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Research on Extension Knowledge Base System for Scheme Design of Mechanical Product

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ABSTRACT

Aiming at the problem of complex bearing information which caused by iterative accumulation of knowledge related to the internal of bearing manufacturer, the process of constructing knowledge base system(KBS) was analyzed, the secondary development in Web, the object oriented modeling and the rough set included. Matter element model, thing element model, relationship element module and composite element model with implication and extension in the metamodeling of extension theory were investigated, a guiding method of constructing bearing information KBS based on metamodeling was put forward. The constructing of press mounting force module in KBS based on the metamodeling was studied, matter element model, thing element model, relationship element model and composite element model with implication and extension included. The result indicates that the extension element theory can not only express the process of constructing a knowledge module in KBS more systematically and comprehensively, but also solve the problem of complex knowledge information.

Keywords: Bearing, KBS, Extension theory, Metamodeling, Press-fit force module.

1. INTRODUCTION

According to the need of solving problem in a domain, KBS [1] (Knowledge Base System) is a set of interrelated knowledge which by using a representation to storage, organize, manage and use in the memory of computer, including theoretical knowledge and data related field. In the 1800s, KBS was derived from artificial intelligence (AI) and database (DB) [2], and the organic combination of the two kinds of computer technology contributed to the emergence and development of it. KBS had solved three main problems, the scientific management of massive knowledge, the efficiency of searching data and the accuracy and efficiency of data analysis. KBS had gradually became a hot researching field of domestic and international, based on B/S structure it only need to upload to the server in centralized storage, to make information management more convenient, where to find faster, and you can directly access the system through the browser in internet. In Beijing University of Aeronautics and Astronautics, for aerospace manufacturers intranet unified and coordinated digital design typical of composite aircraft components, Li Chen and Mei Zhongy [3] proposed a typical composite component design KBS, the organizational method of case in the system are not fuzzy inference mechanism deterministic similarity component retrieval, and ultimately build a web-based composite aircraft design KBS typical member. In Nanjing University of Aeronautics and Astronautics, combined with the demand for composite aircraft component manufacturing KBS of an actual aircraft manufacturer, Zhang Junyan [4] composited material members process knowledge, tooling knowledge and tolerance decision-making knowledg for the three main points. Representation and acquisition of manufacturing composite components knowledge, database design and algorithm design were studied, a data model of composite component manufacturing knowledge was established based on object-oriented modeling. In Germany, a user-oriented view of Rough Knowledge Base System was presented by AV Robin Andersson [5] etc., the system tackles two problems not fully answered by previous research: the ability to define rough sets in terms of other rough sets and incorporation of domain or expert knowledge. In America, S Corporatoin [6] developed a System for linking medical terms for a medical KBS which generates medical knowledge base information by using predetermined data source specific message syntax information in identifying first and second information received from first and second data sources respectively. The first and second information indicates at least one type of medical relationship between the received first and second medical terms.

A new method of constructing knowledge base was proposed based on the research of metamodeling in extension theory [7], which to guided the construction of bearing information KBS. The constructing of press mounting force module in bearing information KBS based on the metamodeling was studied, matter element model, thing element model, relationship element model and composite element model with implication and extension included.

2. THE KEY SUPPORTING TECHNOLOGY AND ALGORITHM OF METAMODELING IN EXTENSION THEORY

2.1 The elements

Extenics [8] was found by Cai Wen who is a professor in Guangdong University of Technology. Based on extension theory and extension method, the purpose of extenics is to research the possibility of matters' expansion and the law of innovation for solving problems of contradiction. The expressional form of entenics is element, such as $B=(O_O,C_O,V_O)$, B is the element, O_O is the object, C_O is the feature, and V_O is the value of C_O. Aiming at the kinds of information about knowledge, metamodeling was adopted to standardize the process of construction and unify the modeling in KBS. Such as parameters of bearing and material, process of experiment and analysis, and tables, pictures, formulas, curves, documents and others forms of knowledge. The metamodeling could make the knowledge modular and clustered, to improve the efficiency of KBS.

