Application of Computer Simulation Technology in Mechanical Design and Manufacturing

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Abstract

Computer simulation technology is based on computer and its related software. The analysis and solution of the problem is achieved by virtual experiment. This paper introduces the characteristics of computer simulation technology in mechanical manufacturing industry and the steps of computer simulation. This paper analyzes the application of computer simulation technology in gear design, mechanical structure design, complex numerical calculation analysis and complex machining research in mechanical design and manufacturing industry. The experimental results show that the simulation technology can be applied to the design of gear and mechanical structure through the creation, transformation and experiment of model. At the same time, the model plays an important role in the research of machining and complex mechanical numerical calculation. The application of simulation technology can optimize the process of mechanical design and manufacturing, which has a certain reference value for the application of computer simulation technology in mechanical design and manufacturing.

Keywords*: Simulation technology, mechanical manufacturing, complex numerical analysis, data fusion.*

I. Introduction

The development of construction machinery involves the integrated collaborative design of machinery, electronics, control and other fields. With the development of distributed computing and simulation technology, virtual prototyping (VP) technology has been gradually applied to the development of construction machinery.

Virtual prototype technology is a new product development method, which is a digital design method based on product computer simulation model. These digital models are called virtual prototype, which simulate real products from vision, hearing, touch, function and behavior. It uses virtual prototype instead of physical prototype to design, test and evaluate products [1-2]. Virtual prototyping technology is based on CAX (such as CAD, CAM, CAE, etc.) and DFX (such as DFA, DFM, etc.) [3]. It further integrates information technology, advanced manufacturing technology and advanced simulation technology, applies these technologies to the whole life cycle of complex system, the whole system, and comprehensively manages them, analyzes complex system from the system level, and supports the "top-down" development mode of complex system. Its core is the integration technology of engineering design technology, modeling / simulation technology and VR / visualization technology [4-5].

Virtual prototyping (VP) is a digital design method based on product simulation model. With the application of computer technology, simulation technology and integration technology, the decentralized product design and development and simulation process are integrated together. The design optimization, performance test, manufacturing simulation and use simulation of the virtual product prototype are carried out intuitively in the virtual environment, which provides a new design method for product development. Virtual prototype technology can significantly improve the quality of product design, reduce the cost of product development, and improve the competitiveness and economic benefits of enterprises. The design method of virtual prototype can help to get rid of the dependence of engineering machinery on physical prototype [6]. The digital model of product (i.e. virtual prototype) can be established by computer technology. It can complete numerous virtual tests (not allowed by cost and time conditions) which can not be carried out by the physical prototype. The optimal scheme can be obtained without manufacturing and testing the physical prototype. Therefore, it not only reduces the number of physical

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prototypes, but also shortens the research and development cycle and improves the product quality.

II. Research on overall technology of virtual prototype of construction machinery

2.1 System engineering technology of virtual prototype

The process from concept to implementation of virtual prototype is a system engineering process, which involves factors in many aspects and fields [7]. These factors can be divided into time dimension, method dimension and logic dimension, which can be represented by hall model figure 1.

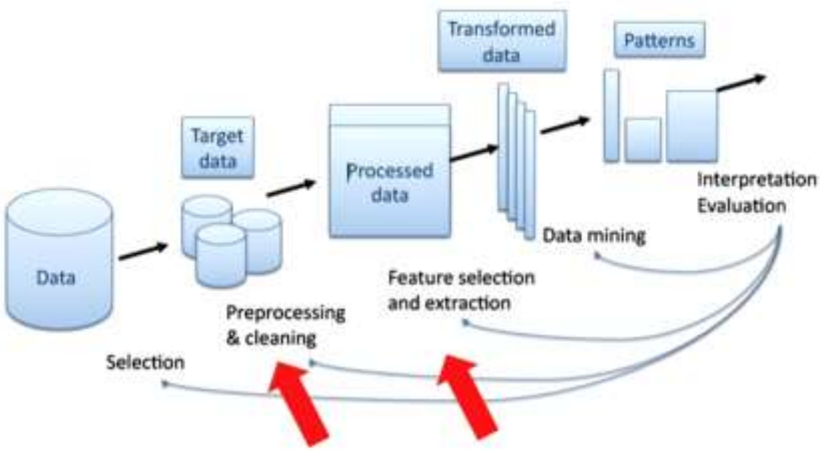

Fig 1: Hall 3D structure of virtual prototype system engineering process

The purpose of product virtual prototype development is to simulate and analyze the appearance, function or behavior of the product, so as to analyze the design requirements of the product, optimize the product design, find and correct the design problems earlier, improve the success probability of product design and manufacture at one time, and reduce the development cost and risk [8]. The process of virtual prototype system engineering generally includes seven stages: problem definition, system demonstration, scheme design, modeling and development, operation and test, evaluation and optimization, and solution. Problem definition mainly analyzes the requirements, structure, function and design requirements of the product in detail, puts forward the problem domain to be solved, and defines the evaluation index of constraints and problem solving.

