Variant design of typical aircraft parts based on CATIA technology

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Abstract: In order to improve the efficiency of product design, the component framework technology was studied. With the help of CATIA secondary development platform, the variant design of typical aircraft parts was realized on the basis of parametric modeling technology, the feature information was extracted quickly, and the intelligent operation was realized. By using object-oriented programming language, a variant design module integrated with CATIA system is developed to improve the design efficiency of typical aircraft parts. Taking the tie rod in the typical aircraft parts as an example, the verification of the variation design method shows that using CATIA secondary development technology and CAA programming tools, the parametric modeling of typical aircraft parts can be achieved to achieve the variation design.

1. Introduction
With the development of science and technology, mass customization has become the mainstream production method in the world today. The production-oriented mass customization method and variant design promote the technological progress of manufacturing enterprises. The variant design of enterprise products refers to the improvement of the relationship between product parameters and dimensions according to the needs of business customers, and the final design of the product is determined. Typical aircraft parts are the basic components of aircraft structure and their design efficiency is closely related to aircraft structure design. In order to improve the design efficiency of typical aircraft parts, this research uses CATIA secondary development as a platform and uses CAA (Component Application Architecture) programming tools to design variant designs of typical aircraft parts. First, a three-dimensional model of the part based on CATIA parametric modeling is established. Then the model is analyzed by parameters to establish a certain variable relationship. Finally, the variant design of the product is completed by parameter driving or removing and adding features. Variant design technology can improve product design efficiency, reduce costs, and ensure product quality.

2. CAA’s product architecture and technology implementation

2.1. CAA Product Architecture
The component application architecture CAA was launched by French Dassault Company, and it is an...
effective tool for customers' secondary development of CATIA. CAA’s product architecture (Figure 1) is mainly to combine and extend its component objects. Based on C object-oriented programming, it uses Component Object Model (COM) and Object Linking and Embedding technology (OLE) for secondary development of CATIA. CAA’s product architecture adopts standard interface technology, which has better module independence and extensibility, which makes CAA program design tend to be standardized and can carry out the development of all functions of the system.

As can be seen from Figure 1, CAA is composed of many modules, and each module contains a series of documents, which contain a large amount of information, and users can implement the required functions according to the document information. There is a certain connection between the CAA module documents. Click the specific module, and you can query the specific functions and application examples needed for CAA programming. Therefore, the modular structure of CAA is very suitable for the further development of the system.

2.2. CAA Technology Implementation
Rapid Application Development Environment (RADE) is an integrated visual development environment that can provide users with a more complete programming tool set. The implementation of CAA is realized through rapid application development environment and different API interfaces. RADE uses object-oriented VC++ as the carrier, and embeds CAA tools. The API interface provides interfaces, tools, and methods for each program object. With CAA, the secondary development of CATIA, full 3D parametric modeling, and variant design based on parametric modeling can be realized.

3. Classification of typical aircraft parts
Typical aircraft parts refer to a class of parts that are representative and can reflect the generality of aircraft parts. They may have certain similarities in structure or manufacturing process. For example, beams have a chevron beam, a zigzag beam, and an I-shaped beam and hook beams. The structure of the aircraft is mainly composed of wing, fuselage, power unit, take-off device and tail wing. Among
them, the wings and fuselage contain a large number of typical aircraft parts, including machine parts, sheet metal parts and profiles. Compared with ordinary parts, typical aircraft parts have the characteristics of complicated structure, large structure, diversified materials, and precise manufacturing.

There are many typical aircraft parts. In order to classify them clearly, typical aircraft parts can be summarized and classified according to their structural characteristics and manufacturing characteristics. In parametric modeling, variant design is mainly used for typical aircraft parts as shown in table 1. Considering the structure and manufacturing characteristics of parts, sheet metal parts, wings, beams, tie rods and girder profiles are typical aircraft parts.

(1) Aircraft sheet metal parts are mainly composed of webs, wing surfaces and edge strips. Through cold processing such as shear stamping, metal sheet parts with the same thickness are generated. The edge strip and the wing surface are bent together to form sheet metal parts. Sheet metal parts usually have flange, line stamping and other characteristics, used to reduce the concentrated stress of sheet metal parts. Sheet metal parts can be divided into two side flanging sheet metal, three side flanging sheet metal, four side flanging sheet metal according to the different flanging; According to the different forward and backward flanges can be divided into forward flanging, reverse flanging; According to whether there is a gash can be divided into a gash, no gash.

(2) The spar is composed of webs and edge strips, and its forces are mainly longitudinal. Edge strips are mainly subjected to bending moments, as well as tensile and compressive effects. The outer structure of the spar is similar to that of sheet metal, and can be divided into C-shaped, Z-shaped, I-shaped and hook-shaped according to the cross-sectional shape of the end. Like sheet metal parts, the spar can be subdivided according to whether the end part is closed, open, or notched.

(3) The tie rod is a mechanical part, which is mainly used as the internal connecting force of the wing. Tie rods in the form of side slots are mainly used to relieve the stress caused by concentrated loads. According to the needs, the tie rod can be divided into tie rod 1-1, tie rod 1-2 and tie rod 1-2.

