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Rapid Locking Assembly Variant Design Based on Product Configuration Model and CBR

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Abstract: Aiming at rapid response to requirements of mechanical transmission products customization, a system for rapid locking assembly variant design was proposed in terms of features of locking assembly. The bases of the system are Product Configuration Model (PCM) and Case-Based Reasoning (CBR). According to the system, PCM of locking assembly was built by extending traditional Generic Bill of Materials (GBOM). In addition, integration of PCM and CBR was completed by combining method of transforming PCM to a case with similarity assessment algorithm. Moreover, a rapid variant design software system based on PCM and CBR for locking assembly was developed. Finally, the software system was applied to design new locking assembly. Results demonstrate that it is effective for PCM-CBR to support rapid response to customization.

Introduction

Shaft-hub connection is an important matter in mechanical design. Traditional key joint is difficult to meet high-accuracy and high-speed requirements of modern mechanical products. Compared with traditional key joint, locking assembly is detachable and possesses high accuracy of centering location and overload protection function. Today's customers are demanding quality, style, and uniqueness over homogeneous mechanical transmission products market. Therefore, how to realize rapid response to customization is a stringent problem faced by locking assembly designers. Variant design is an effective method to deal with the problem mentioned above [1]. There are mainly two methods with respect to variant design, which are Product Configuration Model (PCM) and Case-Based Reasoning (CBR). Mannisto and Sulonen proposed an evolvable PCM framework to support variant design. Jiang et al. analyzed the semantic relationship between generic product structure and data [2]. Xu et al. developed a case reasoning method based on decomposed fixture to improve agility of fixture design [3]. However, researches mentioned above focused on one of the PCM and CBR to realize variant design. They did not combine advantages of the two methods. Therefore, these researches have deficiencies in design efficiency and applicability to some extent. In this study, a rapid locking assembly variant design system based on PCM and CBR was proposed. In this system, structure and semantic relation of product were presented in detail through locking assembly PCM. In addition, PCM instantiation process and similarity algorithm were given to achieve the integration of PCM and CBR.

1 Rapid Locking Assembly Variant Design System

A reasonable product design system is the base of product design. This system includes the following two key steps. Firstly, construct locking assembly PCM to achieve accurate, rapid and agile product configuration process. Secondly, merge locking assembly PCM into all CBR procedures (retrieval, reuse, revision and retention) to realize the integration of PCM and CBR. The basic workflow of this system is illustrated in Fig.1.

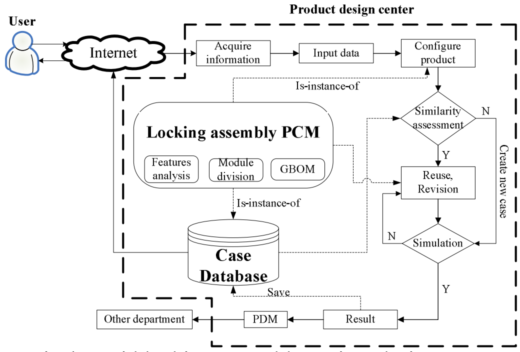

Fig.1 Rapid locking assembly variant design system

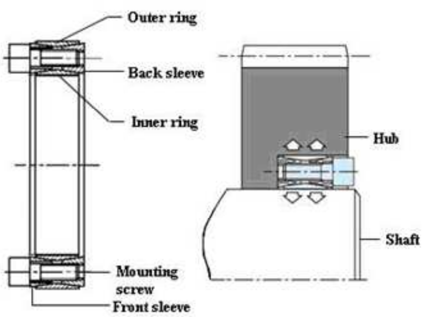

Fig.2 A typical locking assembly

2 Construction of Locking Assembly PCM

2.1 Features Analysis and Modules Division

Locking assembly generally consists of three modules (elastic rings, pressing sleeves and combination screws) plus backing ring. Elastic rings include inner and outer ring. Under the axial force provided by pressing sleeves, radial deformation will occur on inner and outer ring respectively. Hence, they can lock shaft and hub together. Pressing sleeves contain front, back sleeve and mainly provide axial force required by elastic rings. They are commonly installed symmetrically. Some pressing sleeves are also elastic and able to substitute function of elastic rings partly for the purpose of reducing parts, fitting difficulties and costs. Mounting and detaching screws are included in the combination screws module and can provide axial force used to install and disassemble parts. On certain conditions, backing ring is required to meet the location and antiskid demands. A typical locking assembly and its operational principle are shown in Fig.2.

