Research on Intelligent Large Slewing

Lv Kunze, Guo Ming, and Mou Yuhui

***Abstract*—There are many types of slewing ring, it is designed to both types of choices, but also by the size and structure of computing power, set the value of the non-expert planning, reasoning and numerical integration of scientific computing. Therefore, in the design of slewing expert system technology to break through the limitations of traditional analog design personal, integration experience of many experts in the design of a system to optimize the design of the structure, with significant engineering value. Based on the collection and analysis of full slewing design data and design experience, the establishment of a design expert system is as the core of the design, structural analysis and automatic drawing in one of the slewing ring Intelligent Design System - SRBID systems.**

***Index Terms*—Slewing, intelligent, design, expert system, parametric drawing.**

I. Development Status of Slewing Ring Bearing

Structure of slewing ring bearing is similar to large-scale rolling bearing; from the early slewing ring with fixed column and turntable slewing ring to the present rolling bearing type slewing bearing and slewing bearing with rolling ring, it has made a great progress in structure and performance. Slewing ring bearing is now extensively applied to various kinds of cranes, excavators, crawler pile drivers, CT machine standing wave therapy apparatus, navigation instruments, radar antenna pedestals, missile launchers, tanks and robots. Study on slewing ring bearing was launched early in overseas countries and its design and manufacturing technology level is quite mature. At present, large-scale enterprises with competitiveness include some slewing ring bearing manufacturers such as TAPEREX of Britain, KRUPP of Germany, HRS, NACHI and Komatsu. Their products are developing toward high technology content directions of profession, uniqueness, excellence and perfectness. Moreover, they are able to manufacture more than ten series of slewing ring bearing products [1].

China introduced technology from HRE of Germany in 1978 and trial-produced slewing ring bearing products, which marked formal starting of China's slewing ring bearing industry. Before the 1980s, types of slewing ring bearing applied to Chinese market mainly covered slewing ring with rotary column, slewing ring with fixed column and turntable slewing ring. With continuous introduction and innovation of foreign advanced technology, rolling bearing type slewing bearing has been widely applied in China gradually due to its advantages of light operation, small steering resistance, convenient maintenance and long service life. Rolling bearing type slewing bearing is generally composed of inner and outer rings, rolling element, isolation block and sealing strip.

In the development history of slewing ring bearing in China, there are two very important standards. The first one is the ministerial standard of Ministry of Machine-Building Industry of the People's Republic of China – JB2300-84 *Requirements on Types, Basic Parameters and Technology of Slewing Ring Bearing* drafted by Tianjin Engineering Machinery Research Institute of Ministry Of Machine Building And Electronics Industry and Xuzhou Slewing Ring Bearing Plant in 1984. This standard illustrates type, classification, dimension series, technical requirements, and installation and maintenance of slewing ring bearing in detail, which has brought about great convenience to design, manufacture and use of slewing ring bearing in China. The second one is standard of JJ36.1-36.3-91 *Slewing Ring Bearing Applied in Construction Machinery* drafted by Beijing Construction Machinery Research Institute of Ministry of Construction and Maanshan Slewing Ring Bearing Factory in 1991. This standard stipulates type, classification and dimension series of slewing ring bearing with industrial characteristics. Formulation of these two standards has contributed a lot to standardization and rapid development of slewing ring bearing in China. After entering the 21st century, China's piling machinery industry has grown stronger and stronger. As a result, slewing ring bearing product and its technology have gained great development, and its application area and development space have also become wider and wider. It has already been widely applied to other mechanical equipments except construction machinery industry. At present, there are over 50 slewing ring bearing manufacturers in China, but there are only few large-scale manufacturers that can produce multi-series products. Therefore, it still has a great gap with overseas design and manufacture level [2].