The main work of the system demonstration stage is to analyze and evaluate the solution of the problem, and carry out risk analysis to determine the feasibility of the scheme. What needs to be explained here is that the development of virtual prototype is not necessarily the best solution for the problems in product design. At the same time, due to the complexity of virtual prototype technology, the development of virtual sample opportunities brings certain risks, so the systematic demonstration work is necessary. In the scheme design stage, the development scheme of virtual prototype system is mainly formulated, including the overall structure of the system, subsystem scheme, integration scheme, development process, team organization, development plan, etc. The modeling and development stage includes the modeling description, design, development and integration of system elements [9-10]. The work in the operation and test stage mainly includes the formulation of test scheme, the implementation of test and the analysis of test results.

In the evaluation and optimization stage, the problems in the product design will be found according to the test results, and the improvement scheme will be determined. The improved scheme will be returned to the modeling and development stage, the parameters and elements of the prototype system will be improved or redefined, and the test will be conducted again. This is an iterative process, and the result of this process will realize the

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optimization of product design. Until the end of the test, put forward the optimization scheme of product design and improved design requirements.

2.2 Architecture of virtual prototype of construction machinery

The early virtual prototype of products was established on the basis of CAD model and VR technology. They focused on the simulation of product appearance, spatial relationship, dynamics and kinematics, and emphasized the user's operation and interaction from various angles, so as to make qualitative judgment on product behavior and characteristics. With the development and application of concurrent engineering technology, CVP supporting collaborative design emerges. CVP is a new design / development specification based on IPPD. It is the key enabling technology to establish IPTS between enterprises and governments. It is mainly composed of the integrated framework of underlying support function and interaction and the service layer of upper layer providing IPT member interaction.

CVP enables IPT members to interact in parallel through digital model and data exchange, realize function, performance and process testing, testing and evaluation before building a real system, pay more attention to the economy, supportability and maintainability of the whole life cycle, and speed up the production process through VM. In 1997, with the effective implementation of CVP and the development of global economic integration, the U.S. Department of energy and the Department of defense proposed the next generation manufacturing and the next generation simulation based acquisition (SBA) framework. Lockheed Martin and its supply chain members put forward the next generation VP (ngvp) architecture considering the current business technology, framework, organizational culture and cost performance.

Its goal is to generate an open, extensible, integrated and synchronous multidisciplinary product description model, and provide the right and latest data at the right time. Integrate application and use it for function and performance evaluation, optimize data needed for life cycle cost, consider qualitative and quantitative factors, do not bring error information to the next stage, and effectively prevent errors in this stage. Generate real and executable system presentations that support different granularity analysis, provide executable simulation, neutral technology and popular commercial existing tools (COTS) for demonstration and analysis.

According to the above analysis, the future VP has the following characteristics: (1) emphasizing the reuse of knowledge, technology, models and tools; (2) Emphasize the interaction and operation mechanism with synergy, interoperability and high standardization; (3) Emphasize the communication of multi-disciplinary technology and efficient management and organization; (4) Emphasize the openness, flexibility and adaptability of the system. Therefore, a multi-level VP architecture for integrated product and process development (IPPD) is proposed.

In this architecture, the functions of each layer are as follows: (1) Knowledge layer is the physical storage of information, data, knowledge and models related to product development and the technical resource warehouse of the system; (2) Integration layer: providing basic functions such as network environment, operating system, data exchange standard and data collection, processing, exchange, management and maintenance, which is the basic integration environment for realizing integrated product development and product life-cycle management; (3) Logic layer: the control part of the actual operation of the system, the kernel to control and manage business processes, relationships, constraints, interactions and interoperability; (4) Concept layer: This layer contains a large number of tools for development, modeling, analysis, design, optimization and simulation. This layer mainly provides the language for modeling, describing and controlling products and virtual prototypes, and supports the development and application of practical systems. (5) Application layer: according to different development objects and system requirements, use tools and services provided by other layers to design, develop and apply products and VP.