Multiple types of modular information was analysed and arranged by semantic segmentation which could show the complete and independent unit information of modular knowledge. Specific unit information was constructed for different modular knowledge, and was defined with formalization and model by metamodeling. In general, information was divided into three patterns, as static pattern, behavior pattern and relationship pattern.

For static pattern, model of information was constructed by matter element ($J(R)$) in metamodeling. If the number of feature for object was n, $J(R)$ was expressed as follows:

$$J(R)=\begin{bmatrix}\Gamma(N) & C(N)_1 & V(C)_1\\ & C(N)_2 & V(C)_2\\ & \vdots & \vdots\\ & C(N)_n & V(C)_n\end{bmatrix} \tag{1}$$

In $J(R)$, $\Gamma(N)$ is the name of object, $C(N)$ is the feature of design, $V(C)$ is the value of feature. The value of feature could be an exact number, an interval value with fuzzy information, a function, qualitative semantic description and other forms.

For behavior pattern, model of information was constructed by matter element ($J(I)$) in metamodeling. If the number of feature for object was m, $J(I)$ was expressed as follows:

$$J(I)=\begin{bmatrix}\Gamma(D) & B(D)_1 & U(B)_1\\ & B(D)_2 & U(B)_2\\ & \vdots & \vdots\\ & B(D)_m & U(B)_m\end{bmatrix} \tag{2}$$

In $J(I)$, $\Gamma(D)$ is the name of behavior, $B(D)$ is the feature of behavior, $U(B)$ is the value of feature.

For relationship pattern, model of information was constructed by matter element ($J(Q)$) in metamodeling. $J(Q)$ could describe configuration relationship, logical relationship, implication relationship, comparison relationship and others. If the number of feature for object was k, $J(Q)$ was expressed as follows:

$$J(Q)=\begin{bmatrix}\Gamma(S) & A(S)_1 & G(A)_1\\ & A(S)_2 & G(A)_2\\ & \vdots & \vdots\\ & A(S)_K & G(A)_K\end{bmatrix} \tag{3}$$

In $J(Q)$, $\Gamma(S)$ is the name of relationship, $A(S)$ is the feature of relationship, $G(A)$ is the value of feature.

In general, the information in complex design process has three types of characteristics, static pattern, behavior pattern and relationship pattern. Therefore, model of information was constructed by composite element ($J(F)$) in metamodeling. In $J(F)$, conjunction (Θ) was used to characterize the semantic information with multiple layers, where "and", "or" to produce the and-composite element, or-composite element, and-or-composite element, and then the information for design activities was descriped completely. $J(F)$ was expressed as follows:

$$J(F)=\begin{bmatrix}\Gamma(F) & (\Theta)\Gamma(J(R_i)) & V(J(R_i))\\ & (\Theta)\Gamma(J(I_j)) & V(J(I_j))\\ & \vdots & \vdots\\ & (\Theta)\Gamma(J(Q_s)) & V(J(Q_s))\end{bmatrix} \tag{4}$$

In $J(F)$, i is the number of matter element, j is the number fo thing element and s is the number of relationship element.

With implication and extension in different basic elements, in order to describe the information better based on metamodeling, which could be used by transformation of extension to provide support for establishment of KBS. The implication of basic element is as $@J_i \Rightarrow @J_{\mathrm{j}}$, which indicates that J_i implicate J_j and leads the design of framework of KBS. The extension of basic element contains the divergence, the expansion and the correlation. Based on the transformation of extension for basic elements, it could not only establish the method of basic element, but also get the relationship and correlation between basic elements.