Developing content slewing intelligent project consists of two parts: the smart miniature monitor module and slewing state prediction software library. Mainly due to:

1) The Company makes business to provide technical support for slewing enterprises instead of slewing system
2) As for the host slewing

Individual pieces of equipment, integrated in the host device, you can not separate the formation of intelligent systems.

Therefore, using a modular approach, the development of intelligent monitoring module and state forecasting software could be carried out effectively.

Affiliated parts slewing ring manufacturers to the host so that the host intelligent overall system.

The number of intelligent monitoring module according slewing to determine the size, and each module is independent. The number of total monitoring via standard

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The authors are with Overseas Education College, Nanjing Tech University, Nanjing, Jiangsu, China (e-mail: lvkunzex@gmail.com, jamesxiongxiong@gmail.com, abigailmou@gmail.com).

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computer bus interface transfers data to the host. Software module is to form an integrated dynamic link library DLL libraries, the total monitoring software available for the host to call.

II. Design Philosophy, Overall Structure and Function of SRBID System

Design is an innovation process and the process of machine design is design – evaluation – redesign. The pattern of design – evaluation – redesign is also the design criterion of design type expert system. Design type expert system will realize this process in computer, hoping to replace or partly replace prototype production and bench test. Therefore, in design type expert system, the two modules of numerical analysis and graphic output are important resources for evaluation and man-machine interaction as well as the difficult points of system design. In SRBID system, performance evaluation of slewing ring bearing is carried out through reliability calculation of design scheme and finite element structural analysis; graphic output is realized through parameterized drawing system.

Slewing ring bearing intelligent design (SRBID) system has integrated database technology, knowledge base technology, calculation and reasoning technology, finite element analysis technology and parameterized drawing technology together. The entire system is composed of design type expert system, finite element analysis and parameterized drawing. These three parts are combined together and cooperate with each other; meanwhile, they are also independent. Every module can be used as a subsystem.

Design type expert system can complete model selection and structure design of slewing ring bearing by directing at technical requirements and service conditions proposed by users, and provide several design schemes with reliability evaluation for users. Users can choose satisfying schemes among them and conduct structural analysis on the design result with finite element analysis module. The analysis result can be used as basis for redesign of expert system. Parameterized drawing module can output component chart of slewing ring bearing obtained by system design. The system will offer a reasonable explanation for the entire design process and result.

III. Design Type Expert System

Design type expert system is the core in SRBID system and it is composed of four modules.

A. Design Knowledge Representation and Organization Module

This module will provide data, experiential knowledge and design formula required by the design. As the knowledge source of design treatment module, it is composed of database, knowledge base and method base. Database is used to store graph data like material characteristics and dimensional tolerance as well as empirical data in calculation formula. Knowledge base can store various kinds of experiential knowledge required during the design process of slewing ring bearing, including public knowledge recorded in relevant slewing ring bearing design publications and exploratory knowledge that is difficult to formalize and "acquired" from the brain of design experts. Public knowledge is stored in frame structure while exploratory knowledge is expressed by production rule. Method base has provided common calculation formulas of slewing ring bearings in different structural styles.

In order to increase the reasoning efficiency, SRBID system has effectively organized knowledge on the basis of sufficient and correct expression of expert knowledge. Firstly, knowledge hierarchy is utilized to reduce problem solution space and accelerate the reasoning progress. Secondly, servo-type framework knowledge is separated from production knowledge which is dominant in reasoning, and they will be put in different knowledge bases. Thirdly, meta-rules are stored in knowledge base and can be used by inference engine.

B. Design Treatment Module

It includes inference engine, blackboard and interpreter. Inference engine can invoke corresponding knowledge modules to solve problems according to design requirements and service conditions of slewing ring bearing. As the core of copying the thinking mode of experts, inference engine decides which knowledge to be enabled at a certain stage of design. In order to increase effect and efficiency, some strategies should be considered during reasoning process, and common reasoning strategies cover forward reasoning, backward reasoning, forward and backward chaining, bi-directional reasoning and meta-control. Reasoning control strategy adopted by SRBID system is "generation – test reasoning technology under meta-rule strategy control". Blackboard is also known as dynamic database, and it is used to store design requirements, intermediate results and final results. Interpreter is responsible for explaining reasoning process of the design to users.

