Research on Basic Theories and Methods of Conceptual Design of Mechanical Products Based on Demand Dynamics Theory

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Keywords: Demand, Mechanical Products, Conceptual Design

Abstract: The conceptual design of mechanical products and the theoretical design theory of demand dynamics are briefly introduced. The theoretical-based design steps provided by the theoretical design of demand dynamics for the conceptual design of mechanical products are put forward, which make the design process rational. The usability of the theory of demand dynamics in the conceptual design of mechanical product modeling is discussed, and the user individual, social public group and functional technical constraint mode are summarized. This paper analyzes the guidance and convergence of demand dynamic theory in the conceptual design of mechanical product modeling. Focusing on the functional expression, functional decomposition and synthesis, functional reasoning and decision-making of intelligent conceptual design, this paper focuses on the dynamic conceptual design method of functional, principle, layout and structure requirements and the dialectical thinking process of computer simulation of human problem-solving.

1. Introduction

Conceptual design and scheme design are complex creative thinking activities, and their essence is innovation. Conceptual design and scheme design can creatively meet people's needs and even create new demands, thus greatly enhancing the competitiveness of mechanical products and providing important technical support for mechanical product design [1]. Successful understanding of customer requirements in mechanical product design and transforming them into mechanical product requirements are important factors for the success of mechanical products. Mechanical product design is a process of repeated iteration and gradual refinement. At first, it is usually the identification of design requirements, then a series of processes to find the optimal solution to the problem, and finally a detailed description of mechanical products [2]. Because there are many subjective factors in modeling design, it is difficult to control the scheme. The existing research focuses on problem solving, evaluation and establishing user demand relationship model to obtain the optimal design scheme. Renewal innovation or subversive innovation generally refers to the innovation of functional structure and working mechanism, which can only be produced in conceptual design and scheme design [3]. However, important decisions should be made in the conceptual design stage. Therefore, computer-aided conceptual design has become a bottleneck problem of mechanical product automation. So it is necessary to develop design theory, methodology and tools with great efforts so that engineers and designers can put forward optimized design.

2. Basic Connotation of Conceptual Design

Conceptual design is at the initial stage of the whole design process of mechanical product design and engineering design. This stage of work largely determines the performance, quality, price, market response speed and benefits of mechanical products. In the conceptual design stage, table graphs and tree graphs are popular expression methods. They are often used to construct the functions, behaviors and structures of mechanical products. The nodes are used to represent different physical entities, while the edges are used to represent attributes such as speed and force, and the direction of the logistics and the causal relationship between the edges are expressed [4]. Conceptual design includes the working process of determining the design objective, conceiving the

  DOI: 10.25236/scmc.2019.086

design concept, forming the implementation plan, etc. The process of conceptual design is an innovation process from scratch, from fuzzy to clear, from abstract to concrete. The elements that constitute the conceptual design of mechanical products are essentially a constraint relationship, and the goal of the conceptual design of mechanical products is the main constraint of the design process. Research shows that the conceptual design of a mechanical product has determined 80% of the total cost from design to production [5]. Therefore, conceptual design has become the core of mechanical product development and innovation. It is imperative to study a basic theory and method of innovation oriented computer-aided intelligent and integrated conceptual design. The former stage of concept design focuses on innovative thinking, which determines the later stage of innovative concept design focuses on mature convergence thinking and determines the feasibility.

3. Conceptual Design Steps of Mechanical Products Based on Requirement Dynamic Theory Design

Requirement dynamic theory design provides a logic-based theoretical framework for the conceptual design process of mechanical products. The design process is shown in Figure 1.