2.2 The construction of basic elements in KBS

In the process of constructing KBS, the metamodeling is the key step of making existing knowledge into the module information and stored in the database. In the enterprise, experts will work accumulated knowledge into knowledge sources, including experience and examples, rules and guidelines, manuals and literature, principles and methods. The knowledge was extracted and converted into different units by metamodeling. Different knowledge units belonging to different layers and modules of knowledge, and corresponding to matter element, thing element, relationship element and composite element. With the implication and extension of basic element through transferring and mining, the existing knowledge could be clustered and modular, and finally be inputting, testing and storage. For acquiring knowledge, it should be extracted and transferred by processing system, and then it could be converted into knowledge which is suitable for storing in KBS. Here are the two steps [9].

(1) The design knowledge would be extracted to form a knowledge unit, and could be expressed in basic elements.
(2) The design knowledge based on basic elements would be transferred into a format that could be stored in KBS through knowledge processing system.

For complex sources of knowledge, the extracted knowledge units don't exist in isolation but get the associated knowledge and information related to the internal or external by extension transformation, a single or multiple knowledge unit will be formed to modular systematic knowledge. First, to form the corresponding basic element for knowledge unit, and then based on the metamodeling to investigate the constructing of matter element, thing element, relationship element and composite element. The general process and the basic framework of basic element KBS as shown in figure 1.

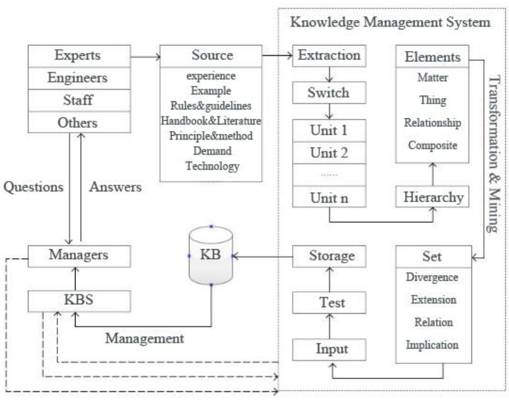

Figure 1. The general process and basic framework of basic element KBS

3. THE DEVELOPMENT OF KBS FOR SCHEME DESIGN OF BEARING PRESS-FIT PROCESS

3.1 The requirement of KBS

According to the type of bearing related information in manufacturer and the method of bearing using, the functions of bearing information KBS should meet the following requirements.

(1) The computer aided design and realization of the key technology in the scheme design of the bearing press fit process.
(2) Unified management and reuse of data of various types of bearings.
(3) Unified management and reuse of process data generated in the process of bearing installation and fixing.
(4) High efficiency and high accuracy of the design of the bearing press fit process design information retrieval, design reuse and total.

3.2 The functional modules of KBS

With a structured, hierarchical model, the KBS for scheme design of bearing press-fit process was divided into bearing module, material module, data processing module, calculation and analysis of the composition module, bearing assembly reference module and user management module.

In the KBS, bearing module consists mainly of rolling bearings and spherical bearings, specific to a certain bearing contains the attribute information associated with the bearing, including bearing inner diameter, outer diameter, width, speed, weight, the rated static load ratings and dynamic load information. In material module, bearing and bearing seat by the use of the materials information included. Each data including elastic modulus, poisson's ratio, mass density, yield strength and linear expansion coefficient of attribute information, can also add materials handbook to refer to. The data processing module including pressure test, tension strength test, aerodynamic torque calculation and experiments of three upload data. The calculation and analysis module including pressing force calculation, profit calculation and simulation data is composed of three parts, pressing force can be calculated by using the theory of elastic mechanics of ideally pressing force is estimated, and the amount of interference module is according to the transfer of force or torque size calculation of interference range and combining them. The simulation data is analysis by software simulation of bearing press mounting, stored in the module for engineering and technical personnel as a reference. The bearing assembly reference module contains the enterprise internal standards, bearing installation standards (including the national standard, the standard, the military standard, etc.), bearing installation specification, bearing fixed four parts. The user management module is to manage the information of users, with the creation of new users and according to the specific user rights allocation and other functions.