2.2 Locking Assembly PCM

According to the contents mentioned above, a general PCM of locking assembly needs to be built up with the aim of rapid variant design. Generic Bill of Materials (GBOM) is usually used to solve problems of product configuration. It can represent variable product family with an incompact and customizable structure. In this study, a locking assembly PCM is proposed by extending GBOM. It is shown in Fig.3. As a consequence, this model includes more semantic contents and is capable of supporting rapid variant design. It is defined as a triple (N, R, T) where N is a node set, R is a relation set, and T is a set of module type.

Node set. The node set N = [R_{xy}, A_{xy}, P_{xy}, F_{xy}] consists of a root node (R), assembly nodes (A), part nodes (P), and attribute nodes (F). x is the level of nodes, y denotes the sequence number of each node. For example, if a parent assembly node is set to be A_{x1y1}, and its child node is P_{x2y2}, then x2=x1+1; y2=y1+(1+S); S is the sum of the number of nodes between the two nodes.

Relation set. Relation set that describes semantic relation between two nodes includes four relations which are Has-part, Is-a, Is-instance-of and Fit-to. Has-part represents hierarchy relation of two nodes. For instance, Has-part (pressing sleeves, front sleeve) means front sleeve is a component of pressing sleeves. Is-a is a relation in schema that serves mainly two purposes. First, the “lower” nodes are called subclasses of the “higher” ones. Second, is-a relation provides a mechanism for sharing common properties by means of inheritance from superclasses. For example, is-a (normal, front sleeve) denotes that normal sleeve is a subclass of the front sleeve. Is-instance-of is the relation between individuals and classes. As for locking assembly, a product of PCM is the class, while a certain type of this product is the individual. Fit-to is the relation between two nodes in the same level to guide assembly process.

Module type set. It contains three types which are basic, optional, and displaceable module. Basic module is the base of the PCM, such as pressing sleeves and combination screws. The relation between basic module and its parent node is Has-part, while and its child node is Has-part or Is-a. Optional module provides basic one with additional functions, such as elastic ring and backing ring which can be selected in the light of customer needs. The relation between optional module and its parent node or child node is the same as that between basic module and its parent node or child node. Displaceable module includes a set of nodes, such as normal and elastic pressing sleeve. The relation among them is xor, and the relation between displaceable module and its parent node is Is-a.

