Development on CAD/CAPP Parametric Design System of Train Axle

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Abstract. With the train axle product as the research object, based on analysis of the functional needs of the CAD/CAPP parametric design system of train axle, the overall functional framework of the system is decided, and the Unified Modeling Language (UML) activity diagram of the system is designed. The parametric design methods of the system are discussed, including the shaft shape features and parametric programming, the establishment of feature drawing function. Based on Visual Basic 6.0 programming language and SQL Sever database technology, the CAD/CAPP parametric design system of train axle is developed, and an application example is given. The application result shows that the system is easy to operate and significantly saves the design time of the product. The format of its generated drawings is unified, and accords with the national standard specification.

1. Introduction

At present, the products of domestic manufacturing enterprises are stable, and the daily product design mode of enterprises is usually to modify the existing similar products according to customer needs [1]. Because of the customers' individual and diversified demand for the train axle product, the modified design based on the basic product involves a lot of tedious drawing design and process design work, and its design efficiency is low and easy to make mistakes. The traditional interactive computer drawing is difficult to meet the needs of custom-made production. It is necessary to use CAD and CAPP parameterized technology to realize the rapid design of the product, in order to shorten the design cycle and improve the efficiency and quality of the design.

In order to study the stress field of axle, the visual data checking of axle was carried out in Southwest Jiaotong University [2] based on OpenGL technology, and a parametric modeling system of axle was realized by modularization idea. However, the parameterized modeling function of the system is only for the main parameters of the axle, and lacks the automatic drawing function of the intermediate process in the manufacturing process of the axle.

Aiming at the deficiency in reference [2] and the actual demand of a train axle manufacturing enterprise, this paper puts forward the overall functional framework of the CAD/CAPP parametric design system of train axle and the work flow model of the system. Then, this paper focuses on the parametric design methods, including the shaft shape feature and parameter planning, the construction of the feature drawing function and so on. Finally, the CAD/CAPP parameterized design system of train axle is developed, and the parameterized design of train axle and automatic generation of engineering drawings and process drawings are realized.
2. The General functional framework of CAD/CAPP system
According to the actual requirements of a train axle manufacturing enterprise, the CAD/CAPP system should meet the following functional requirements:

1) Fast selection function of Shaft shape feature. According to the PDF drawings of the axle product provided by the customer, the corresponding local shaft shape features can be quickly selected from the CAD/CAPP system and parameterized.

2) Function of reverse design. According to the PDF drawings of the axle product provided by the customer, the designer can automatically draw the two-dimensional drawings of the preceding processes after entering the design and process parameters in the CAD/CAPP system.

3) Fault tolerant function. The function is to prevent error operation, check the rationality of relevant parameters, in order to reduce input errors and improve design quality.

4) Search function. The system should provide a quick retrieval of the information about the shaft profile of the existing railway axle products, which can be used to design the similar axle quickly and avoid repeated design.

5) User rights management function. According to different users, the authority is assigned and the operation rights of the corresponding modules are provided, which is convenient for the management of user and product information.

6) Interface function. It provides the interface with the PDM software, facilitates the product information follow-up management and the utilization.

Based on the above development requirements, the overall functional framework of the system is developed with Visual Basic 6.0 object-oriented development tool and SQL Server database as data carrier, as shown in figure 1.

As can be seen from figure 1, the overall functional framework of the CAD/CAPP system consists of the following modules:
1) User Management Module. It includes "new user registration", "change password" and "logout" functions used by ordinary users, also includes "set user permissions" and "delete user" functions used by administrator users. According to the authority of the user, the system provides the corresponding module operation rights.

2) Feature matching module. Typical shaft shape features include: chamfer rectangular, right rectangular arc, left rectangular arc, right cone, left cone, right arc, right cone, left conical arc, right rectangular cone arc, left rectangular cone arc and so on. The designer can select shaft shape features according to the finished product drawing of the train axle, and their order can be adjusted, i.e. a certain feature can be moved to the left or right. At the same time, you can also open the selected prior to the similar shaft shape features for local adjustment.

