UML Modeling and Parametric Design for Cross Shaft Universal Coupling CAD System

Yongming Wang
Anhui University of Technology, Maanshan, China
E-mail: wym_ahut@163.com

Jiangtao Li
Anhui University of Technology, Maanshan, China
E-mail: ljt1988_2006@126.com

***Abstract*—In order to realize rapid custom design for cross shaft universal coupling products, enterprises need a parametric CAD system. On the basis of analyzing its functional requirements, this paper proposed the overall functional framework of cross shaft universal coupling CAD system, which mainly includes user management, product drawing, product design, document management and technical interface functional modules, etc. Based on UML modeling method, analyzed its use cases models, key class diagrams and activity diagrams of the CAD system. Then, by using Visual Basic 6.0 ActiveX Automation technology and SQL Server database technology, a parametric CAD software for cross shaft universal coupling was successfully developed, which has been used in enterprise's design. Its application shows that the parametric CAD software is convenient to operate, and can rapidly realize parametric design of cross shaft universal coupling parts, so it helps to reduce the labor intensity of designers, and improve the quality and efficiency of design.**

***Index Terms*—cross shaft universal coupling, CAD, unified modeling language, modeling, parametric design**

I. INTRODUCTION

Cross shaft universal coupling is a device used to connect two shafts together at their ends for the purpose of transmitting power. It has become the first choice of shaft coupling and is mainly used in the main transmission of hot continuous roughing mill, large steel rolling mill, piecing mill, medium plate mill and other heavy machinery. There are many types of cross shaft universal coupling, and the traditional design mode is often based on modifying the base type products in order to meet the requirements of different customers. This kind of custom design involves many complicated jobs, the traditional interactive design mode is hard to adapt to the demands customized by the customers, and its design efficiency is low and error-prone. To short product design cycle and improve the design efficiency and quality, enterprises urgently need to realize rapid design by parametric CAD technology [1]. The Unified Modeling Language (UML) is a general-purpose modeling language for visualizing, specifying, constructing and documenting the artifacts of software-intensive systems [2]. UML combines techniques from data modeling (entity relationship diagrams), business modeling (work flows), object modeling, and component modeling. It can be used with all processes, throughout the software development life cycle, and across different implementation technologies [3]. Now, it is the most popular modeling language of object-oriented software systems. Aiming at the development requirements of cross shaft universal coupling CAD system, this paper proposed the overall functional framework of CAD system and then proceeded to construct its UML model. On this basis, the parametric CAD design software for cross shaft universal coupling was successfully developed and applied in enterprise's design.

II. REQUIREMENT ANALYSIS OF THE CAD SYSTEM

Based on the actual product design needs of enterprise, the cross shaft universal coupling CAD system should meet the following functional requirements.

Design functions: According to the national standards of product design, and in order to not only save materials and reduce cost, but also meet its performance requirements, the CAD system should have some design functions, such as products service life calculation, strength check of parts and dimensional parameters optimization.

Drawing functions: Based on the product database support, the CAD system should design parts geometrical elements automatically according to the dimensional constrained parameters inputted by the users. Based on characteristic parameters united drive principle, it can realize the parts parametric design rapidly and generate corresponding drawing automatically.

Fault-tolerant function: In order to reduce input errors and improve the design quality, the CAD system should be able to check the rationality of related parameters inputted by the users according to the relevance of dimension between components.

Retrieval function: The CAD system should provide rapid retrieval and advanced retrieval functions for related product image file information in order to avoid repeated design.

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User permissions management functions: According to different roles to assign user permissions, and provide the operating permissions for the corresponding module.

Interface requirements: In order to facilitate human-computer interaction, the CAD system should provide favorable user interface with navigation and instant prompt functions. It also should provide the interfaces with Product Data Management (PDM) and Computer Aided Process Planning (CAPP) software, so it is convenient to manage generated product parts drawing files information effectively and conduct the follow-up process design.

III. Overall Functional Framework of the CAD System

Based on functional requirement analysis of the cross shaft universal coupling CAD system, its overall functional framework was proposed by using Visual Basic 6.0 ActiveX Automation technology [4, 5]. Its main functional modules include: user management, product drawing, product design, document management and software interface, etc, as shown in Fig.1.