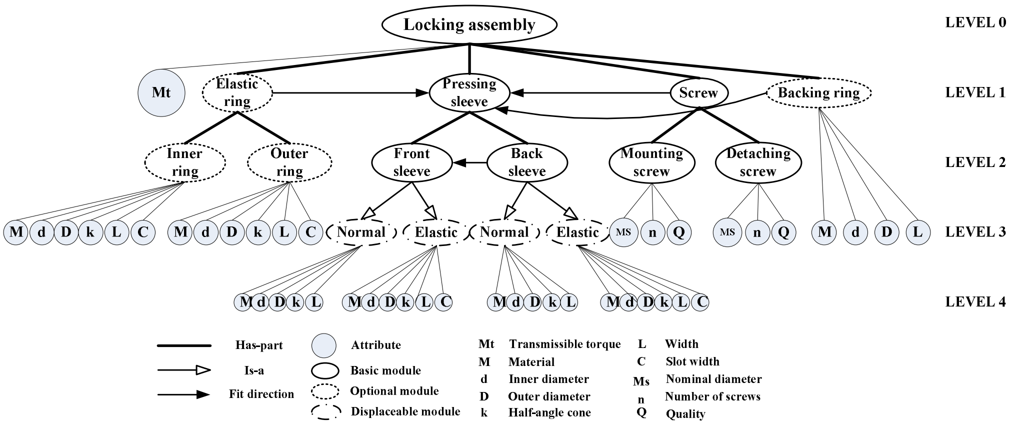

Fig.3 Locking assembly PCM

3 Integration of PCM and CBR

3.1 Instantiation of PCM

No matter constructing the case database or designing new locking assemblies, the PCM must be instantiated. It is shown in Fig.1. Therefore, instantiation of PCM is the key process in integration of PCM and CBR. Take the KLAA-20 locking assembly for example. KLAA-20 is composed of a normal front sleeve, an elastic back sleeve and combination screws. According to the PCM mentioned above, KLAA locking assembly can be configured. Each node is numbered in terms of the definition of node set. As nodes on the higher level are closer to the final product, the relative importance of the nodes on parent level is bigger than that of the nodes on the child level [4]. Furthermore, a parent node usually consists of many child nodes. Consequently, the summation of the number of nodes itself and that of the nodes below decides the weight of nodes.

3.2 Similarity Assessment

The core of CBR is the similarity assessment. Since the case after instantiation adopts structuring description method, many more similar cases will be acquired by means of structure similarity assessment [5]. In this study, a similarity assessment method is proposed based on hierarchy of the case and domain knowledge. Furthermore, a similarity algorithm is designed for nodes on the following three levels which are attribute nodes, assembly or part nodes and root node.

(1) First, for the retrieval and comparison of cases, it is important to check whether the cases are equal in terms of each attribute. a_j is the value of the jth attribute of input case, a_j^i is the value of the jth attribute of the ith case in the case database, $S(a_j, a_j^i)$ is the similarity of the two attributes and $S(a_j, a_j^i) \in [0,1]$. The algorithm of attribute similarity is shown as follows.

{ If a_j contains Chinese, English or null character then

If $a_j \equiv a_j^i$ then $S(a_j, a_j^i) = 1$ else $S(a_j, a_j^i) = 0$ end If

else

If $0 \le \dfrac{a_j}{a_j^i} \le 1$ then $S(a_j, a_j^i) = \dfrac{a_j}{a_j^i}$ else $S(a_j, a_j^i) = \dfrac{a_j^i}{a_j}$ end If

End If }

(2) Second, assembly and part similarity requires to be calculated. $Sim(a_j, a_j^i)$ represents the

similarity of the jth assembly or part of input case and the jth one of the ith case in the case database. z equals to the sum of the number of nodes in the child level node of the jth attribute and the node itself. The similarity of the assembly or part can be obtained from Eq. 1 below:

$$Sim(a_j, a_j^i) = \frac{\sum_{k=j}^{l=j+z-1} S(a_k, a_k^i)}{z} \quad (1)$$

(3) Finally, the similarity $Sim(a, a^i)$ between cases needs to be calculated. This can be done by dividing the summation of the product of the weight W_j of the jth attribute and the similarity output of Formula (1) by the sum of weights, $\sum_{j=0}^{n-1} W_j$. n is the summation of all nodes. The similarity between cases is denoted as Eq. 2.

$$Sim(a, a^i) = \frac{\sum_{j=0}^{n-1} [W_j Sim(a_j, a_j^i)]}{\sum_{j=0}^{n-1} W_j} \quad (2)$$

4 Software System Development and Application

A local manufacturer of mechanical transmission products at Sichuan, China was used as a case study. The company intended to build up their product configuration and design system for the purposes of product specification management and customized product development. To achieve these purposes, a rapid locking assembly variant design software system was developed and shown in Fig.4. This system includes the following two functional parts. (1) Digital information sharing service platform. It provides designers with kinds of information and knowledge, such as product standards, rules, and successful cases. In addition, customers can also search for useful information and give their customization needs through this platform. (2) Product design module consists of three interfaces, which are information input interface, similarity assessment interface and case revision interface.

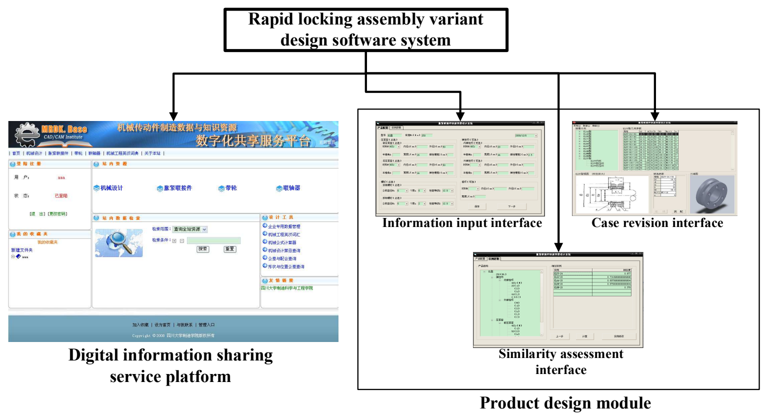

Fig.4 Rapid locking assembly variant design software system

In terms of customization needs from a customer and using the rapid locking assembly variant design software system, a new locking assembly was developed. The development steps are as follows.

