Research on the knowledge flow evolving model for mechanical product innovation design

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Abstract

The innovation and competitiveness of product require the fulfilment of customers demand. The key is to acquire knowledge of customer needs. In this article, a design knowledge flow cognitive model was built on the traditional FES model, using the acquirement of product demand for a start. It fuses the user's demand, function, effect, structure, constraint and recycling of product for product innovation. According to the model, the level of knowledge classification and description methods was studied and an object-oriented description method of knowledge was proposed. The relation between knowledge and knowledge flow was analysed and so were the vertical relation and horizontal relation between each knowledge point. The evolution process of knowledge was researched based product family Take example for Curve sawing products to validate the proposed model in this article.

Keywords: innovative design, knowledge flow, jig saw

1 Introduction

The decision will be made increasingly based on the data and analysis rather than experience and intuition in the commercial field, economic field and other fields with the coming of "Big Data" era. The ownership and using ability of the knowledge resources has become the source of enterprise's core competitiveness and product innovation in the era of big data. And the effective flow of knowledge is the important premise of innovation and is the main way to improve enterprise competition [1].

The knowledge flow refers to the knowledge's production, dissemination and application between multiple participants according to certain rules or procedures [2]. Design knowledge flow refers to that the design knowledge transmits between all parties of the design activities in the process of product design. Nonaka has proposed the 2D knowledge flow model based on epistemological dimension and the ontological dimension. This model could be used to describe the flow process of implicit and explicit knowledge between different ontology in an organization [3]. Nissen has proposed the 3D model to describe knowledge flow. He made clear that knowledge is dynamic sticky and not distributed within the organization evenly. If there is no relevant triggering mechanism, the static knowledge will always be static, and only the flow of knowledge can create value [4].

Yang Kun etc. have put forward product innovation solving model in which design flow and knowledge flow has interaction of multi-level reciprocating mappings. The different goals of products could be achieved using multi-level reciprocating mapping between design flow and knowledge flow [5]. Qingsong Xing etc. have proposed a kind of product innovation knowledge ontology semantic representation method based on OWL, and established the access mechanism of knowledge sharing and prototype system [6]. Zheng Liu etc., who adopted the method of knowledge flow modelling, has used knowledge node ontology knowledge system to identify knowledge source for the sake of obtaining dynamic creative knowledge [7]. Su Hai has analysed the function of knowledge map in knowledge chain management and presents the knowledge reuse model based on knowledge map [8]. Shengfa Wang has introduced resource space model to describe the knowledge in the knowledge flow. The knowledge is controlled through the integration of knowledge flow and workflow [9]. Haiqiang Liu has put forward a product integration design knowledge model, which could support multidisciplinary design optimization, to acquire product relative design knowledge with an integration of design examples and rules [10]. Qingfeng Bao has put forward a kind of manufacturing enterprise knowledge flow model based on life cycle. The knowledge flow process is divided into four stages: knowledge germination stage, growth stage, mature stage and knowledge recession stage [11].

Currently, the study of design knowledge flow is mainly focused on the aspect of knowledge sharing and

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reuse. The reuse of enterprise existing knowledge, such as data and information, can be realized by building knowledge management system. A company, whose innovative product is developed based on account of a quick access to relevant knowledge of customers' requirements and design tasks, could fulfil the needs of customers in the tight development cycle to gain advantages in the fierce market competition.

2 Knowledge flow model based on product innovation design process

The essence of product design activities is that the design process is driven by knowledge. The product innovation and its competitiveness of product edge require the fulfilment of customers demand and the key is to acquire knowledge of customer needs. In addition, product recycling and reuse should be taken into consideration in order to meet the requirements of sustainable development and energy saving using green design methods. In this article, a design knowledge flow cognitive model was built on the traditional FES model, using the acquirement of product demand for a start. It fuse the user's demand(R), function(F), effect(E), structure(S), constraint(C) and recycling(R) of product for product innovative design, as shown in Figure 1. The original target of product design is to obtain customer needs and then the function of products could be designed according to customer's demand. Meanwhile partial of the demands will be transformed into constraint during product design process. Following the determination of product function, the function is mapped into generalized physical effect to seek original theory. The product structural design can be conducted on the basis of original. The factors of constraint, recycling and reuse should be taken into account in the process of structural design. Eventually, the overall solution for products will be obtained.

