

STUDY OF CONCEPTUAL DESIGN OF THE EXTENSION METHOD FOR MECHANICAL PRODUCTS

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ABSTRACT

On the foundation summing up existing intelligent conceptual design method, this paper puts forward the research content, characters, path, and method of the conceptual design of extension for mechanical products. This paper rounds the core technology of intelligent conceptual design to research the modeling method of extension design in function-principle-layout-configuration. It includes the function expression, function decomposition and synthesis, function illation and decision. The computers are utilized to simulate the human dialectic thought when resolve problems in this method. The given example shows that the extension method has been applied in the field of conceptual design for mechanical products. This method has important significance to resolve the bottleneck problem of theory studying and engineering realizing of intelligent CAD.

KEYWORDS

Conceptual Design, Mechanical Product, Intelligent CAD, Extension

1 INTRODUCTION

The conceptual design is a process that searches for all kinds of possible product schemes, which can implement the function and satisfy the kind of technical and economic items. It is also a process that confirms the optimum scheme at the end. The conceptual design is divergent thought and creative design process. It has many characters including creation, multi-result, stratification, approximation, experiential and synthetic nature in the stage of conceptual design. It is also a complicated decision-making process. The study results reported: conceptual design of product decides 80% consumption that is spent in process of design and manufacture. So conceptual design is a central problem in the process of designing new products. It is necessary to study a new fundamental theory and method that faces computer aided

intelligent and integrated conceptual design. With the development of design method, computer technology and artificial intelligent technology, the new implication of conceptual design is represented with Computer Aided Conceptual Design (CACD) that is directly used to innovation.

2 RESEARCH STATUS CONCEPTUAL DESIGN

On the aspect of conceptual design method subject, many domestic and oversea specialists put forward decision-making technology that is under indeterminacy statue. They applied the hierarchical information structure to realizing function-carrier alluding^[1]; on the research of conceptual design modeling, many methods are put forward, such as, the hierarchical conceptual model, the function-behavior-structure model^[1], the conceptual model based on power figure,^[2] broad sense characters^[3] and the conceptual design based on cooperating mechanism.^[4] On the aspect of conceptual design creative research, they also put forward the method such as the problem of design intelligence(DI), the qualitative heuristic search mechanism, the method of intelligent selection schemes based on design catalogue^[5], the inference mechanism based on logical illation and fuzzy synthetic appraisal^[1], conceptual design based on hierarchical reasoning mechanism^[6], the problem of redesign and example retrieving and reusing based on example^[7], knowledge expression and reasoning method based on prototype^[8], virtual product conceptual design based on several surrogate technology^[9,10], etc.

The existing theories and methods could drive the development of conceptual design research. But the creative activity searching for rules, which is in the early stage of conceptual design, is studied rarely. It is short of effective innovation, dialectic thought formalizing and modeling method. Main problems are as follows: First, the classical combination of artificial intelligence(AI) method and expert

system (ES) emphasize particularly on the holistic problems of design are being described, the knowledge and experience being inherited, but the deep-seated knowledge and creative thought rules are difficult to be expressed by it. Second, the object-oriented design method utilize natural tendency that people classified and abstracted something, and define the concept such as object, class, message, inheritance, and so on; and describe all aspects of something and relations of them. But it is difficult to express something such as heuristic knowledge. So its application scope is limited in some extent^[11]. Third, the artificial intelligent net technology develops a new path for many things, but it is difficult to solve the complicated problems owing to lacking the intelligent computer hardware. Last, the fuzzy technology can describe subject degree of membership of yes and no with the number that is in the range from 0 to 1. However it can not express the changeability of yes and no. Therefore, it cannot apply the dialectic and seeking different thought to solving non-compatible contradiction problems.

Therefore, it is the difficulty and hotspot of conceptual design that to start from the thought process of conceptual design and discuss the new technology that accords with the human creative thought process, support the computer aided design and decision-making, research creative design and multi-scheme design technology of products. Many of existing methods study the conceptual design from the aspects of design subject, artificial intelligence, neural net, fuzzy technology, virtual realization, modeling and simulating of facing object. But, it is the tenet of study to search for the cross-subjects of thought science, system science and management science, to discuss the creative mechanism and method of conceptual design continually, to make the design method reach the higher ambit.

3 INTELLIGENT CONCEPTUAL DESIGN BASED ON EXTENSION METHOD

Extenics is a new edge subject^[12-16], which is crossed with system science, thinking science and mathematics, and it researches things capability, rules and methods of being exploited and being innovated. The extenics is composed of extension theory, extension method and extension engineering. It is being applied in design fields of products.