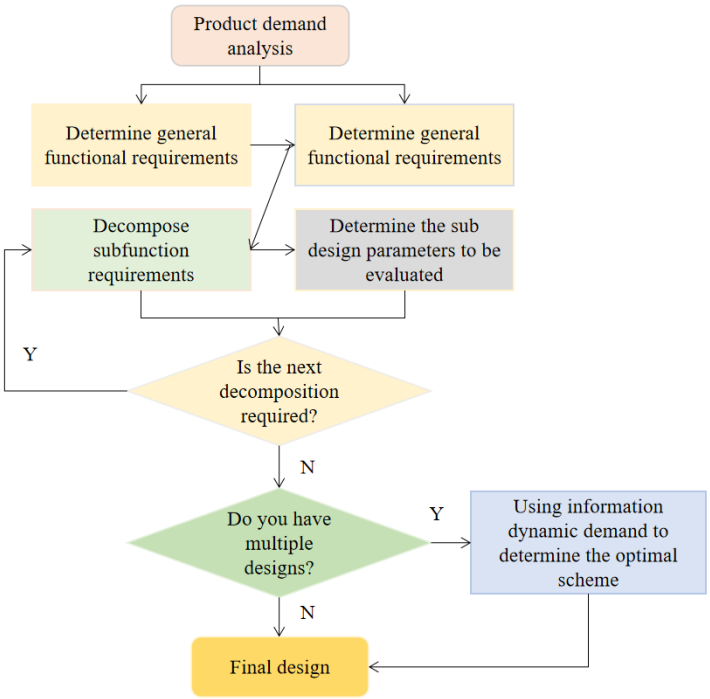

Figure 1 Flow chart of requirement dynamic design

3.1. Requirement Analysis of Mechanical Products

Information is collected from various aspects to determine the characteristics of mechanical products that are in great demand in the current market. User requirements are defined through comprehensive analysis. Elements or structures with certain relationships are extracted as representatives, which are called design features. They are used to design, analyze and evaluate the system and constitute the feature elements of the system. In addition to satisfying some necessary and universal attribute requirements, the attributes of non-customer-determined mechanical products include various industry standards and necessary customer requirements. What really determines the competitiveness of mechanical products is the attributes of customer-determined mechanical products [6]. Customer demand normalization includes demand acquisition and demand transformation. The former mainly extracts, analyzes and synthesizes customer demand information, while the latter transforms the obtained customer demand information into effective technical demand information. Instinct layer corresponds to the emotional experience of mechanical product modeling, behavior layer corresponds to the emotional experience of mechanical product function and utility, and reflection layer corresponds to the emotional experience of mechanical product

image Each main function can be corresponding to it. Through the spatial or structural relationship between the principle components, they can be organically combined [7]. The presentation of functional requirements not only requires the designer to fully understand the customer needs, but also needs to consider the market feasibility, at the same time, it is subject to the strength of the enterprise. In the framework of constraint pattern, the concept constraint system is formed by multiple constraint rings in modeling design, and the concept design route is formed.

3.2. Determine the General Functional Requirements and General Design Parameters

According to the needs of users and the operation of the enterprise, determine the overall functional requirements of the mechanical products to be designed, determine the overall design ideas, put forward the overall design plan, obtain the overall design parameters. Use matter-element and matter-element to formally describe the functions, principles, layout and structure in the conceptual design, and establish the corresponding matter-element model and matter-element model. At the same time, according to the effective algorithm or formula to calculate the similarity, the similarity is transformed into a mathematical model to solve. Let customers evaluate these virtual mechanical products according to their preferences by scoring, sorting and other methods [8]. Different from the traditional qualitative survey method, which allows interviewees to evaluate each attribute, joint analysis allows interviewees to select or score multiple attributes at the same time, and uses different statistical methods to calculate the relative importance of each attribute and the relative importance of each attribute level. These mechanical products with different performances form a mechanical product family, but have the same principle, and various specific mechanical products meeting different customer requirements can be obtained through structural modification [9]. In the course of conceptual design, designers are required to master modern design methods, advanced manufacturing technologies, professional theories, commercial operations and other aspects of knowledge.