III. Research on collaborative design technology of Construction Machinery Virtual Prototype

3.1 Collaborative design technology of virtual prototype

The English expression of collaborative design is collaborative design or eoversative design. It is the application of Computer Supported Cooperative Work (CSCW) in the field of design, and is the further deepening of advanced manufacturing modes such as concurrent engineering and agile manufacturing in the field of design. The concept of collaborative design has been involved in previous studies, but there is no clear definition. Rosemna defines collaborative design as a design method in which each member undertakes the corresponding part of the design tasks around a design project with the support of computer, carries out the design work in parallel and interactively, and finally obtains the design results that meet the requirements.

With regard to collaborative design, many scholars have made in-depth research on it from their respective angles, and made many achievements, which make collaborative design have the following rich connotations: (1) Collaboration refers to that two or more design subjects (or experts) complete this general design task together with different design tasks through a certain information exchange and mutual coordination mechanism. (2) Collaborative design is a process of communication processing, in which communication and negotiation are the most important issues. (3) Collaborative design is a process of collaborative work: With the development of computer-supported collaborative work CSCW, people bring collaborative design into the calculation framework of CSCW, and regard collaborative design as an application of CSCW, that is, a design process in which all design experts work together. (4) Collaborative design is a process of knowledge sharing and integration. Each design expert must be able to share knowledge and design experience, and transfer understanding of design background and goals to each other, and finally integrate them to produce new ideas and schemes.

Therefore, the main purpose of collaboration is to realize the sharing of information and resources among different groups and levels, and coordinate the handling of various changes, conflicts and competitions. There are three elements in Collaborative Design: organization, designer and technology. Among them, technology is the basic means and human is the main body of activities. Organization reflects the relationship between people in the design process. A truly economic and efficient collaborative design system should ensure the harmony and integration of organization level, individual level and technology level.

3.2 Parametric design

Parametric dimension driven is a driving mechanism of parametric dimension driven, which is based on the operation of graphic data. Through the parameter driven mechanism, the geometric data of the graph can be modified parametrically. At the same time, the constraint conditions of the graph can be met. The necessary means of Constraint Association is constraint linkage, which is realized through the relationship between constraints. Because parameter driving is based on the operation of graph data, the process of drawing a graph is to establish a parameter model. The drawing system maps the graphics to the graphics database, sets up the data structure of the graphics entity, and fills in different contents in these structures to generate the required graphics when driven by parameters. Parameter driven can be regarded as operating database content along the drive tree. Different drive trees determine that parameters drive different operations. Because the driving tree is based on the graphic features and related parameters of the parametric model, when drawing the parametric model, we should consciously use the graphic features and mark the related parameters according to the actual needs, so that we can grasp the operation of the database and control the changes of the graphics when the parameters are driven.

The realization of parameterization is as follows: the sketch technology is used to generate two-dimensional profile, and the exact position and size of the contour need not be given in the input of sketch, and can be obtained in the process of parameter design in the future. Then, the system can generate 3D features by stretching and rotating. With this foundation, and a CSG tree recording the modeling process, the parameter design of the model can be completed. It is important to emphasize that the parameters here are not the design parameters of the final model, but the modeling parameters to complete the modeling process.

Parametric technology takes constraint as the core, which is a novel and better modeling technology than constrained free modeling technology. This technology decomposes the complex design process into three sub-processes, namely, sketch design, constraint on sketch and constraint solving. Parametric technology has the following three advantages: (1) The initial design requirements of designers are low. There is no need for precise drawing, only a sketch can be drawn, and then the required precise figure can be obtained through appropriate constraints. (2) It is convenient for serial design. After one-time design and molding, different size series of parts of the same specification can be obtained through size modification. (3) It is easy to edit and modify, and can meet the needs of repeated design. When inappropriate parts are found in the design, the designer can easily get a new design by modifying the constraints. These advantages make parameterization technology very suitable for supporting the whole design process. Because the purpose of design is to meet certain functional requirements, and these functional requirements can often be transformed into appropriate design constraints. Designers can realize the functions of products conveniently and flexibly by controlling a design constraint.

3.3 Distributed computer collaborative design system based on network

Computer supported cooperative work (CSCW) is a new research field with the development of information technology and the integration of communication technology, computer and network technology. It is an inevitable product of the development of information technology. Computer cooperative work combines computer technology, network communication technology, multimedia technology and various social sciences closely, and provides people with a new working environment and communication mode.

Compared with CSCD, the traditional CAD system has serious shortcomings: (1)CAD system only adapts to a single designer as the development center, and cannot support the information exchange between designers, designers and technologists, and engineers of other departments. (2) "Automation Island" phenomenon. Design data exchange is difficult, information sharing is poor, and information flow is blocked. (3)CAD system and its analysis tools only focus the designer's thoughts on their own single task, but can not consider the whole life cycle of products and even the whole process of recycling and recycling of products and their parts and components. (4) The design cycle of products is long, and modifications are frequent.

