knowledge is the users' demands for additional functional requirements of products.

The application of tacit knowledge in product innovation design: Transform the users' additional functional requirements for the products into specific product functions, and decompose the functions by the way of function-structure chart until getting the product structures, and finally the concrete product improvement program was acquired.

The evaluation of the scheme of product innovation design: Designers can compare the acquired scheme of product improvement design to the former product scheme. If the current scheme is more innovative and practical, then output it; or, retest it.

V. EXPERIMENT

5.1 Acquisition and expression of users' tacit knowledge

This paper took small ads. cleaning machine as an example. Due to the current small ads gradually spread, a growing number of city workers begin to use an effective and convenient tool instead of the traditional tools

such as small blades, shovel etc. to clean up the small ads, so that the prospect of using small ads. cleaning machine is very large, but the basic function of small ads. cleaning machine is to clear the paper of the wall, so, this paper will focus on the study of its additional functions.

Prior to the testing, pre-set 20 groups of adjectives related to product function semantics by consulting experts, and after a comprehensive analysis of the designer, we selected the following four groups of adjectives as the users' evaluation vocabularies, as shown in Table 5:

Table 5 Adjectives

NO.	Adjective
1	Integrated - Dispersed
2	Lightweight - Heavy
3	Fine - Rough
4	Environmental - Consumed

This part of the test got the users' evaluation by the way of questionnaires.

Subjects were selected: randomly selected 50 city workers with more than 3 years experience, including male 30, female 20;

Test materials: one small ads cleaning machine, four groups of adjectives;

Test requirements: Introduce to the subjects about the relations between adjectives and product function semantics, and remove the nameplate of small ads cleaning machine, subjects were asked to complete it independently based on their own emotion and experiences to select; the questionnaire is shown as Table 6:

Table 6 Questionnaire (section)

Positive issue	Having integrated function, how do you evaluate?
	□I like it □It must be so □Indifferent
	□I can bear it □I don't like it
Negative issue	Not having integrated function, how do you evaluate?
	□I like it □It must be so □Indifferent
	□I can bear it □I don't like it

Test results: To the choice of the functional requirements for integration, there were 28 people chose additional function requirement of two points, 12 people chose 1 point, 5 people chose 0, and 5 people chose -3 and -2.

Data processing: Firstly, remove the unreasonable requirements of -3 points and -2 points, and other numbers were averaged, the results: integrated functional requirement is 1.51 points. So the requirement for dispersed function will no longer be investigated and analyzed.

For reasons of space, we will not analyze in detail. Other scores of functional requirements: lightweight functional requirement is 1.83 points; fine functional requirement is 0.83 point; environmental functional requirement is 0.83 point. Because of the same score between fine functional requirement and environmental functional requirement, then, we will need to calculate the weights of the two kinds of requirements, the results are: the weight of environmental functional requirement is $W_1 = 0.6$; the results are: the weight of fine functional requirement is $W_2 = 0.4$, so when designing functions and a collision occurs, additional functional requirements with higher scores need to be considered as a matter of priority.

5.2 Product innovation design based on tacit knowledge

1. Function design

According to the Obtained four kinds of functional requirements of the users for a small ad cleaning machine, we can carry out specific function design as shown in Figure 2: arrows represent calculated scores and weights, when product design, if a collision occurs, priorities should be considered.
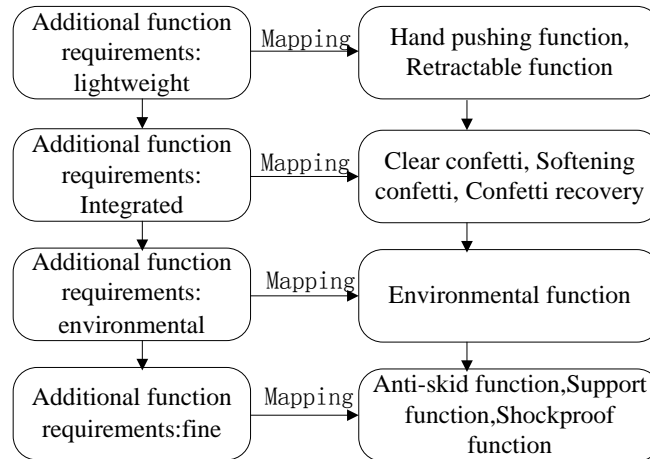