With the proceeding of product development, the design knowledge of product is improved increasingly. During the process, which starts with user's demand and end with a fruit of a complete product solution, product design knowledge is indispensable. At the same time, it flows among every stage of the product design and continuously improves during the process. Meantime, the product's design is iterative with the process of perfection of knowledge and the knowledge flow will get corresponding feedbacks. From the view of natural evolution, knowledge itself in each stage is endowed with a process of evolution. Therefore, in order to support the product innovation design better, different stages of knowledge should be described and relation of knowledge in different stages should be established to construct a knowledge network.

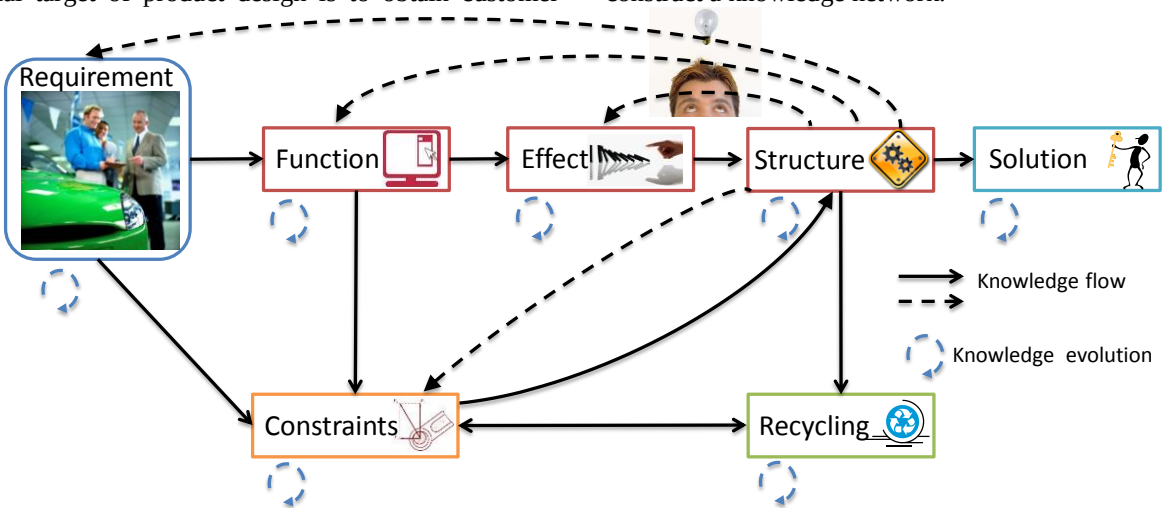

FIGURE 1 Knowledge flow model based on product innovation design process

3 Classification and description of different levels knowledge

According to the knowledge flow model mentioned above, knowledge could be classified from four levels. Here take jig saw products for example to describe four different levels of knowledge, as shown in Figure 2. Jig saw is a kind of normal electric tools, which is widely used in the fields of automobile, shipping and decoration etc. During innovative design of jig saw, customer's demand is reflected mainly in the aspects of material, cutting stroke, sawing thickness. Meanwhile customers also hope it is of low vibration and low noise in the process of using. Its main function is to realize the saw cutting through reciprocating movement. The electrical parts, transmission parts and supporting part should be designed in the developing process of jig saw. Take the transmission part as an example, gear drive is adopted. So the drive ratio of gear drive can be calculated with relevant mechanical principle knowledge. Then the speed, input power and torque of each shaft can be determined. After accomplishment of the designing calculation, corresponding structural parameters can be determined. The drawings and 3D model will be mapped out in the end.