User management module: This module includes some functions such as set user permissions, delete users, modify password, register users, and logout users, etc. The CAD system assigns user permissions according to his roles. It can automatic recognize his operating permission according to user login, and provide corresponding functional module for the user to use.

Product drawing module: According to customer needs, this module provides two parameter set: standard parameter set and user parameter set. The former is a standardized parameter set which enterprise often uses, and the latter is used to save the customization parameter. The user can input demanded dimensional constraint parameters in this modular interface, according to united parameters driving rules, it can design geometric elements of components automatically and realize parts drawing parametric generate rapidly.

Product design module: It includes two sub-modules: performance design and parameter set design. The former is used to complete the service life calculation of the coupling and check the strength of parts. On the premise of meet performance requirements, then design the product parameter set including optimal design of geometric constrained parameters, cooperating dimension parameters, linked dimension parameters, tolerance parameters and so on. In addition, according to special requirements of customers, this module can describe the coupling product with parameters set, and also can effectively manage customer product knowledge base.

Document management module: It includes two sub-modules: document storage and document retrieval. The former can achieve to store document information of the CAD system effectively, including the CAD drawing, Bill of Materiel (BOM) and the relevant design information such as name, drawing number, type, material, designer, design time, etc. In order to help the users find corresponding document information, the sub-module of document retrieval provides two different kinds retrieval methods: quick retrieval and advanced retrieval based on fields.

Software interface module: It provides the interface with PDM software, so it is useful to manage the drawing files information effectively. It also provides the interface with CAPP software, and is convenient for the follow-up process design

Database: The database used in the CAD system is established by using SQL Server 2005 software, and it includes user database, feature database, product knowledge base and document database, etc. The user database is mainly used to store relevant information about users and records the roles that user belong to and corresponding privileges. Feature database saves basic information of cross shaft universal coupling parameters,

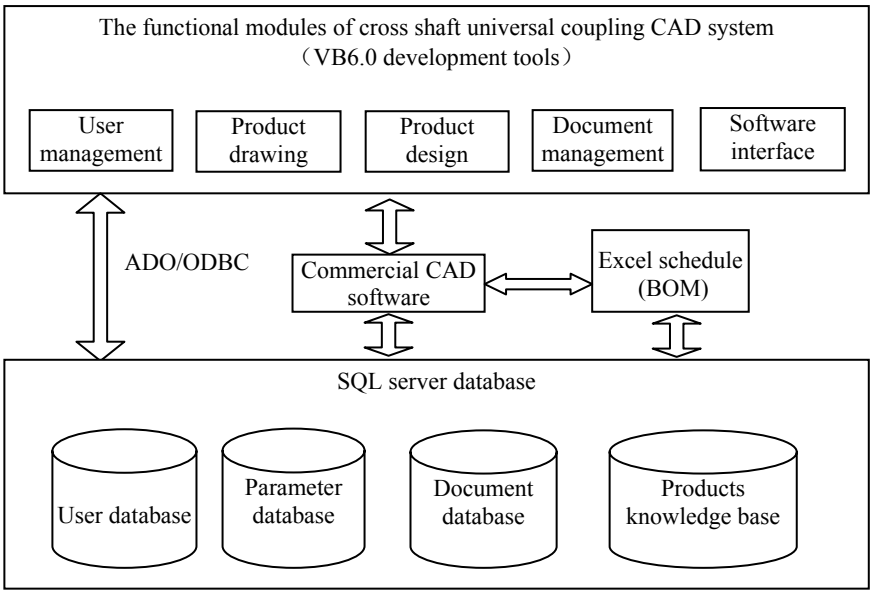

Figure 1. Overall functional framework of cross shaft universal shaft coupling CAD system

including associated parameters, geometry characteristic parameters, matching parameters and driving parameters, etc. Product knowledge base stores all kinds linkage dimensions knowledge, performance checking knowledge and drawing characteristic parameters knowledge, etc. The drawings and related documental information created in the CAD system can be stored in document database.

IV. UML Modeling of the CAD System

According to the overall functional framework of cross shaft universal shaft coupling CAD system as shown in Fig.1, its use cases models, key class diagrams and activity diagrams were analyzed based on the UML modeling method.