It is well known that the mechanical product conceptual design has many characters such as creation, multi-result, complicated nature, multi-scheme nature and indeterminacy of designing illation. The extenics, which is the newest artificial intelligence mathematics tool, is applied to research the extension knowledge expression of conceptual design, to uniting the qualitative and quantitative knowledge of process of design, to setting up the conceptual design matter-element model, to studying the formalization method of human general thought process when people design a new product. According

to the extensibility of matter-element of divergent design and adopting the condition of the matter-element changing towards the uniformity, we can obtain all kinds of schemes. By using the extension decision-making method, we can get optimum scheme.

Based on to the extensibility of matter-element, a series of development schemes of products can be obtained, which is the first test and also is a mature method. Ref. [16~18] discussed and researched the conceive method of products elementarily, put forwarded the rhombus thought method and three creative method of product design. The extension method is successfully applied to the scheme design of mechanical products in ref. [19~23].

3.1 Research content of intelligence conceptual design based on extension method (Fig.1)

3.1.1 Study of extension expression method of conceptual design acknowledge

With the background of the conceptual design of typical product, we analyze and conclude acknowledge and the creative thought rules of the conceptual design process. With the acknowledge of matter-element and thing-element, we describe formally the function, principle, layout, configuration, and build the corresponding matter-element model and the thing-element model. Adopting the divergent extension methods to express the deep-seated acknowledge in the design process, the function of conceptual design can be analyzed. Using the implicative system of the function characteristic to describe the function of conceptual design and utilizing the extension characteristic of matter-element to construct the system figure of function and matter-element, we can unify the matter, characteristic and measure to system figure of function and matter-element. So the conceptual design can be revolved around the function design.

3.1.2 Building the rhombus thought method of the conceptual design

Build a multi-stage rhombus thought model of function decomposition and synthesis. At first, begin with one main function matter-element, go along with different paths using the extension method of matter-element, develop many divergent function matter-element and upriver-downriver function, design many selectable schemes and realize the divergent thought process of function creative design. Then from the feasibility, good-bad nature, true-false nature and compatibility of matter-element, the many matter-element that are obtained from the divergent design can be appraised. Select a few ones that accords with the demand, so the process of convergent thought can be realized.

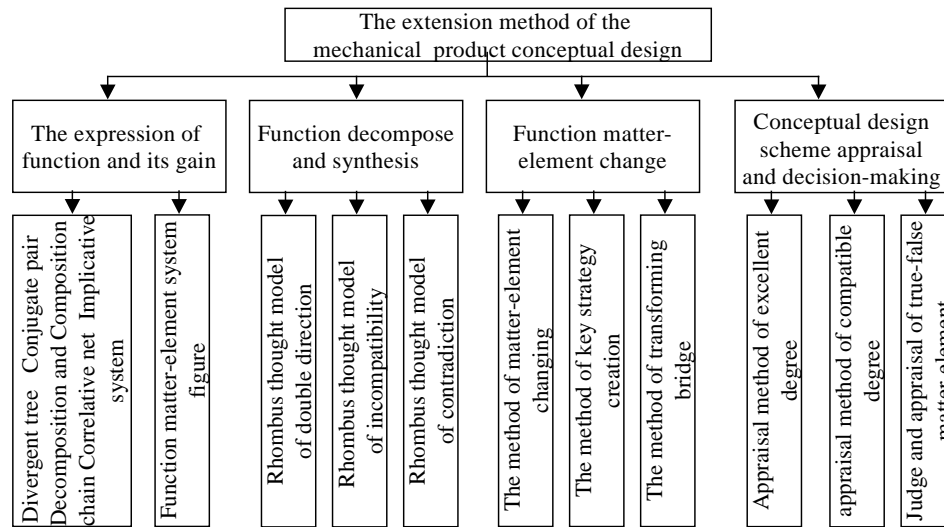


Fig.1 the administrative levels relations of conceptual design of extension

3.1.3 The change of the function matter-element and thing-element

By change and combination of the function matter-element, principle matter-element, layout matter-element and configuration matter-element of conceptual design. It is another extension method that solves the multi-schemes and multi-strategies of conceptual design. Utilize the transposition, decomposition, addition and deletion, expanding and shrinking, combination transformation of matter-elements and thing-element; we can research the correlation and conduction rules of design creative process. In order to solve the non-compatible matter-elements and contradictory elements, the method of transforming bridge is applied. By the way of non-compatible feeding back to adjust main target value, it changes matter-element consistent degree problems to compatible problem. So the contrary target can be turned to general target. Then, we realize the complex reasoning and decision-making, express the dialectic thought rules and improve the intelligent level of design process. Many methods such as matter-element, transforming bridge, the key strategy method, etc, have played an important role in the non-compatible problem innovation and the forming of creative scheme.