A CSCD system is far more complex than a simple CAD system, which is mainly manifested in the following aspects: (1) CSCD system runs under the network environment, which can be Internet or Extranet, that is, virtual network. (2) Different CAD systems are relatively independent, and their tasks are divided; (3) Different CAD systems should interact and cooperate around design. (4) The design process or process should be coordinated and controlled. (5) The design data, version and results should be controlled cooperatively. Therefore, it is necessary to consider the collaborative control and management of the databases of each subsystem, that is, to establish a "collaborative database management system" or "collaborative database". In this way, the architecture of the composition principle as shown in fig. 2 can be given.

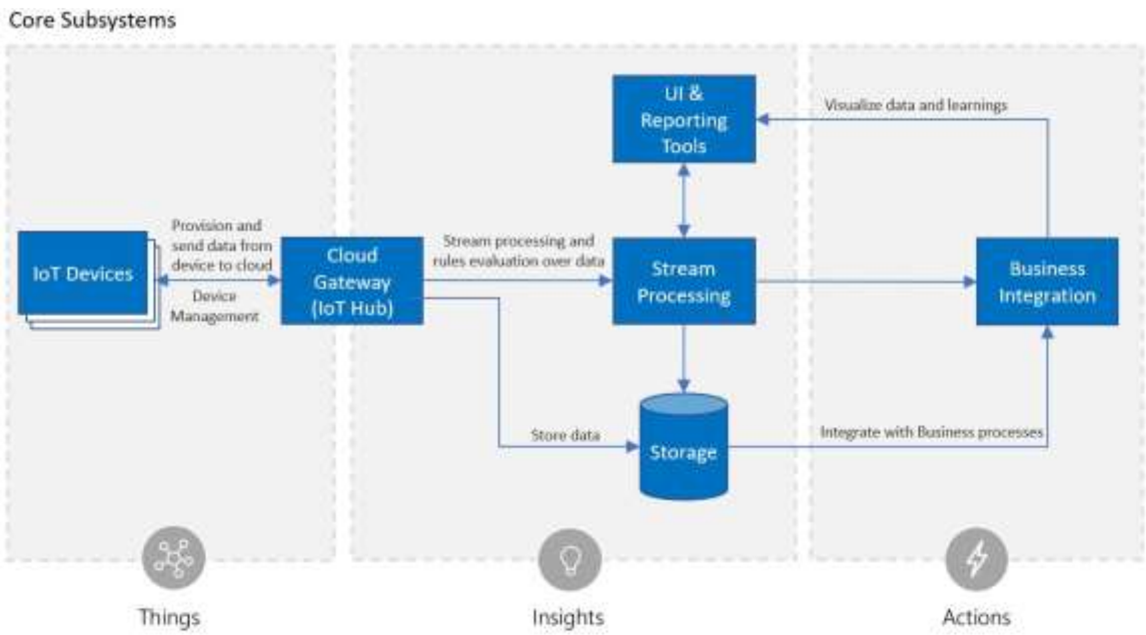

Fig 2: Composition architecture of CSCD system

According to this kind of architecture, CSCD system is built in combination with practical tasks and requirements. Generally speaking, the CSCD system should have the following integrated technical characteristics: (1) High-speed broadband network to ensure the correct and reliable transmission of 3D multimedia information data. (2) With intelligent and dynamic workflow management system (IDWFMS), the coordinated control and management of design process or process can be realized. (3) Establish a "database collaborative management system" to cooperatively control and manage distributed heterogeneous databases, design databases, versions and results.

IV. Overall solution of virtual prototype system of vibratory roller

This paper studies the overall solution of virtual prototype of typical construction machinery vibratory roller, and puts forward an integrated system solution that supports and manages the virtual design process and performance evaluation activities of the whole product life cycle, supports the team to design by CAD/DFx, and adopts simulation tools to develop and implement the virtual prototype. The scheme consists of five subsystems: design subsystem, simulation subsystem, test and evaluation subsystem, management subsystem and support subsystem.

1) Design subsystem of virtual prototype system

The design subsystem should be able to provide corresponding CAD/DFx design tools, appearance design and collaborative design tools to support the following product design activities: (1) Design and development of subsystems in different disciplines (such as machinery, control, etc.). (2) Design and development of virtual prototype function, behavior and performance model; (3) Design and development of virtual prototype.