A. Use Cases Analysis

A use case diagram depicts actors, use cases, and the relationships among them [6]. The main purpose of UML use case is to help development team to understand the functional requirements of the system by a visual way, including the relationship between roles that based on basic process and the relationship between the use cases in the system. According to the development requirement of cross shaft universal coupling CAD system, its UML use cases diagram is shown in Fig.2. It includes two kinds of users: super user and ordinary user. There are twelve use cases, such as 'user management', 'product drawing', 'product design', 'document management', 'system help', 'software interface', 'parametric drawing, 'database', 'performance design', 'parameter set design', 'CAPP' and 'PDM'. The father cases of 'product drawing', 'product design' and 'document management' is the use case of 'database' and they also have expanded use cases. The 'software interface' use case has 'CAPP' and 'PDM' two sub use cases. The super user owns all the relevant operation privileges of each use case model while ordinary users only can operate the authorized use cases

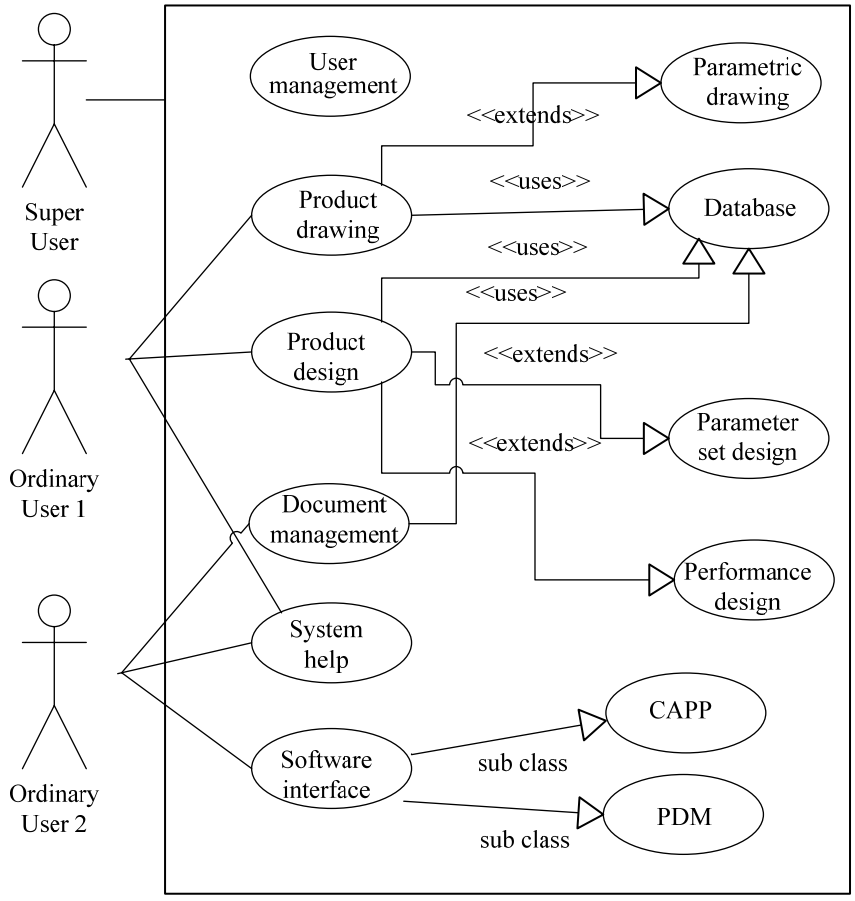

Figure 2. The UML use case diagram of cross shaft universal coupling CAD system

B. Key Classes Design

According to the UML use cases diagram of the CAD system as shown in Fig.2, we analyzed the problem domain objects, abstracted the same type of objects to classes and then established the class diagrams that can reflect the CAD system structure and composition [7]. The key classes and their relationship of the CAD system were shown in Fig.3.

There are thirteen key classes in Fig.3, but in actual CAD system, there are other classes besides these. This paper only describes their interaction and involved method of the key classes.

CProductDesign class: Firstly, the user interacts with CProductDesign class and then selects corresponding operation through this class. CProductDesign class includes two sub classes: CDatabase class and CPerformance class, and they are combined aggregation relationship with CProductDesign class. CDatabase class is used to store attribute values including document data set, parts parameter set and product knowledge.