C. Design Knowledge Management Module

It is used to manage knowledge required by slewing ring bearing design and composed of database management module, knowledge base management module and method base management module. Through design knowledge management module, operations like addition, modification, deletion, checkout and maintenance can be carried out for database, knowledge base and method base.

D. Design Knowledge Acquisition Module

This module will extract special knowledge involved in slewing ring bearing design from some knowledge sources and then change them into executable codes for computer. Knowledge acquisition requires the joint effort and cooperation of knowledge engineer and domain expert. SRBID system adopts the method of combining automatic acquisition with manual acquisition.

IV. Finite Element Analysis

This part will mainly make a structural analysis on slewing ring bearing provided by the design results, so as to offer basis for further design. Data required by geometric modeling of slewing ring bearing are delivered from the design results, the load parameters are initial input data, and

material characteristics are called in from database. This module can also be used independently and at this time, these data will be interactively entered on user interface. Due to the dialog box developed under Windows environment, users can complete this job easily.

Slewing ring bearing often works under low speed and heavy load, so this module mainly conducts static structural finite element analysis.

A. Pre-Processing

In this paper, a finite element pre-processing system with mature functions is developed by aiming at structure and bearing characteristics of slewing ring bearing. Its functions cover grid automatic generation, load displacement and constraint condition treatment. See Fig. 1 for its workflow. Isoparametric elements like three dimensional eight nodes are adopted as element type. The grids are generated along radial direction, circumferential direction and vertical direction. Grid density can be automatically determined by procedures, or users can also adjust and control it by way of interaction. In order to help users clearly observe the grid generation situation, algorithm of Literature [3] is adopted in this paper, to blank the three-dimensional finite element grids. Principle of this algorithm: elemental area of finite element is decomposed into triangles and then every elemental side and triangle are tested; if the elemental side is not shielded by any triangle, then this elemental side is visible side, or it is invisible side.

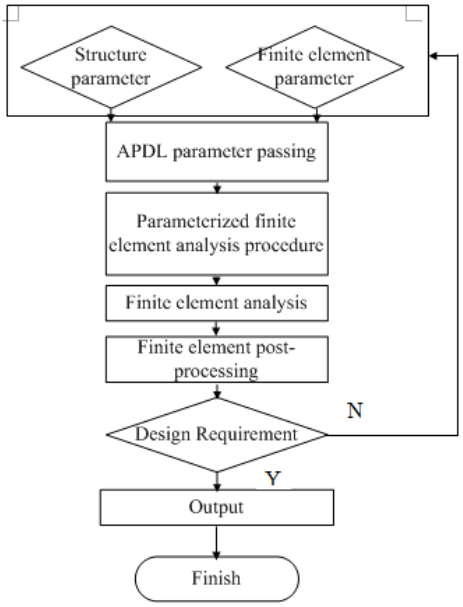

Fig. 1. Flow chart of finite element analysis.

Pre-processing module developed by this paper has the following characteristics: 1) friendly user interface: various parameters and control parameters can be entered in man-machine dialog form, there are no inspection measures, error correction can be conducted in time, and a simple, convenient and reliable operating environment is provided for users; 2) as for the grid generation situation, single element and the entire grid will be displayed and conversions like translation, rotation and proportion can be conducted, thus designers can modify dissatisfactory parts of element division via interactive graphic system through observation [4].

B. Finite Element Calculation and Post-Processing

Finite element calculation can be completed by directly invoking software of finite element analysis (ALGOR can be selected for SRBID system) according to data files generated in pre-processing.