3.1.4 The decision-making, appraisal and redesign of conceptual design

The extension of matter-element provides conceptual design with various selectable schemes. We should think about the consistent nature, condition and restriction of design process, and select some from these matter-element, paths or schemes. We adopt the extension decision-making and appraisal method, and analyze sensitive degree of schemes, and appraise schemes on technical, economic, and societal factors. If the scheme is rational we regard it as the decision-making scheme. Otherwise through the information feeding back, we adjust the main target values, redesign the scheme until we get

the optimum scheme. By the excellent degree appraisal method, true-false matter-element appraisal and judging method, consistent degree judging method, it build decision-making and appraisal system. It also complements and improves the intelligent decision-making technology.

3.2 The characteristics of researching

3.2.1 The difference from mathematics basement and start point of existing intelligent conceptual design

With the tool of extension, we build the extension model of conceptual design question and study the extension method based on acknowledge being procured and expressed, decomposed and synthesized, induced and decision-making method. With the method of qualitative (extensibility of matter-element, etc) and quantitative (the dependent function, etc) being synthesized, it forms the extension engineering method of conceptual design. Utilizing the model of matter-element, the model of thing-element and extension method to formally express of creative process, it can form a creative system of computer aided intelligent conceptual design, which still has not been reported in home and oversea. The extension set is the complementarity and development of the classical set theory and the fuzzy set theory. It can describe matter that not only has certain characters but also has contradiction. So it can avoid the "Russell absurdity" of the classical set theory. So the model of matter-element can express and deal with the information transforming relation in the conceptual design process.

3.2.2. The difference from study methods of existing intelligent conceptual design

The extension mathematics model is used to express the deep-seated knowledge. The transformation of matter-element is used to dialectic analysis and reasoning of seeking different. The non-compatible factor of design restriction is changed. The

optimization design of system, in which the quantitative numeration and the dialectic analysis decision are common existing, is solved. Then intelligent design theory method based on the extension model is formed. The essence of this method is formalizing, modeling and combination quantity with quality. It builds the model of matter-element, avoids the disadvantage of the mathematics - some practical contents often are given up, and also avoids the disadvantage of the creative method ----the formalization and the quantity are inadequate.

3.2.3 The difference from content and stress of analogue search of domestic and oversea

The extension engineering method is earliest used to study the mechanical product conceptual design - the key technology of the intelligent CAD. To the difficulty of mechanical product design process, it studies the creative algorithms, and tries to develop a new path for the mechanical product intelligent technology.

3.3 The research method and path (Fig.2)

First, start from the function, principle, layout, shape and configuration analysis of the general mechanical product conceptual design, we study the characteristic of extension set at the aspect of acknowledge expressing and reasoning, and induce the experience, the common sense and configuration acknowledge of design process. Regarding the function, principle, layout, shape and configuration etc matter-element as main characteristic of conceptual design matter-element models

we particularly study the extension acknowledge expression of function information, imperfect information and non-compatible information, and put forward the deep-seated acknowledge expression method based on extension set.

Second, it is divergent design according to the extensibility of matter-element. Build the rhombus thought model with the quantitative tool of dependent function. During the process of design, we should not look the restriction condition (limiting matter-element) as stable and indeterminable, while look it as alterable and dynamic. Utilizing the extensibility of matter-element to research kinds of possibilities of restriction condition change. Thereby, the possible schemes, which can realize the design target, are developed. With the matter-element transformation, the method of transforming bridge and the method of key policy creation we can make the target matter-element and the condition matter-element change toward the uniform. By this way we create an extension method of multi-scheme design that combine the qualitative with the quantitative.

Third, it is convergent design according to the extensibility of matter-element. With the extension synthesis appraisal method we can gain optimum scheme design. Study the extension model of building the process of conceptual design appraisal, decision-making, redesign, and form the mechanical product conceptual design extension appraisal method and decision-making method that regard the appraisal method of excellent degree, the judging of true-false information and the judging of consistent degree as its core.