3) Parameter setting module. According to the selected shaft shape features, the input function of feature parameters and process parameters of related processes is provided, which is convenient for reverse design of intermediate process drawings.

4) Product drawing module. According to the feature selection module and parameter setting module, the module automatically draws the required drawings according to the feature parameters and process parameters information returned by the module.

5) Software interface module. It provides interface with PDM software for product information management.

6) Database. The system adopts SQL Server database, including "user database", "product database" and "characteristic parameter database"[3]. The "user database" is used to store the relevant information and authority of the user, and the "product database" is used to store the relevant information and detailed information of the train axle product. The feature parameter database is used to store product-related feature parameters and related process parameters.

3. Key Technologies of CAD/CAPP system Development

3.1. UML activity diagram of the system

The Unified Modeling Language (UML) [4] activity diagram is used to describe the interaction behavior of each object in the whole workflow of the system, so as to clarify the interaction process and information interaction among the functional modules, as shown in figure 2.

Figure 2 shows that the system can be divided into three swimming lanes, indicating that the three layers of the system are "user layer", "logical layer" and "database layer". The "user layer" is user-oriented, which mainly receives and recognizes the user operation information, transmits the relevant information to the "logic layer" and returns the result to the user. The logical level is used to determine the user's operational information and execute commands, such as accessing a database. This layer is not only the link of "user layer" and "database layer", but also the layer to realize the main functions of the system (such as drawing), which is the core of the whole system. The database layer provides data support and product information management to ensure the operation of the entire system.

3.2. Shaft shape features and their parameter planning

Train axle is an important part of railway locomotives and rolling stock. The quality of manufacturing is closely related to the safety of railway transportation. The typical axle products of a certain enterprise include VE914, QY 650, TJ 840 and TR920 and so on. By analyzing the shaft shape of the typical axle products mentioned above and combining the actual processing of the axle, the shaft type of the train axle is mainly composed of axle head, shaft neck, dust guard seat, wheel seat, axle shoulder, brake disc seat, axle body and so on, as shown in figure 3. Although there are many kinds of axle and Shaft shape features of train axle, from the angle of drawing two-dimensional engineering drawings, they can be summed up as: chamfer rectangle, circular arc at both ends, rectangular arc (right / left), cone (right / left), arc (right / left), cone (right / left), rectangular arc (right / left), etc.
Figure 2. UML activity diagram of the train axle CAD/CAPP system
Figure 3. A train axle and its shaft shape features

Based on the principle of parameterized design [5], it is necessary to carry out parameter planning for the features of train axle, and transform the product into parameter set, so as to facilitate the parameterized design. Taking the two ends arc feature as an example, figure 4(a) is the feature and its input parameters, and it is the diagram in the feature input interface, figure 4(b) is the feature and its drawing parameters, which can be used in parameterized programming.

(a) Feature and its input parameters
(b) Feature and its drawing parameters

Figure 4. The two ends arc feature and its parameters

Set the drawing function of the two ends arc feature is \( f \), the structural feature is \( y \), and take the parameters shown in figure 4(b) as independent variables, and the following relations can be obtained:

\[
(1)
\]

In the formula (1): \( d_1 \) is the left end axis diameter, \( d_2 \) is the middle end axis diameter, \( d_3 \) is the right end axis diameter, \( l_1 \) is the left end axis length, \( l_2 \) is the middle axis length, \( l_3 \) is the right end axis length, \( r_1 \) is the left axis radius, and \( r_2 \) is the right axis end radius.

By modifying the independent variable in formula (1), the structural feature \( y \) of different parameters of the two ends arc feature shaft segment can be obtained, so as to achieve the effect of modifying the design. Using the same method for other axial segment features, the structural features of each type of shaft segment feature are constructed as the corresponding feature drawing function \( f_1, f_2, \ldots, f_n \). By selecting different feature drawing functions \( f \) and modifying the corresponding independent variables, different axle segment features can be automatically drawn by the system, thus the fast parameterized modification design of train axle can be realized.