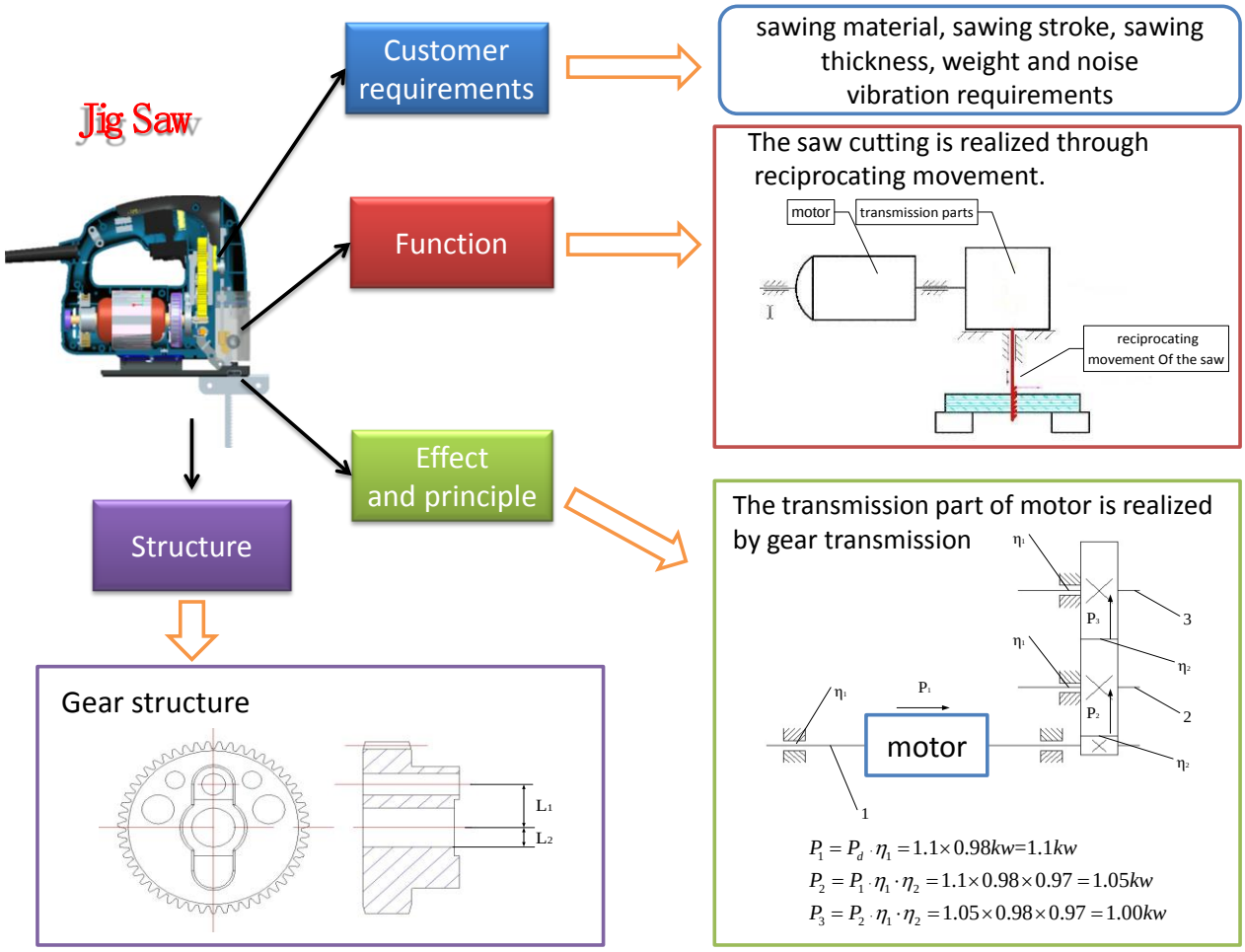

FIGURE 2 Knowledge description of jig saw products in four aspects

The knowledge description should be satisfied the needs of designer and the computer. In other it should be convenient for the usage and exchanging among the designers and also be easily to store in the computer to realize computer-aided designing. Designers communicate with each other via natural language, graphics, formula and model etc. While the computer is apt to realize the management and storage of structured information and knowledge. Therefore an object-oriented method is applied to describe knowledge. The knowledge could be regarded as an object and a management object will be created to describe knowledge. Then the knowledge master record (KMR), which is the structuralized data of knowledge, will be created to be managed easily by computer. As to specific knowledge, general description method can be adopted to describe the specific knowledge for facilitating communication among designers, as shown in Figure 3.

In Figure 3 some attributes of object is defined to organize and manage knowledge. By means of these attributes, the content and features of knowledge can be reflected in different hierarchies. A living example for knowledge is shown below.