CProductElement class: It uses to describe constitute elements set produced in product design module. It has three attributes: element type, element value and element linked value. The first attribute refers to geometric elements, remark elements and BOM elements, etc. The second attribute is not only used to describe specific

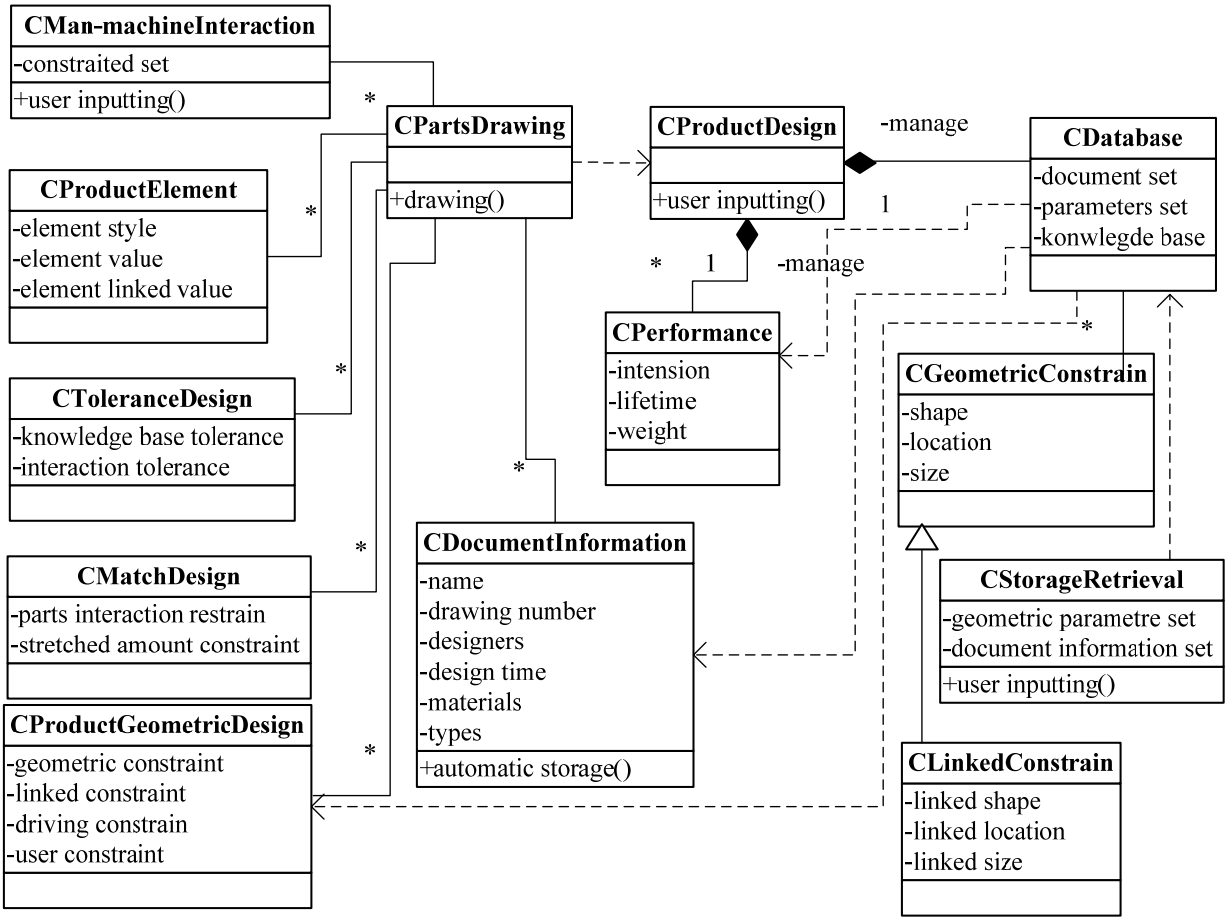

Figure 3 The key classes and their relation of cross shaft universal coupling CAD system

CStorageRetrieval class: The class relies on CDatabase class and uses for data storage, retrieval and modification. Through inputting retrieval conditions, the user invokes the geometric parameter set and document information set.

CPerformance class: It is used to check parts strength, calculate coupling service life and estimate parts weight. It has three attribute values: strength, life and weight. If design can't satisfy performance requirements, it should return to CProductDesign class for redesign. Only on the premise of meeting performance requirements, design parameters can be stored in CDatabase class.

