Domain Knowledge Driving in Intelligent Design of Series Mechanical Product

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Abstract

Mechanical product design is one of typical fields which strongly depend on past experience, and its domain knowledge constitution is complex. Oriented to industrial application and product design process, driving serial design of mechanical product by domain knowledge can make the designers release from the onerous repeated work. According to characteristics of mechanical product design and its knowledge constitution, the product model based on design unit and integrated knowledge model are constructed. On the foundation of above, the product design process model is built, by which intelligent design of series mechanical product and intelligent synchronous assembly with design is realized.

Keywords: Series product; Knowledge driving; Product model; Design unit; Design process model

1. Introduction

Mechanical product design strongly depends on past experience. The design process is complex and tedious, which involves lots of domain knowledge. Series design and variant design is common in mechanical design field. Oriented to special industrial application and product design process, the special CAD system can be constructed in which the domain design principal and knowledge, similar design, experts' experience can be merged into geometric model, through which reuse of knowledge resource, intelligent and automatic design can be realized for mechanical products design especially for series and variant design. The designers can be released from the onerous repeated work and concentrate on innovative work.

The design process of one mechanical product is a complex flow which is deprived from the long-term experience of the enterprise and its workers, represents the knowledge accumulation. It is an important research subject in the field of CAD and artificial intelligence to construct the intelligent design system oriented to special industrial application and product design process. In this paper, the realization mode of intelligent design about series product is studied by the construction of a special knowledge driving CAD system combining with the valve product design, and intelligent assembly synchronous with design is tried.

2. Domain knowledge constitution and knowledge driving of mechanical product design

2.1. Characteristics of mechanical product design

Characteristics of mechanical product design are as followed.

1) The design task is multi-discipline collaborative. The knowledge involved in product design is multifarious, disorderly, complex and widely.

2) The representation forms are diverse, which involves principle chart, sketch, two/three dimension drawing, chart, table, process card and so on, which are connected with each other by complex relevance.

3) Sometimes, product design is completed with unreliable knowledge and exploring strategy, which is dynamitic and real-time, the treatment and expression of which is tedious.

4) There are many factors influencing mechanical product design which can not be expressed by accurate theories model. The design is strongly depends on past experience.
2.2. Domain knowledge constitution of mechanical product design

Generally, mechanical product design knowledge involves legislative regulation, national standard, industry standard, enterprise standard, design axiom, formula, patent and so on[1], which is included in diverse design documents. The design experience and skill accumulated by the designers in long-term work decides the living and developing of an enterprise. The mechanical product design knowledge is reflected in four fields, which are industry standard, design rule, experience rule and team skill. The concrete contents are decided by the special industry and its product design.

(1) Industry Standard: Industry standards involve the relative international standards, national standards, industry standards, enterprise standards, which can construct serial rules to promote standardization of commonly used parts and assembly parts, and raise production efficiency and manufacturing level.

(2) Design Criterion: Design criterions are the regulations deprived from repeated tests or long-term accumulation, such as theorem, equator and design specification. One mechanical product design follows the special design specification and design process, which includes the relative general design requirement, verification and calculation, selection of structure type, generating sequence of components and so on.

(3) Experience Criterion: Experience criterion is the instructive rule, which usually exists in the thought of experienced engineers, and is reflected in the product case completed by them. For the special mechanical product design, it is an important content of knowledge reuse to summarize and induct the relevant experience data of the existing product and merge them into application system. Experience knowledge includes structure parameter series usually used, structure type of special component and etc.

(4) Team Skill: Team skill represents the deep comprehension of design group, which is centrally expressed in the product design cases completed by different designers. This is the key factor influencing the competitiveness of an enterprise. Because there are differences between the members of a design team, to ensure that the rational, normative and efficient experience knowledge is absorbed into design system, the experience data must be identified, which will improve the design skill of the whole team.

2.3. Domain knowledge driving of mechanical product design

In the application of traditional CAD technology, general CAD systems are used to design mechanical products. The general CAD system focus on generality, but ignore the characteristic of design object and the influence of design process to improve design level and efficiency, can’t give consideration to the requirement of special industry application and design process, are lack of the integrated support of specific domain knowledge and powerful secondary development support. At the same time, the traditional CAD technology can’t integrate domain design principal and knowledge, similar design, experience into geometric model, and the knowledge resource can not be reused. Designers have to do lots of repeated work and the design efficiency is low.

Domain knowledge driving design[1 ～ 7] focuses on the connotation and nature of product design, combines design process with traditional CAD system, tries to realize efficient support of synthetic domain knowledge to design process. So the CAD system based on domain knowledge support can improve automation and intelligence of product design. By using continuous design standard and experience, quality of design and manufacturing is improved. Design process can be reused. Design experience can be digitally obtained.

3. Construction of intelligent design system based on knowledge driving

3.1. Analysis of mechanical product series design

A mechanical product consists of parts and components, and the components may consist of the subassembly parts and parts. And so on, a mechanical product can be considered to be composed of some parts that have the specific assembly sequence.

The series product has the same or similar design process and the typical structure married with design process. Therefore, through the research and analysis of structure characteristic and design process of specific series product, the domain knowledge of product design is summarized and classified, which can be used to drive series product design. Series product design of knowledge driving reflects the complete picture of the specific series product, assembly relation
of the parts, product design process and all kinds of domain knowledge involved in design process.

Valve is one of typical series products, which series design usually develops in the following dimensions: Nominal Diameter, Nominal Pressure and driving mode. At the same time, series valve product consists of main construction and acuter. The design process of valve product is shown in Figure 1.