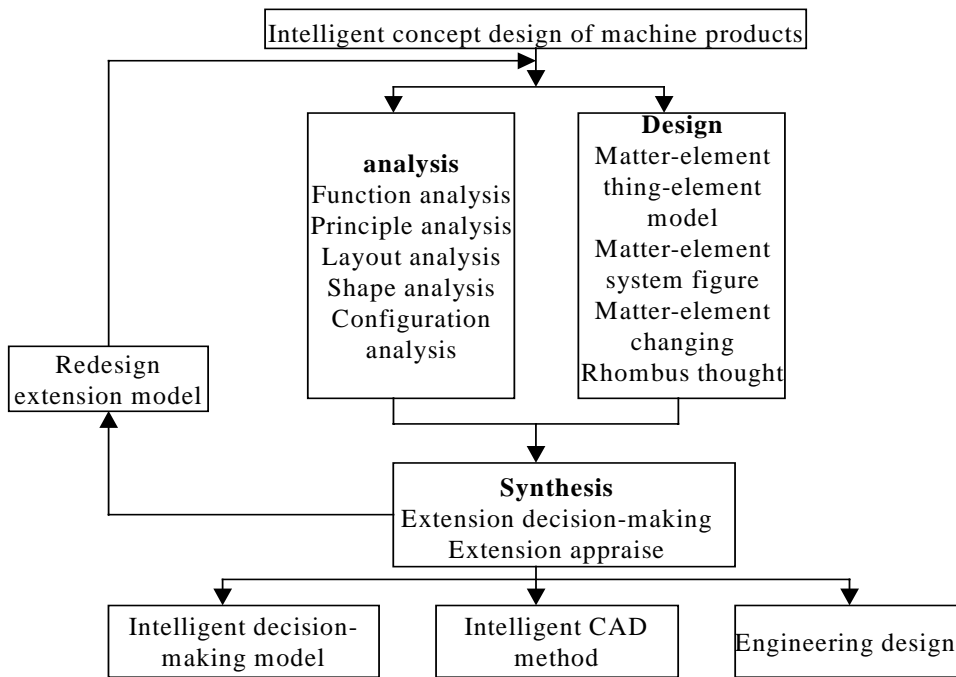


Fig.2 research method and path

Last, we apply this theory achievement to the system of intelligent design, and study the intelligent CAD of mechanical product conceptual design based on extension model, and certify the validity of intelligent design system based on the extension method.

4 RESEARCHING EXTENSION APPLICATION OF MECHANICAL PRODUCT CONCEPTUAL DESIGN

In this paper, the mechanical product conceptual design based on extension method is applied to the intelligent CAD system of the tool storage design of machining-center, and the corresponding knowledge based on extension, graph warehouse, database, method warehouse, the set of extension appraisal and decision policies were built. And they are applied to the redesign of scheme. The divergent tree method of the extensic is applied to developing the machining-center tool storage conceptual design system E-MCCAD such as Fig.3.

5 CONCLUSION

The paper puts forward the conceptual design new theory based on extension method, and applies it into tool storage design schemes. It certifies that this method is feasible and valid by the sample. In addition, by the study and comparison the domestic and oversea information, it has its own new characters:

1.The method applies the divergent tree method of extension: the divergent tree method can make people's thought formal. It also applies the computer to simulating the human being creative thought process, so it will be possible to develop computer aided conceptual design system.

2.The extension is put forward to solve the non-compatible and contradictory problems, and it has abundant thought. Applying the extension method to conceptual design process, people can consider the problem much generally and objectively.

3.Applying the extension method and putting forward the rhombus thought method to construct product, it provides product configuration and optimization with the formal tool.



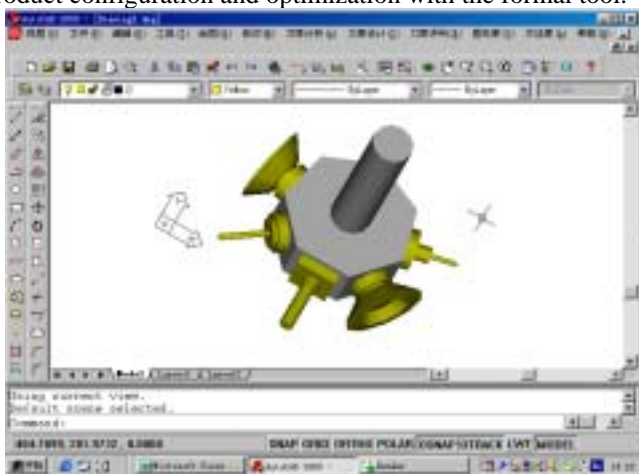
(b) Sample of chain tool storage design
Fig.3 The sample machining-center tool storage conceptual design

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(a) Sample of turning tool-storage design

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