CMan-machineInteraction class: It mainly provides input interface for the user to input the CAD parameters. According to the parametric constrained relation, it automatically checks the rationality and validity of user input parameters. For effective input parameters, it will prompt the user to save, while for unreasonable input parameters, it will prompt error message timely.

element values, but also describes the element replace relations values. The last attribute is indispensable and important component of dimension linked optimization which describes the parts dimension linked rules.

CToleranceDesign class: It provides marked requirements of tolerance and has two attributes: knowledge base tolerance and interaction tolerance. The former is the tolerance values stored in knowledge base, when parts drawing, it is called to generate tolerance automatically, while the latter is used to complete the geometrical element tolerance design in man-computer interaction way.

CMatchDesign class: It's mainly used to match geometrical element between various parts in assembly drawings. According to requirements of matching rules that clients offer, CMatchDesign class have two attributes rules: parts interaction restraint and stretched amount constraint.

CProductGeometricDesign class: The class is used to design parts geometrical elements and has four attribute: geometric constraint, linked constraint, driving constrain and user constraint. Among them, geometric constraint provides geometric parameters for parts; linked constraint produces linked parameters of parts based on assembly relation of assembly drawings and the rules of linked parameters; driving constrain is used for driving other parameters by some parts characteristic parameters; and user constraint is used to interact with the geometric design products directly.

CDocumentInformation class: The class is used to store relevant drawing documentation and information of cross shaft universal coupling in process of parametric drawing and has some attributes: name, drawing number, designers, design time, materials, types, etc.

CPartsDrawing class: The class is used to complete components and parts parametric drawing function of cross shaft universal coupling. The input parameters are transferred to CPartsDrawing class, and produce corresponding geometric parameter constraint sets and performance parameters constraint sets. Then, they are transferred to other modules with constraint sets. During the transferring process, this class will generate the corresponding parameter dialogs and the user can redefine some parameters. Then, CPerformance class and CProducDesign class decide their rationality automatically; give the optimal parameter constraint sets and transfer back to CPartsDrawing class finally. Finally, CPartsDrawing class performs parametric drawing for corresponding part by using AutoCAD ActiveX Automation technologies.

C. UML Activity Diagram Design

UML activity diagram is used to describe the interaction between objects [8, 9]. According to actual development requirements of cross shaft universal coupling CAD system, the activity diagrams were designed, as shown in Fig.4.

There are three lanes in the UML activity diagrams of cross shaft universal coupling CAD system: user interface, logical interface and database interface. User logins the main window (select operator interface), and it will provide related operations in accordance with user's permissions. The CAD system can accomplish parts drawings and assembly drawings automatically according to their basic parameters and linked characteristic parameters. Before drawing the parts drawings, it will check the related performance according to product knowledge base. Only in the precondition of meeting performance requirements can draw parts. In the drawing process, the document information of drawings will also store in document database for users to query next time. The drawing documents are saved to the database directly with binary format, which enhances the integrity and safety of document information.

V. An Applied Example

Aimed at the cross shaft universal coupling products, a parametric CAD system was developed successfully based on UML modeling and Visual Basic6.0 development tool, using ActiveX Automation technology to visit internal graphics entity objects of commercial CAD. Fig.5 shows a parametric drawing interface of the spline shaft part, the left area is type selection and serial number input interface, the middle area is basic parameters and design parameters input interface, the right area shows product specific geometric characteristic parameters. Fig.6 is a spline shaft part plotted by the CAD system automatically.

The CAD system has been applied in Anhui Taier Heavy Industry Co., Ltd. in China. The results of application show that the CAD system is convenient to operate, and can realize rapidly parametric design of cross shaft universal coupling parts. What's more, it solves the tedious performance check calculation, reduces designers' labor intensity and has good economic efficiency.

VI. Conclusions

This paper analyzed the functional requirements of cross shaft universal coupling CAD system, and proposed the overall functional framework of the CAD system development. Based on UML modeling method, this paper established some UML models of the CAD system, including use cases models, key class diagrams and activity diagrams. On this basis, by using Visual Basic 6.0 ActiveX Automation technology and SQL Server database technology, this paper completed a parametric CAD software for cross shaft universal coupling, and realized the product parametric design, which can overcome the defects of artificial design and improve the quality and efficiency of product design.

The CAD system development process shows that using UML modeling methods and object-oriented programming technologies is advantageous to communicate with developers easily, which will improve the development efficiency and shorten the development time.