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3.2. Product model based on design units and its integrated knowledge representation

As a product family, series mechanical product can be classified into different classes. According to difference of contracture and usage, the industry valve product can be classified into butterfly valve, ball valve and etc. Every product class can be developed in the three dimensions mentioned above. On this library, realization mode of knowledge driving product design will be explored by the construction of product model and its integrated knowledge representation oriented to specific valve product class.

(1) Hierarchical Structure of the Product Model Based on Design Units

Serial mechanical products generally have their special hierarchical structure of parts. By designing part sets, components and structure units, which are of special relevant relations, as design Units which can be independently driven by parameters, the complex design problem can be decomposed and be realized easier. Meanwhile, following the definition of general design parameters (description of design problem and product attributes), According to generating sequence of parts decided by the design process and giving different design unit different parameters and properties, the corresponding serial products can be designed.

In this paper, Design Units are some design relevant units which constitute a product and have assemble and design relevance each other, and can be independently driven by parameters, which may be components, parts, and assembly or design units. It makes product design process accords with designers’ thinking way and working custom to construct product model based on design units, and the assemble relevance and restriction between design units ( and inside of a design unit ) can be defined predictably. The series mechanical product model based on design units is shown in Figure 2.

![Figure 1. Basic design process of valve product](image)

Figure 1. Basic design process of valve product

![Figure 2. The series mechanical products model based on design unit](image)

Figure 2. The series mechanical products model based on design unit

(2) Integrated knowledge presentation

The product model based on design units expresses the abstract concept union of product design case and the class hierarchy structure of product. The overall perspective of product can be reflected by super class, sub-classes, relations and attributes. When the attributes are assigned different values, accordingly different case, objects of series product can be generated. Therefore design unit becomes the design node in design process. The integrated knowledge
model[1] of product design consists of task description, solution knowledge and library support which are according to the relevant design node. The integrated knowledge model is an attachment, which is appended with product model and corresponded with the relevant design unit. Integrated knowledge representation is shown in Figure 3.

Figure 3. Concept model of product knowledge

3.3. Construction and management of knowledge library

The driving knowledge library is constructed on the basis of product model and design knowledge constitution of different design units, which provides support for product design of specific valve and manages design knowledge. The knowledge library consists of general knowledge library, special knowledge library and product case library, which users and their limits of authority are given by user management.

(1) The general design knowledge library is used to save and manage the general knowledge needed in all valve products design.

(2) The special design knowledge library can save and manage the special data needed in specific valve design, such as industry standards data, diverse standard parts or general parts and their parameters, design calculation, typical structure (design units or components) and their parameters, setting parts (actuators) and etc. The contents of this library reflects the concluding and reuse of past design experience and knowledge.

(3) The product case library is used to save product cases and the relevant procedure data generated from special design process navigation mechanism, which is the basis of case retrieve and reuse, past experience data reuse. With the accumulation of product case, experience knowledge can be explored to provide reference for the new product case design.

The complete constitution of knowledge library is shown in Figure 4. According to the design unit generating sequence determined by the product designing flow model, the relative knowledge composing in knowledge base provides knowledge drive for different design nodes.

The special knowledge library of specific valve (butterfly valve) is shown in Figure 5.

3.4. Product design process model of knowledge driving

The product model and its appended integrated knowledge model have defined product structure hierarchy and its design knowledge constitution, transmission and relevance between design data. On this basis, the design process model is constructed, which will navigate design process, drive parametric model of design object, and realize intelligent assembly synchronous with design process. The design process model of typical valve product is shown in Figure 6.

The process model defines the generating sequence of design units corresponding to product model, and the field knowledge composing in the relative knowledge base. According to the predefined knowledge supporting system and adopting active supporting or human-computer interactive way, the field knowledge supporting can be provided for the node in different designing process. Knowledge driving design can be achieved by the construction of design units’ parametric models. The intelligent assembly synchronous with the design process is realized.

4. Conclusion

As for the characteristics of design and knowledge constitution about series mechanical product and the driving requirement of product design, taking the construction of product model for series valve product as example, constructing comprehensive integrated knowledge model and design process model, the realizing mode of series mechanical product design based on knowledge driving is studied, which may be an efficient way to improve the level of normalization,
standardization, automation and intelligence for product design.

Figure 4. The complete constitution of system knowledge library

Knowledge base of the valve product design

- General part base
  - General knowledge library
    - DN series
    - PN series
    - Face-to-face-dimension series
    - Knowledge library of the butterfly valve design
    - Knowledge library of the ball valve design
    - Knowledge library of the goggle valve design
    - Knowledge library of the bleeding valve
  - Typical structure base
    - Corollary parts base
    - Thickness of body
    - Flow diameter
    - Diameter of stem
    - Face flange
    - Upper supporting
    - Under supporting
    - Packing
    - Sleeve
    - Algorithm of sealing structure
    - Open and close torque
    - Strength check
    - Double-eccentric center butterfly valve
    - Three-eccentric center butterfly valve
    - Other butterfly valve
    - Yoke
    - Actuator
    - Manual actuator
    - Electric actuator
    - Pneumatic actuator
    - Hydraulic actuator

- Basic database
  - PN0.25
  - PN0.6
  - ;
  - PN2.5
  - Valve pot
  - Under supporting subassembly
  - Anchor supporting

Figure 5. The special knowledge library constitution of butterfly valve product design
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References