3.3. Transformation from User Requirements to Functional Requirements

The fuzzy user requirements are converted into functional requirements and related constraints, and the functional domain vectors in the design process are defined. This process is a difficult point in the design of dynamic theory of requirements. Different types and levels of systems have certain order structures, which determine the overall characteristics of the system. When the order structures of the systems have commonality, similar characteristics appear between the systems, and the magnitude of similarity increases with the degree of commonality of the order structures, and decreases otherwise [10]. The implication system of functional characteristics is used to describe the functional relationship of conceptual design. The functional matter-element system diagram is constructed dynamically according to the requirements of matter-elements, and things, features and values are considered in the functional matter-element system diagram to make conceptual design revolve around functional design. When the number of factors is not large and the number of levels of each factor is not large, the most direct method is comprehensive test. Make the same number of tests on different level combinations of each factor, for example, make one test on different level combinations of each factor. Therefore, it is very necessary to realize the classification of customer groups through the analysis of customer demand information, so as to obtain the different individual needs of different customer groups, so as to meet the requirements of structural transformation.

3.4. Write out the Design Equation and Determine the Design Scheme

According to the relationship between the functional requirements and the selected design parameters, the design equations of this stage are written. According to the dynamic theory requirements of independent requirements, the design matrix should be diagonal matrix or triangular matrix. Using the dynamic demand method of matter element, along different ways, multiple branch function matter elements and upper and lower function matter elements are developed, so that the design scheme has various alternative ways to realize the divergent thinking process of functional innovation design. Any system is a set of certain elements with a certain structure, and information is a way of interaction between various elements of the system. The

formation and development process of all system sequence structures are closely related to information and directly controlled by information. It is common practice to show each interviewee a set of test cards to test their respective preference for mechanical products. Interviewees rate or rank each simulated mechanical product according to the degree of preference or purchase possibility. It is believed that scoring is more convenient than sorting and easier to analyze, so the scoring form is more common than sorting. According to the random customer demand information in the market, the customer demand classification tree is established to build the customer demand template to collect the demand information and obtain the decentralized customer demand information. At last, the paper analyzes the scheme of the above process and selects the best design scheme by using the dynamic theory of information demand

4. Intelligent Conceptual Design Based on Requirement Dynamic Method

4.1. Dynamic Expression of Conceptual Design knowledge

Based on the conceptual design of typical mechanical products, this paper analyzes and summarizes the deep knowledge and innovative thinking rules in the process of conceptual design. Since the generation, storage and transmission of information are all in the form of fields, the formation and evolution of the system's order structure are also closely related to the role of information. Generally, two sets of data need to be collected, one for calculating the utility of attribute level, and the other for estimating reliability and effectiveness. In order to implement different mechanical product strategies for different customer groups, further, the demand information is divided into two types: main function demand and constraint demand. Finally, the standard function description and quality function configuration method are adopted to convert the demand information.

The dynamic demand of matter elements provides various possible schemes for conceptual design. On the premise of considering the constraints and compatibility of the design process, these matter elements, paths and schemes are screened. Figure 2 below is a flow chart of dynamic conceptual design of requirements.

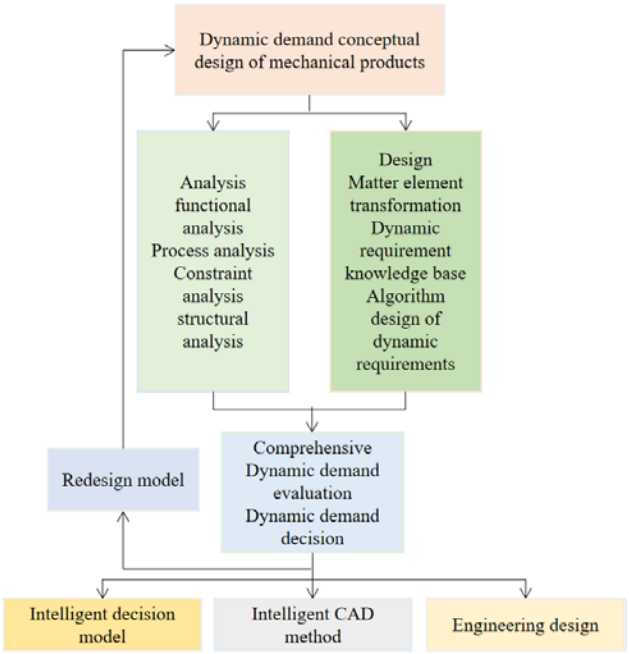

Figure 2 Flow Chart for Conceptual Design of Dynamic Requirements

Only through innovation can competitive mechanical products with novel structure, excellent performance and low price be obtained. The innovation here can be multi-level, such as from low-level innovation work of structural modification and structural replacement to work principle replacement. The deep-level knowledge in the design process is expressed by using dynamic

demand methods such as divergent trees, and the dynamic demand analysis of functions in conceptual design is carried out. This is a compromise process of customer needs. There is a complex many to many mapping relationship between customer requirements and functional technology requirements. A large amount of reusable knowledge has been accumulated in the past mechanical product design, which is of great benefit to clarify the relationship between requirements and functions and to define new mechanical products.