Figure 2 The mapping model of function requirements to function design

2. Function–Structure chart

From the functions of small ads cleaning machine and its function–structure chart, we can get the specific structures and components of small ads cleaning machine , as shown in Figure 3:
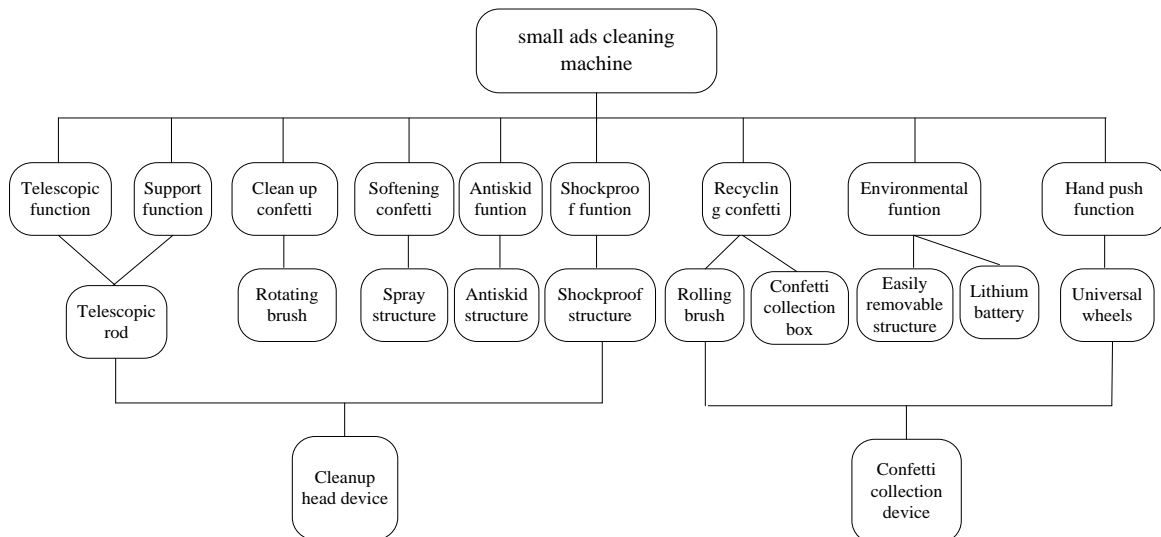

Figure 3 The Function–Structure chart of small ads cleaning machine

The assembly drawing of multi-function small ads cleaning machine is shown in Figure 4: This machine consists of two parts: the head of this machine, and confetti collection device. The head of this machine includes a telescopic rod to, rotating brush, spray structure and the antiskid structure and shockproof structure which were fixed in the telescopic rod which can advoid Vibration and loose generated by the rotating brush at work, the telescopic rod is made of a hollow aluminum alloy and it can connect with water pipe, elastic, the top of telescopic rod can also connect with spray structure, the head of brush is a replaceable wire brush head and easy

to disassemble; Confetti collection device includes universal wheels, Rolling brush, confetti collection box and geared motor and lithium battery, the geared motor which directly made the rolling brush rotate and collect confetti by moving the universal wheels. Complete the innovation design of small ads cleaning machine.
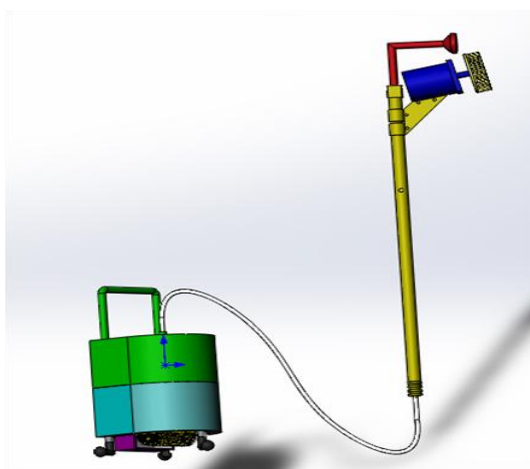

Figure 4 The assembly drawing of multi-function small ads cleaning machine

3. Scheme Evaluation

You can compare the design scheme of ads cleaning machine to the former, and we can know that this scheme has the functions of cleaning up confetti, softening confetti and recycling confetti, thus in order to avoid secondary pollution problem caused by cleaning up confetti. So we can think that this scheme has a certain innovation.

VI. CONCLUSION

In order to improve the quality of product design fundamentally, we propose a method of the application of product innovation design based on tacit Knowledge. Now this article will be summarized in the following two areas:

(1) The tacit knowledge is an important source of product innovation design. By selecting the city workers as subjects, determining the emotional adjectives related to product function semantics and using the questionnaire of improved Kano model, in order to select his product function requirements, according to the users' emotion and experiences, and calculating the same score of function requirements with AHP, thus so as to get the users' function requirements for product.

(2) And then we will transform the obtained the users' function requirements for product into specific product functions which will be transformed into the function-structure chart of product and finally get the specific structures and components of product, and complete the innovative design of small ads cleaning machine, And after demonstrated ,that the scheme has a certain innovation.

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