One the one hand, post-processing system can combine the existing software with independent development to realize visualization of the calculation by invoking the powerful special finite element post-processing module, Super View. On the other hand, it has also developed a module independently to make numerical analysis on the calculation, and the obtained results and suggestions can be fed back to design expert system [5].

V. Parameterized Drawing

Parameterized drawing is corresponding to interactive drawing. Only by realizing parameterized drawing, can the rapid and accurate characteristics of CAD be fully expressed. Its superiority is especially prominent in engineering drawing. SRBID system sets AutoCAD R13 for Windows as graphic platform, C++ as programming language and ADS as development tool to develop a complete set of parameterized drawing procedures of slewing ring bearing. Under AutoCAD environment, three layers are set up and they can be used in drawing, dimensioning, and inserting title bar and technical requirements respectively. In addition, the system has also set up a common standard symbol base and annotation subroutine base by directing at national standard annotations of roughness, base level and geometric tolerance which are often used in the drawing process. As a result, the annotation speed and veracity have been greatly increased, and it can also be applied to other CAD systems of enginery under the same development platform.

Parameterized drawing module in SRBID system can not only rapidly generate normative engineering drawings according to the design results of expert system, but also allows users to directly enter their own design results into the system and generate engineering drawings. Therefore, it possesses great flexibility and relative independence. In addition, this module has also established database of slewing ring bearing of common series according to relevant materials. Data in database can be accessed by way of ASI function programming, so as to complete the automatic drawing process of slewing ring bearing. Users only need to choose models of slewing ring bearing during use. Meanwhile, the system can also help users examine and modify the design results of expert system or other existing design results. Besides, files after examination, modification and input can be stored into the disk in user-defined names for invoking.

Flexible dialog box based on intelligent method is adopted as man-machine interaction interface in the system. Thus it can provide a visualized environment with both graph and character for users, vivid, natural, simple and rapid.

VI. Conclusion

Discussion in this paper is launched by combining with

the horizontal topic "Theoretical Research on Slewing Ring Bearing Design and CAD". SRBID system is developed by adopting Microsoft VisualC++ language and the whole system runs under two environments. Data input and a large amount of calculation and reasoning in the former part are completed under Windows environment while drawing operates under Auto CAD 13.0. In this way, arithmetic speed of the former part won't be restricted by Auto CAD environment. This system has already been put into trial, so the original development objective has been achieved. The following conclusions have been gained from research and development of SRBID system:

1) Design of slewing ring bearing contains a large amount of calculation and abundant reasoning, so design type expert system should be adopted to realize automation of the design.
2) Knowledge distribution is very important for solving slow searching caused by big knowledge base. Knowledge hierarchy and functional decomposition can reduce problem solution space and increase efficiency.
3) Outcome evaluation of engineering design expert system can be carried out through finite element analysis. Pre-processing and post-processing of finite element analysis has a heavy workload and they are also tedious and bald. Study on development of automatic and semiautomatic pre-processing and post-processing will make finite element analysis convenient to a large extent.
4) Parameterized drawing technology can greatly relieve labor of project planners, so its application is becoming more and more extensive.

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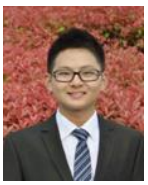
Lv Kunze was born in Lianyungang Jiangsu province China on Januray 3rd, 1993. He will graduate from Nanjing Tech University and get the bachelor degree of mechanical engineering.



Guo Ming was born in Zhenjiang Jiangsu province China on March 9th, 1993. He will graduate from Nanjing Tech University and get the bachelor degree of mechanical engineering.

He is a global volunteer of AIESEC, who take two months in Kumasi Ghana to help local university students build their own workshop by the assistance from local business man. Mr. Guo win the top 16 of 286 university in 2013 Enactus World cup of China station as a team leader of Enactus NJUT.

Mou Yuhui was born in Yining Jingsu Province China on June 23, 1993. She will graduate from Nanjing Tech University and get the bachelor degree of mechanical engineering.