4.2. Establishing Diamond Thinking Model of Conceptual Design Process

The multi-level rhombus thinking model of functional decomposition and synthesis should be established from a main functional matter element. The design decomposed in the design process can meet the dynamic theory of independent demand. The design parameters are all leaf design parameters which can be composed of finished parts. Although they are not completely uncoupled design, they are also acceptable decoupling design. The subsystems can be well combined with each other Work together and adapt to each other to form a unified system as a whole. When a large number of subsystems in the system appear order state through self-organization and self-adaptive, they adapt together in order, thus forming similarity, otherwise, chaos state will appear. Because the accuracy of data is not the key to joint analysis, the key is to determine the relative relationship of attributes and the approximate trend of level from the calculation results. Its fundamental purpose is to obtain a physical scheme of mechanical products that meets certain functional requirements. It is function-oriented, and the corresponding customer requirements are more concentrated on the functional and performance requirements during the purchase stage of mechanical products. Different functional definitions, functional decomposition and working principles will lead to completely different design ideas and methods, thus resulting in completely different solutions in the design of functional carriers. The image scale method is adopted to classify different styles of mechanical products, and the general style and its components of mechanical products are determined according to the distribution of mechanical products in the image scale diagram.

4.3. Functional Matter Element and Matter Element Transformation

The transformation and combination of functional matter element, principle matter element, layout matter element or structure matter element in conceptual design is another dynamic method to solve the generation of multiple schemes and strategies in conceptual design. In order to design diversified and serialized mechanical products, a similarity system design method, i.e. similarity element design method, is proposed. Through the number and characteristics of similarity elements, similarity ratio is obtained to carry out serialized and personalized design. As the technical characteristics of mechanical products are known, the designer's job is to determine which technical characteristics are the main factors affecting the properties of mechanical products. However, due to the Inherent Inconsistency between the limited design resources and the mechanical product attributes, the design process also needs to consider the performance requirements. These performance requirements are described as qualitative or quantitative constraints. Using the substitution, decomposition, addition and deletion, expansion and contraction and compound transformation of matter element and matter element, the correlation and conduction law of design innovation process are studied. If the grey correlation degree of all instances is lower than the threshold, the similarity between the instances in the knowledge base and the current requirements is poor, and the designer decides whether to use the instances according to the actual situation. Through the processes of sketch conception, scheme optimization, scheme optimization, two-dimensional scheme and three-dimensional modeling, the traditional computer-aided design method is adopted to display the modeling. Matter-element transformation method, transformation bridge method and key strategy method play a key role in the transformation of incompatible problems and the generation of innovative schemes in the innovation process.

5. Conclusion

Aiming at the problem that it is difficult to converge after divergent thinking in modeling design,

the conceptual design method of mechanical product modeling based on the demand dynamic theory is proposed by combining the demand dynamic theory with modeling conceptual design. The whole method is divided into two parts: conceptual constraint and scheme design. According to the difference in importance of customer needs, appropriate weights are given to examine the similarity from the overall needs so as to make the search more reasonable. Further analysis is made on the requirements of similar mechanical products so that the design inherits the parts of the existing design that satisfy customers. It enables the designer to select the design parameters corresponding to the relevant functional requirements accurately in the design process; what makes the design no longer simple is the accumulation and application of experience, but a reasonable science. The diamond thinking method proposed in the dynamic method of application requirements constructs mechanical products, which provides a formal tool for the design and optimization of mechanical products. Concept design is put forward on the basis of wide application of CAD. In order to make it practical and widely used, the development of intelligent computer-aided concept design system will be the focus of future research.

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