3.3. The establishment of feature drawing functions

The key to develop the CAD/CAPP system of train axle is how to establish the feature drawing function in the program according to the feature parameters input by the user. Take the right arc feature as an example (figure 5), the establishment of the feature drawing function are introduced.
The right arc feature in figure 5 is about x axisymmetric. It is only necessary to establish the feature drawing function of the graph above x axis and then draw the complete feature of axis segment by using mirror function. The values of the parameters input by the user are \( D_1, D_2, L_1, R_1 \) in figure5(a), then these four values can be read directly during the establishment of the feature drawing function, that is \( d_1, d_2, l_1, r_1 \) in figure5(b) is a known quantity in the course of the establishment of the drawing function. In addition, in figure 5 (b), the drawing starting horizontal and vertical coordinates of a and b for this feature are programmed as the known variables, the starting and terminating radians of the upper end arc is respectively \( r_q \) and \( r_z \), and \( r_q \) is \(-\pi/2\), so the key to establish the feature drawing function is to solve the \( r_z \).

As shown in figure 5(b), the distance between the vertical point \( P \) and the circular arc center point \( Q \) is \( x \), \( r_z \) is \( \theta \), then the formula (2) is obtained.

\[
\begin{align*}
\tan \theta &= \frac{l_1}{x} \\
x &= r_1 - \frac{d_1 - d_2}{2}
\end{align*}
\]

From formula (2), the formula (3) is obtained.

\[
\begin{align*}
\theta &= \arctan \left( \frac{l_1}{r_1 - \frac{d_1 - d_2}{2}} \right) \\
r_z &= -\left( \frac{\pi}{2} - \arctan \left( \frac{l_1}{r_1 - \frac{d_1 - d_2}{2}} \right) \right)
\end{align*}
\]

The value of \( r_z \) can be obtained by formula (2). In this way, the feature drawing functions parameters (i.e. \( d_1, d_2, l_1, a, b, r_1, r_q, r_z \)) of the right arc feature are all known, so the right arc features shaft segment can be successfully drawn by using the program language.
4. Application example

Based on the idea of parametric design, using SQL server database as data carrier and ActiveX Automation technology of Visual Basic 6.0[6], a CAD/CAPP parameterized design system of train axle is developed successfully. Figure 6 shows a train axle feature selection interface. According to the PDF drawing of the finished product ordered by the customer, the designer selects the corresponding shaft shape feature from left to right in the interface. After the selection is completed, the features are arranged from top to bottom in the "feature ranking" box on the left side of the interface. If the selection is incorrect, the designer can click [up] or [down] button to modify the feature order in the feature sort box, and then click [complete] button to enter the feature parameter setting interface, as shown in figure 7. If the features parameters and the relevant process parameters are inputted, the designer can click the [plot] button, the system will draw six two-dimensional engineering drawings automatically in AutoCAD software, which are respectively finished product drawings, outer circular grinding drawings, molding grinding drawing, finish turning drawing, semi-finish turning drawing and rough turning drawing, as shown in figure 8.

Figure 6. The train axle feature matching interface

Figure 7. Feature parameter setting interface
The CAD/CAPP parametric design system has been successfully applied to a train axle company. The practice shows that the system meets the design requirements of the enterprise, and successfully solves the problems of low design efficiency, poor precision, blind processing and so on. The engineering drawings produced by the system meet the technical requirements of the industry and the national standards, and also meet the customer's personalized customization needs.

5. Conclusion
In view of the low design efficiency of train axle in China, a CAD/CAPP parametric design system of train axle is developed, which can be used to assist the design of train axle and improve the design efficiency. The system has been successfully applied to a train axle company. The practice shows that the CAD/CAPP parameterized design system of the train axle can better meet the needs of the modification design of the train axle, and successfully solve the problem of the low efficiency of the modification design of the train axle. The quality of the drawings is in line with the industry technical requirements and national standards.

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