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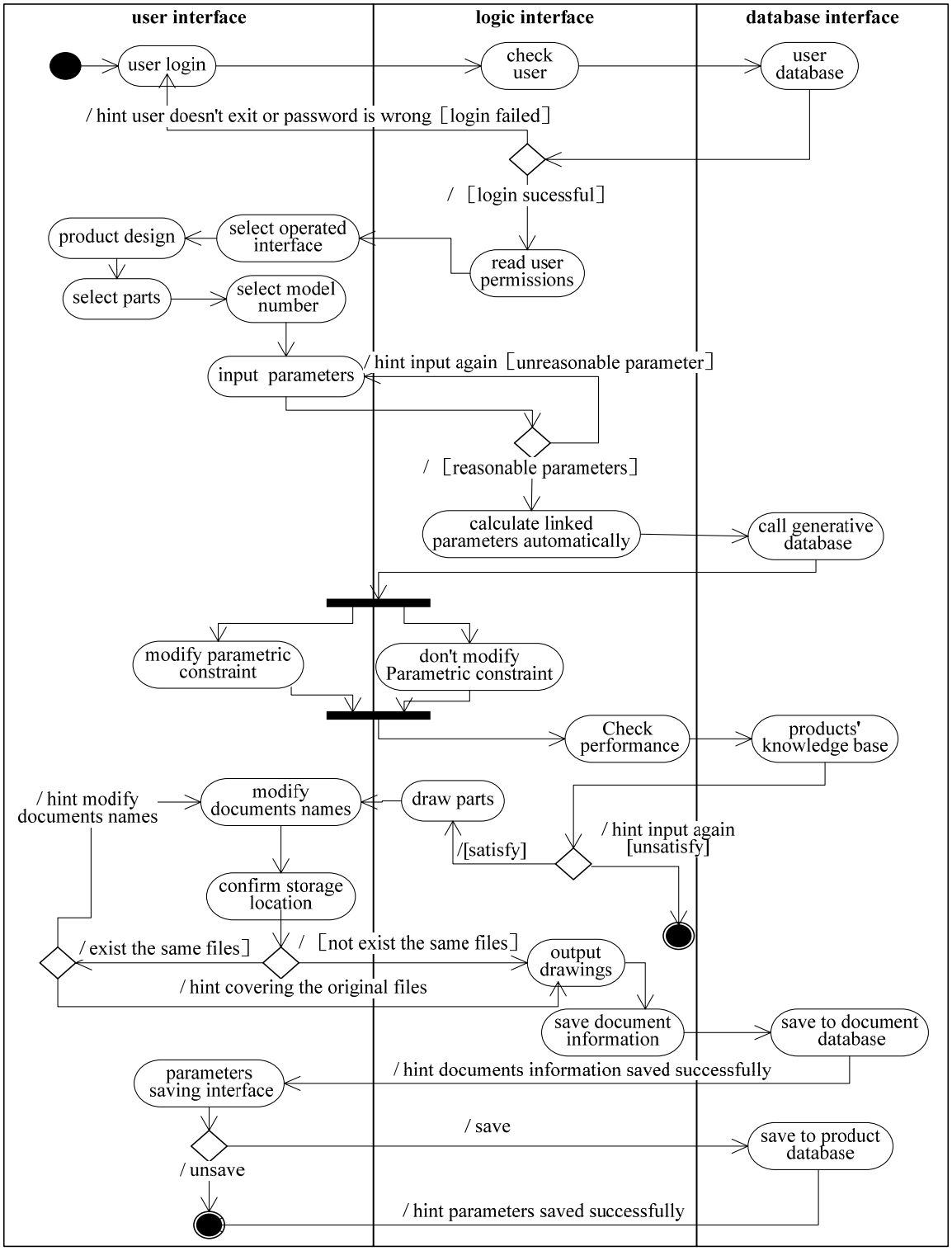