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  <Gear Design notes>
  <Shaft>
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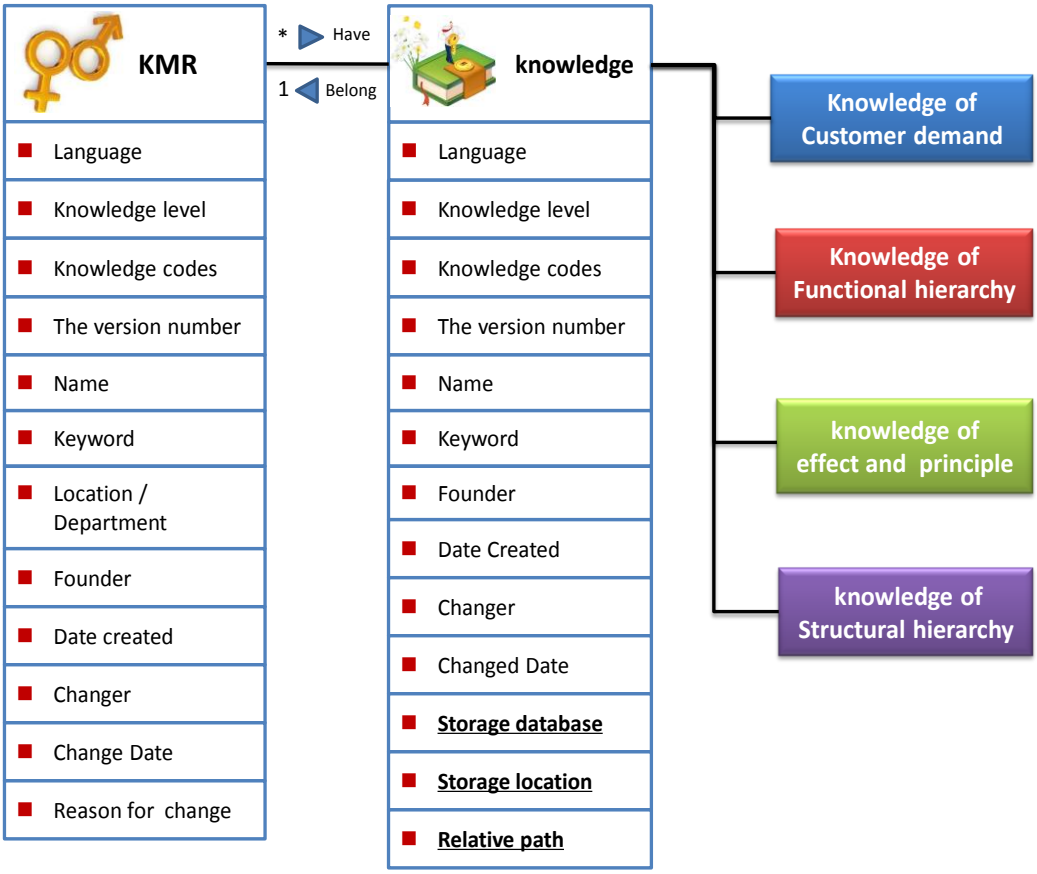

FIGURE 3 Object-oriented knowledge descriptions

Knowledge as an object, a method should also be needed besides the definition of its attributes. Figure 4 describes the "display" method of object via which the relevant properties of the object can be demonstrated.