The main research contents include: (1) CAD system in the virtual prototype development environment, CAD subsystem is responsible for building the product model in the design life cycle. The generality of the model directly affects the work of other systems in the virtual prototype development environment. CAD subsystem is the main tool to build virtual prototype model of product, which provides a basic model for other virtual prototype testing methods. (2) DFX subsystem of DFX (Design for x) system is a very important design optimization assistant tool in the process of virtual prototype development. X in DFX represents a certain stage in the product life cycle, and also represents the attributes of product competitiveness, such as quality, cost, etc. Using DFX idea, designers can consider the needs of downstream links in the early stage of design, predict the possible problems in these links in advance, and solve these problems before the design is completed. This is consistent with the development idea of virtual prototyping, virtual prototyping must include the support of DFX tools in order to play an effective role. The topology logic of simulation analysis is shown in Figure 3.

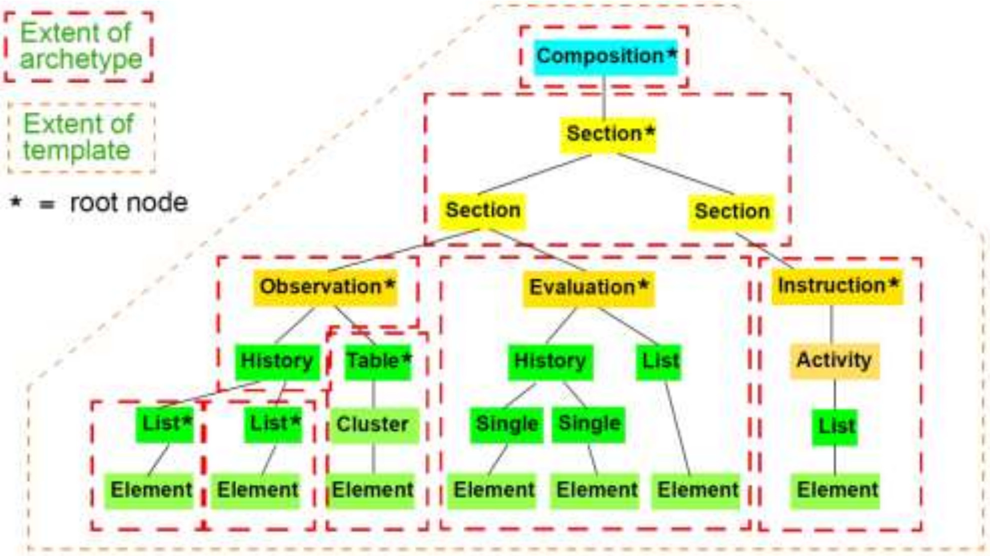

Fig 3: The topology logic of simulation analysis

2) Collaborative simulation subsystem of virtual prototype system

The simulation subsystem supporting the development of virtual prototype is established, and the function and performance of virtual prototype are simulated through the corresponding database, model base and simulation tools. The main research contents include: establishing the collaborative simulation platform of virtual prototype, which takes the CAD / CAE system as the platform tool library, establishing the simulation model of the product, simulating the performance of the product, and realizing the management and sharing of the model and data. Management and sharing, including 3D CAD geometric model sharing, FEA / CFD physical data resource sharing and load, constraint conditions sharing, post-processing results resource sharing. In addition, CAD / CAE software platforms of different companies can be integrated on this platform. In this integrated system, designers can not only quickly create 3D "virtual prototype" geometric model required by users according to market changes, but also quickly simulate and analyze the performance of the "prototype".

3) Management subsystem of virtual prototype system

The management subsystem provides an integrated management platform based on enterprise level PDM, which manages the design subsystem, simulation subsystem and test subsystem in a unified way. It supports the design, analysis and evaluation of virtual prototype, relevant document management, virtual prototype data / model management, engineering change management, personnel organization and authority management, workflow management, and project management.

4) Test and evaluation subsystem of virtual prototype system

The simulation results of virtual prototype need further test verification of physical prototype, so it is necessary to integrate the test results of physical prototype performance test-bed with simulation platform organically, establish the test results database associated with simulation results, accumulate experience data, and provide verification and support for new product development based on virtual prototype.

5) Support subsystem of virtual prototype system

The network system, database system, model base and knowledge base system supporting the development of virtual prototype are constructed.

V. Conclusion

Based on the typical background of construction machinery products, this project is supported by the major project of Shandong science and technology development plan "Research on complex product virtual prototype technology" hosted by Shandong University of science and technology and the project "development and application of construction machinery virtual design and manufacturing technology" hosted by Changlin group. The key technology of virtual prototype of construction machinery is studied, and the "collaborative development platform of virtual prototype of construction machinery" is developed innovatively, which realizes the collaborative simulation, collaborative design, and effective management of team, process, data, etc. in the process of product development in the field of construction machinery.

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