Figure 4. The UML active diagram of cross shaft universal coupling CAD system

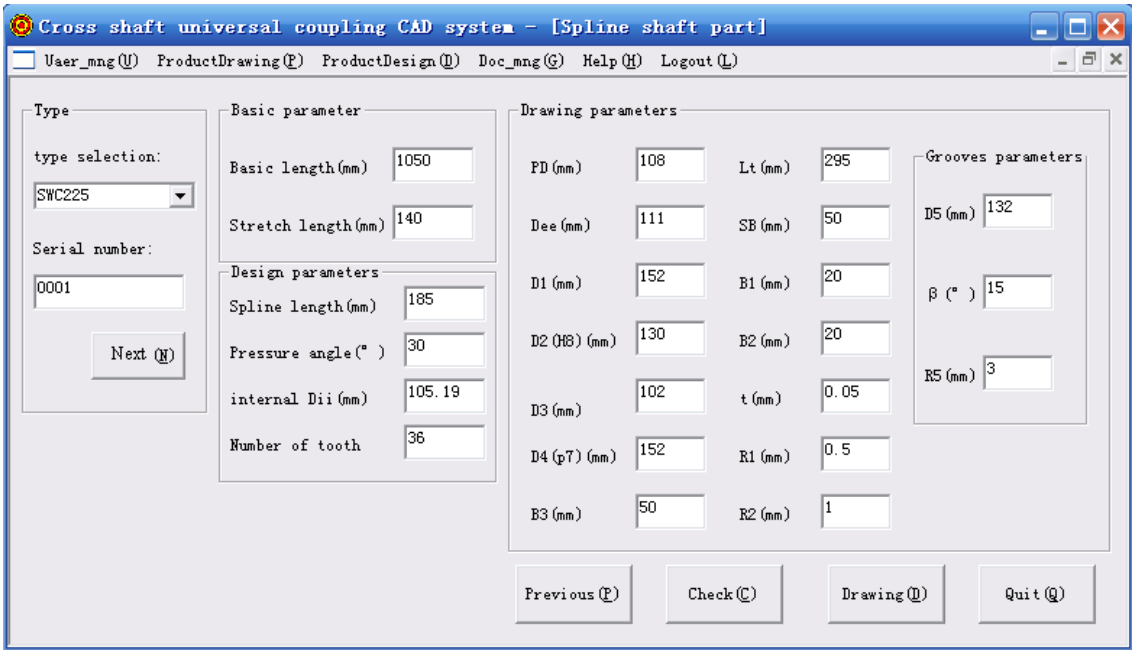

Figure5. The spline shaft part drawing interface of the CAD system

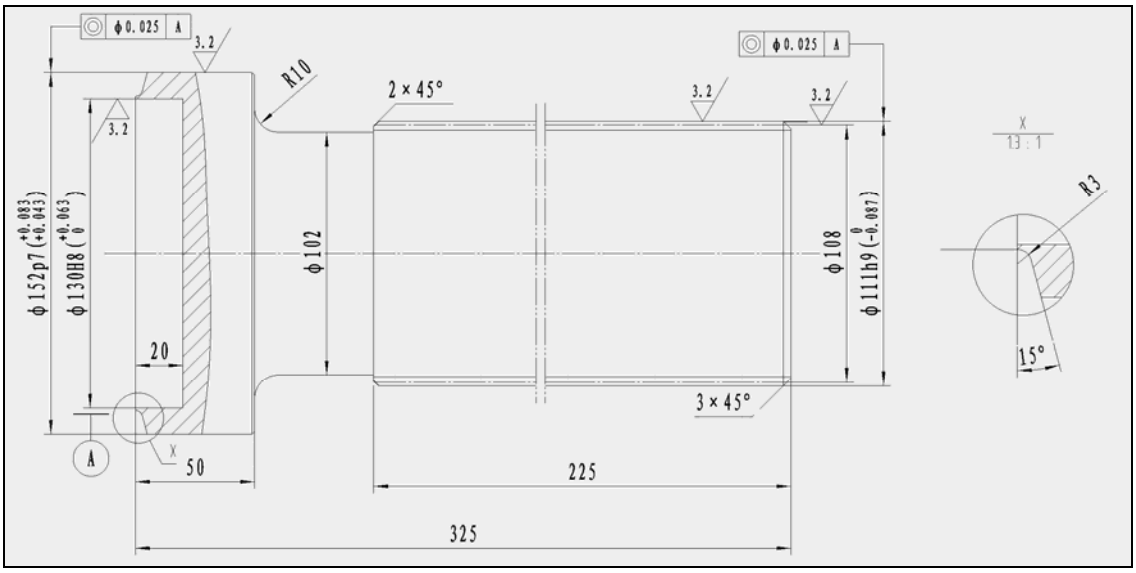

Figure 6. The spline shaft part drawing plotted by the CAD system automatically

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