Step 1: Acquire customization requirements, which are cutting down number of parts, reducing assembly difficulties and improving efficiency of torque transfer. Other information includes transmissible torque(250N•m), shaft diameter (20mm), central hole diameter of hub(50mm), etc.

Step 2: Input data in information input interface.

Step 3: Perform similarity assessment. For simplicity, only the nodes on the first three levels of input case and KLPP locking assembly form case database are selected to present the calculating process.(1) $n = 16$, $j = 0,1,...,15$; (2) $W_j = \{16,1,3,1,1,3,1,1,3,1,1,5,1,1,1,1\}$ and $\sum_{j=0}^{n-1} W_j = 41$;(3)

The input a_j={KL, 250, elastic ring, inner ring, , pressing sleeve, front sleeve, back sleeve, screw, mounting screw and detaching screw, , , , , };(4) The KLPP a_j^i={KL, 210, elastic ring, inner ring, , pressing sleeve, front sleeve, back sleeve, screw, mounting screw and detaching screw, , , , , };(5) According to Eq. 1 and Eq. 2, $Sim(a_j, a_j^i) = \{0.97, 0.84, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1\}$; $Sim(a, a^i) = 98.4\%$. Actually, there are five similar cases (KLPP, KLGG, KLAA, KLHH and KLNN) in the case database. The values of similarity are 87.7%, 73.2%, 68.8%, 67.5% and 37.8%, respectively. Obviously, KLPP is the most similar case with the input one. As a consequence, it can be used as the prototype for reuse and variant design.

Step 4: Reuse, revise with respect to product structure and feature parameters, and then begin to simulate.

Step 5: Evaluate the new product. Firstly, the new locking assembly adopts the general structure of KLPP and abandons the outer ring. As a result, the number of parts and assembly difficulties are reduced. Secondly, elastic pressing sleeve of the new locking assembly can partly substitute the function of outer ring. Therefore, the new locking assembly ensures the high efficiency of torque transfer. Thirdly, The transmissible torque is 242 N•m which is higher than KLPP's 210 N•m. To sum up, the new locking assembly meets the customer needs.

5 Conclusions

With the aim of rapid response to requirements of mechanical transmission products customization, a rapid locking assembly variant design system based on PCM and CBR was proposed. With the use of locking assembly PCM, the knowledge and experience are standardized. This approach reduces the time needed to configure product. In addition, through the integration of PCM and CBR, designers can share with each other their knowledge and experience. More importantly, the loss of experience and the same mistakes can be avoided in process of product design. However, the flexibility problem of similarity algorithm which exists in the comparison of cases needs to be solved in the future research.

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References

[1] Qi Congqian and Jia Weixin, in: Research on assembly modeling for product variant design[J].Chinese Journal of Mechanical Engineering, 2004,40(1):38-42.

[2] Jiang Weiguang, Wu Jianwei and Pan Shuangxia, in: Configurable product structure model for variant design[J].Computer Integrated Manufacturing Systems, 2008,14(5):849-854.

[3] Xu Lei, Yin Guofu and Ning Qian, in: Agile fixture design based on function-case reasoning[J].Computer Integrated Manufacturing Systems, 2005,11(4):458-462.

[4] Armengol E and Plaza E, in: Similarity Assessment for Relational CBR[C]//Aha D W. Case-Based Reasoning Research and Development. Berlin Heidelberg: Springer-Verlag,2001:44-58.

[5] Lopez De Mantaras R, McSherry D and Bridge D, in: Retrieval, reuse, revision and retention in case-base reasoning [J].The Knowledge Engineering Review, 2006,20(3):215-240.

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