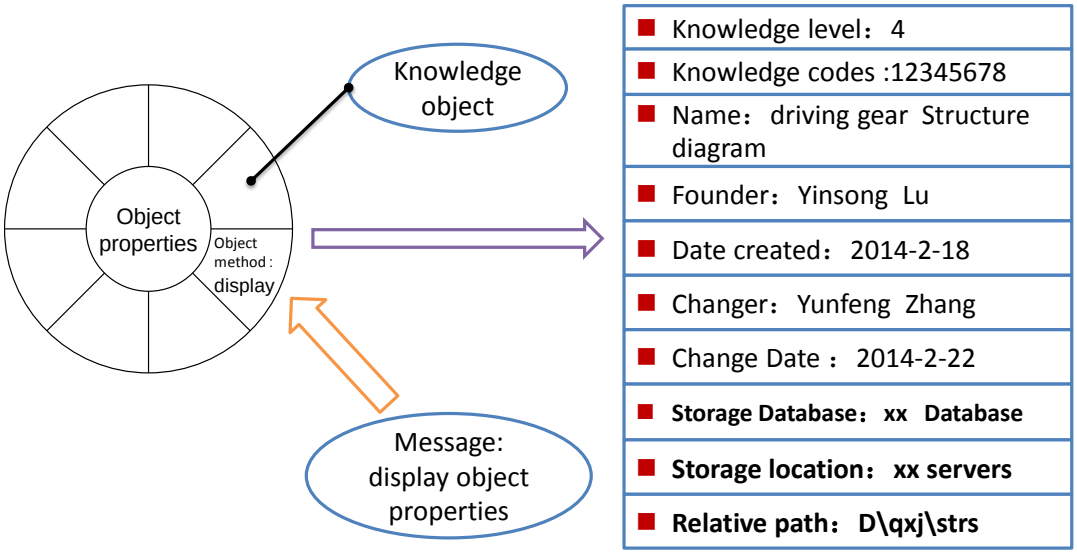

FIGURE 4 Example for knowledge object method

4 Contact and flow between the knowledge of various stages

The process of innovative design for mechanical product can be seen as a process in which the knowledge produces, flows, shares and apply between different designers, as shown in Figure 5. There are many relations between knowledge. Here the relationship between transverse knowledge and longitudinal knowledge is described mainly. The horizontal linkages refer to knowledge flows between the different levels and different stages of knowledge. The vertical linkages

refers to the different stages belongs to the innovative design of the same product. It remains relatively integrity of knowledge. The knowledge of different stages is needed to design a product. It is difficult to design a product by only grasping a certain stage of knowledge, which truly meets customer's needs outside and is easy to design and manufacture inside. Horizontal linkages illustrate the flow and timing of knowledge, which can only truly be used for innovative product design and truly reflect the value of knowledge when it flows. Meanwhile the process of knowledge development is a time sequence. Only when the first stage has been completed or partially completed, the next stage could be started. Knowledge of the previous stages may be the input of subsequent stages while the next stage may require the use of knowledge generated previously.

If the enterprises want to win in the fierce market competition, the products must be meet customers' requirements. So knowledge of acquiring customers' needs is the starting point in product innovation design. After a clear understanding of customers' demand, the customers' needs should be mapped to specific product functions. After determination of product function, the following steps are to seek for specific knowledge of effects and scientific principles and then to propose preliminary concept design. The initial solution for concept design should be analysed and compared and the final solution could be concluded. Also the structure design of product will be done via computer analysis. Innovation design process of mechanical product can be regarded as a process in the premise of the given knowledge input where designers are driven by design goals to create knowledge output through specific design behaviour. Throughout the whole process, the design knowledge is constantly improved, the product structure continues to be improved and a complete solution comes into being finally.