3.3 The framework of KBS

The KBS is an integrated platform of information for the intelligent scheme design of of bearing press-fit process, and which is a computer aided design system for building internal R & D management standards and improving the efficiency. As shown in Figure 2, the system is mainly composed of three layers: application layer, support layer and base layer. MyEclipse was as an integrated development environment and the underlying database using 11g Oracle.

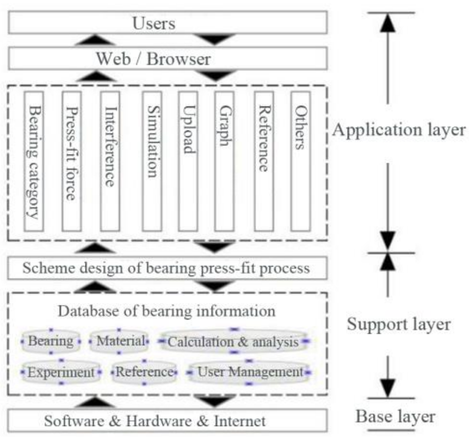

Figure 2. The framework of KBS

The application layer is directly associated with the users, and is the tool set of scheme designing for bearing press-fit process. And the application layer is responsible for the data interaction between users and KBS, such as data inputting and data outputting with appropriate form.

The support layer is the foundation of the KBS and implemented by bearing module, material module, experimental data module, and calculation-analysis of database module and other modules.

The base layer mainly refers to the operating system, network and computer hardware environment as the normal system operation to provide the basic conditions for software and hardware environment.

4. THE TECHNICAL REALIZATION OF BEARING INFORMATION KBS

The part of press-fit force was as an example to describe the process of building bearing information KBS based on extension theory in detail. According to the calculation of the press-fit force and the theory of elastic mechanics [10-11], the calculation is divided into three parts. The first part is basic parameters which including the friction coefficient and the amount of surplus. The second part is structure size and material parameters of the inclusion (bearing or bushing), this part including the outer diameter, the diameter of the mounting hole, the height of the mounting hole, the elastic modulus of the inner cylinder and the Poisson's ratio of the inner cylinder. The third part is structure size and material parameters of tolerance (the bearing or shell parts of the installation bearing or bushing), which including outer ring diameter, inner hole diameter, height, outer cylinder elastic modulus, outer cylinder Poisson's ratio and yield strength. The matter element model was expressed as follows:

$$J(R_{Press-fit\ force})=\begin{bmatrix} \text{Input} & \text{Friction coefficient} & f \\ & \text{Interference} & \delta(mm) \\ & \vdots & \vdots \\ & \text{Yield strength} & \sigma_S \end{bmatrix} \tag{5}$$

According to the data obtained in the theoretical calculation of the pressing force, the radial displacement at the outer radius of the inner cylinder, the radial displacement of the inner radius of the outer cylinder, the set pressure and the pressure loading force included. The matter element model was expressed as follows:

$$J(R'_{Press-fit\ force})=\begin{bmatrix} \text{Result} & \text{Displacement 1} & \text{u1（mm）} \\ & \text{Displacement 2} & \text{u2（mm）} \\ & \text{Set pressure} & \text{p（N）} \\ & \text{Press-fit force} & F_X\text{（N）} \end{bmatrix} \tag{6}$$

Above all is the knowledge of calculation of press-fit force. According to the motif of the implication which is $@J(R_{Press-fit\ force})\Rightarrow @J(R'_{Press-fit\ force})$, that only height in pressing and press-fit force of enveloped part were in changing. And the final value of height in pressing was H1 which is the height of enveloped part, so a curve defined by press-fit force and height in pressing was obtained.