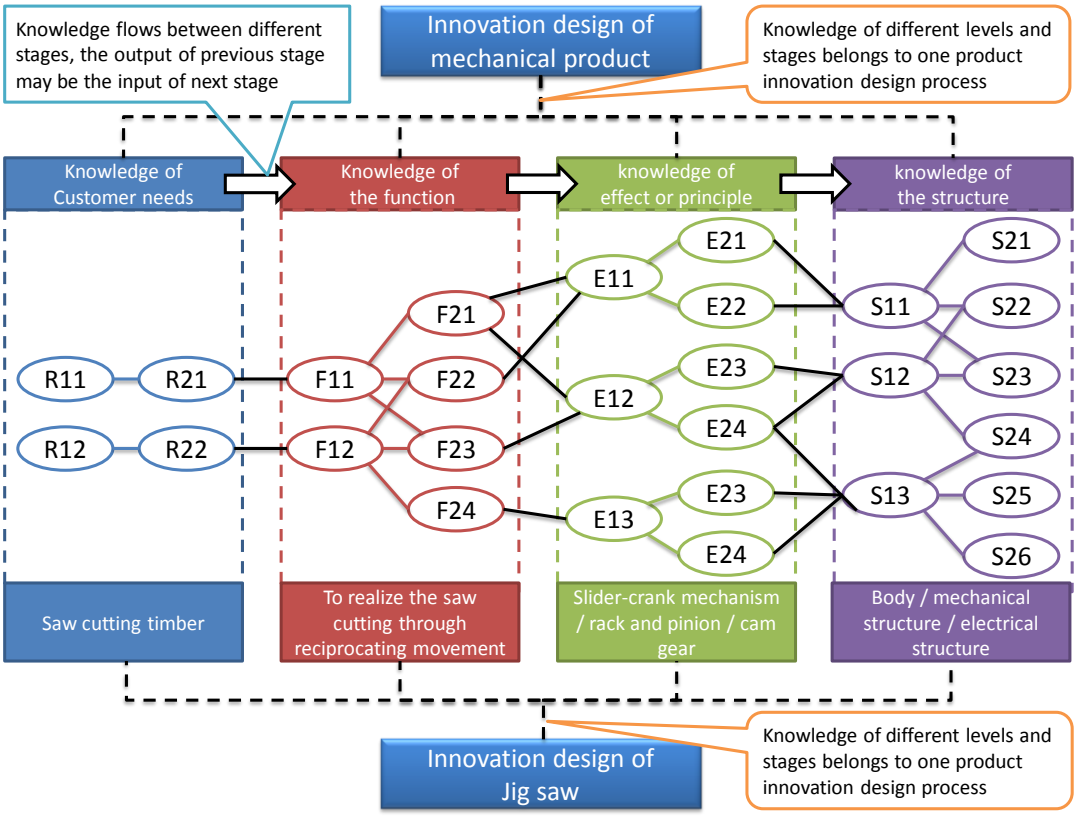

FIGURE 5 Contact and flow between different levels of knowledge

5 Evolution of knowledge itself

Mechanical product innovation design process requires the flow of knowledge. From the perspective of the product family, the product itself is also continually evolving and evolution. Therefore, the knowledge needed to design products is constantly evolving and evolution, as shown in Figure 6. The knowledge flows between different levels and stages in process of product innovation design. The improved design is an improvement on the basis of the original product. And the corresponding knowledge also needs to be evolved based on original knowledge. It is a spiral process. With the improvement of product and the evolution of knowledge, some new changes will be produced for the original product. Consequently, knowledge feedbacks will be inevitably generated.

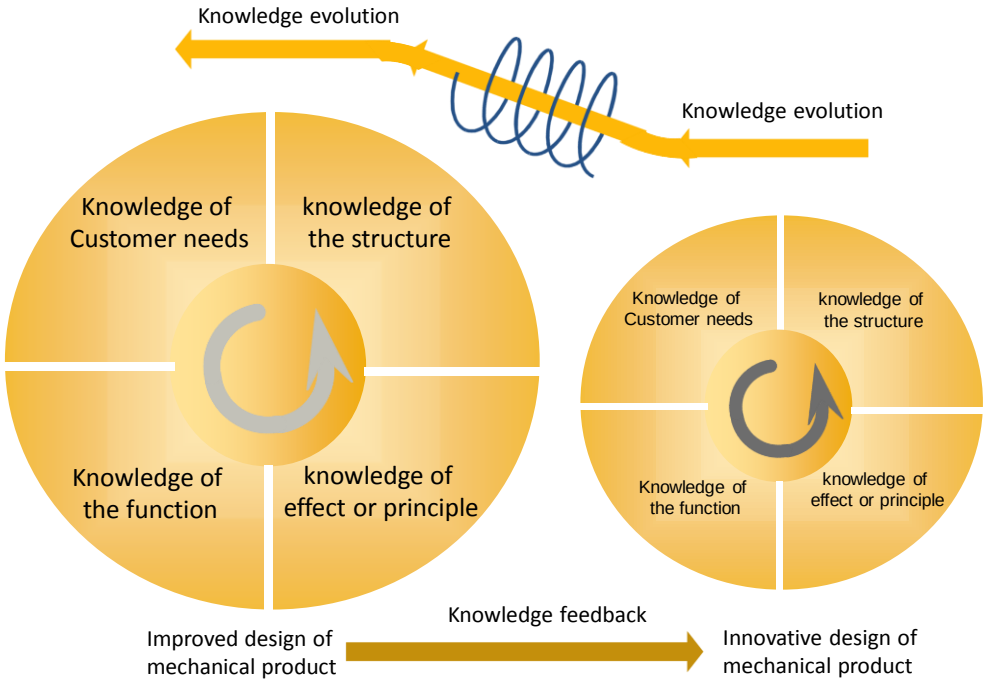

FIGURE 6 Evolution of knowledge itself

5 Conclusions

In order to provide the low-cost, high-quality products that also meet the needs of customers, enterprises' product design is in the direction of rapidity, modularity and knowledgeable. Innovative design of mechanical products is based on knowledge and is aimed at obtaining knowledge of customers' needs as a starting point. Therefore, the evolution model of a knowledge flow's established to describe the flow of knowledge. It will facilitate the flow and sharing of knowledge and serve for the innovative design of mechanical products in a better way. There are many categories of knowledge. How to carry out a unified description of knowledge and realize knowledge integration of the various stages and levels is needed study ulteriorly. And how to build a design knowledge management system is also requires further research. Knowledge can only create value and make better sharing when it flows. But knowledge is sticky, how to improve the flow of knowledge still needs further study.

Acknowledgments

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