Professional terms often be colloquial in the actual production process, so reference was needed for inputting calculated values. And for the friction coefficient, it is a predetermined value that should be choosen according to the reference materials. In view of the above compression force calculation process of the behavior of the event, the output result is listed in the four values. According to the needs, the intuitive graph of curve is necessary, as well as the sketch map and commonly were used as a reference factor. The $J(R_{Press-fit\ force})$ and $J(R'_{Press-fit\ force})$ were extended transform to get the following matter element model.

$$J(I_{Press-fit\ force})=\begin{bmatrix} \text{Operation} & \text{Output} & \text{u1/u2/p/Fx} \\ & \text{Graph} & \text{Displacement/Press-fit force} \\ & \text{Friction} & f \\ & \text{Diagram} & \text{Coordinate} \end{bmatrix} \tag{7}$$

From the feature of graph in $J(I_{Press-fit\ force})$, time was the third basic element contained in the curve defined by displacement and press fitting force. According to transformation of extension, three kinds of curves were carried out. Namely time&displacement diagrams, time&pressure diagram and displacement&press-fit force diagram. The matter element model was expressed as follows:

$$J(I_{Graph})=\begin{bmatrix} \text{Display} & \text{Time-Displacement} & t/s \\ & \text{Time-Froce} & t/f \\ & \text{Displacement-Force} & s/f \end{bmatrix} \tag{8}$$

In the above reasoning process, acquisition paths of knowledge were data inputting, formula calculating and results appearing. According to the conjugate of the matter element and the graph data was as the known condition, the thing element model was expressed as follows:

$$J(I_{Experiment})=\begin{bmatrix} \text{Experiment} & \text{Data} & \text{Point} \\ & \text{Part} & \text{Fitting curve} \end{bmatrix} \tag{9}$$

For both path process, the relationship element model was expressed as follows:

$$J(Q_{Press-fit\ force})=\begin{bmatrix} \text{Conjugation} & \text{Calculation} & \text{Graph} \\ & \text{Experiment} & \text{Graph} \end{bmatrix} \tag{10}$$

Based on the above information, it could be deduced that the bearing information KBS is about the two conjugate modules of the pressing force:

Pressure derived outer cylinder radius of radial displacement, outer cylinder radius radial displacement, pressure suits, pressure force is computed. The curve diagram of displacement and pressure; input amount of calculation value of the reference diagram; friction coefficient when the input reference common friction coefficient files;

On the data in the file for reading and analyzing, the that time and displacement curve diagram, time and press fit force curve, displacement and press fit force curve; through the input theory calculation value, get theory of displacement and pressing force of the graph, also shows experimental data according to the displacement and pressure curve graph and contrast can be directly obtain the deviation of experimental data and theoretical calculation. According to the experimental data of a certain interval interception, and within the range of the data fitting, the fitting curve is obtained; for data acquisition, direct display press mounting force experiment file inside the data values.

The composite elements model were expressed as follows:

$$J(R_{Calculation})=\begin{bmatrix} \text{Calculation} & \Gamma(J(R_{Press-fit\ force})) & V(J(R_{Press-fit\ force})) \\ & \Gamma(J(R'_{Press-fit\ force})) & V(J(R'_{Press-fit\ force})) \\ & \Gamma(J(I_{Press-fit\ force})) & V(J(I_{Press-fit\ force})) \end{bmatrix} \quad (11)$$

$$J(R_{Experiment})=\begin{bmatrix} \text{Experiment} & \Gamma(J(I_{Graph})) & V(J(I_{Graph})) \\ & \Gamma(J(I_{Experiment})) & V((I_{Experiment})) \\ & \Gamma(J(Q_{Press-fit\ force})) & V(J(Q_{Press-fit\ force})) \end{bmatrix} \quad (12)$$

5. CONCLUSIONS

Constructed by using the metamodeling of extension theory was a new method for KBS based on researching of matter element model, thing element model, relationship element module and composite element model with implication and extension. The constructing of press-fit force module in KBS based on the metamodeling of extension theory was studied. The rusult indicate that the extension element theory could not only express the process of constructing a knowledge module in KBS more systematically and comprehensively, but also solve the problem of complex knowledge information.

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