(4) Long truss profiles mainly bear axial forces caused by wing bending moments and shear forces caused by local aerodynamic loads. Long truss profiles can be divided into ordinary long truss profiles and skin long truss profiles.
4. Analysis of variant design of typical aircraft parts

Parametric design is the mainstream method of mechanical design. In order to reduce the complexity of the design of the typical parts of the aircraft, improve the design efficiency, and increase the profit of the product, this study uses the design technology of the typical part variants. The variant design is to modify the size and structure of the original design to meet the requirements of the product design without destroying the original design principle and structure of the product to produce a new product similar to the original design. The variant design technology is essentially a special case of parametric design technology. By modifying the parameters or the relationship between the parameters and the parameters, the mechanical parts are re-constrained to generate new models.

Variation design of typical parts in CATIA system, when the initial parametric model of typical parts is built, the typical parts are sorted and classified according to their structural similarity according to user needs, and then variation design is modeled. Ordinary parts can only be modified one by one, the product design efficiency is low. After the classification of typical parts, the similarity of external geometric features is relatively strong, and the deformation design can shorten the modeling step, quickly repeat the original operating steps, improve the design efficiency and reduce the cost. Typical part variation design is the reuse of model. For two similar models, the reuse of the geometric model can be realized by modifying the model parameters and driving the update of the model.

The theme of variant design of typical aircraft parts is: firstly, analyze and categorize the structural features of typical aircraft parts, then build their modules, design the variant models in each module, and finally achieve the purpose of parts reuse. Therefore, variant design combined with parameterization technology can improve the flexibility of product design and better adapt to the development and design of multi-model products.
5. Establishment of variant design dialogs for typical aircraft parts
Add the Dialog to the already built interactive interface and create an empty Dialog: first set the work object to the current Module, then click the file-> CA V5 item-> CATIA resource-> Dialog.
Add controls in the empty dialog box, add controls to the CATDlg dialog box according to user needs, click all save buttons to save the file, the program will automatically generate in the Build function:

```
_Frame001 = new CATDlgFrame ( this, “Frame001”, CATDlgFraNoTitle | CATDlgGrid Layout);
_Frame001 -> SetGridConstraints ( 0, 0, 1, 1, CATG RID_4SIDES);
```

......

The variation design dialog box of typical aircraft parts established in this study is shown in figure 2. For all typical parts, the initial 3d model that needs to be changed can be invoked in the knowledge template preview of the dialog box, clearly visible.

![Figure 2 Typical part variant design dialog](image)

6. Implementation of variant design methods for typical aircraft parts
Typical parts of aircraft are designed according to their structural and manufacturing similarities. According to the classification of typical aircraft parts, the parameters and structures are analyzed, and a three-dimensional parametric model is established through CAA programming tools. Then the variation design of typical parts can be completed by classifying and modifying the model based on the parametric model. The variation design of typical parts can be divided into size parameter variation and structure characteristic variation.
6.1. Based on size parameters
After the typical aircraft part model is built by parametric modeling technology, if the dimensional modification of model features is to be realized, it is necessary to modify the dimensional parameters of corresponding features and update such models to form a new model. Firstly, through the secondary development technology of CATIA, the interactive design interface was established with the aid of CAA programming tools, and then a program was written to make the size parameters in the typical part model associated with the size parameters in the interactive interface dialog box, and the size parameters drove each other. Finally, the variation design was realized by changing the size parameters. The main implementation process is shown in figure 3.

![Figure 3 Design and implementation process of typical aircraft variants based on dimensional parameters](image)

6.2. Based on structural features
Variation design based on structural features is a reuse based on feature instances. A feature is the smallest unit of a part, which can express not only the shape information, but also the size constraints and other information. Structural feature parameters are dynamic parameters, which can be used to control the shape and position of features, and realize variant design according to users' requirements. The relationships among structural features include location relation, boolean relation and hierarchy relation. Location relation refers to dimensional tolerance in part features; Boolean operation relation refers to the modeling sum and the difference between the parts' features. Hierarchical relationships are similar to those in analytic hierarchy process.

The variant design of typical aircraft parts based on structural features is based on the typical geometric model of aircraft. Users can delete or add the features such as boss, groove, hole and rib of typical aircraft parts to generate new models. The main implementation process is shown in figure 4.

![Figure 4 Implementation process of variant design of typical aircraft parts based on structural features](image)

According to the modeling process of typical aircraft parts, the designer can delete and add the features of the original typical parts model to quickly realize the variant design and achieve the purpose of variant design of typical aircraft parts.

7. Examples of variant design of typical aircraft parts
There are many kinds of typical parts of aircraft. Here, the variant design method is introduced by taking the tie rod 1-2 as an example. Firstly, the characteristics of the tie rod were analyzed to determine the
size parameters of single lug radius \( r_1 \), single lug radius \( r_1 \), single lug thickness \( h \), binaural radius \( r_2 \), binaural radius \( r_2 \), binaural thickness \( h \) and binaural spacing \( S \). After determining the size parameters, CATIA secondary development technology and CAA programming tools were used to establish the initial tie rod 1-2 model. After the modeling is completed, the size parameters are modified to realize the parameter variation.

1. Get the current document:
   ```
   CATFrmEditor * spFrameEditor = CATFrmEditor::GetCurrentEditor();
   CATDocument* pNewInstanceDoc = spFrameEditor->GetDocument();
   ```

2. Obtain the document prt-container through GetRootContainer() method, and obtain the part design features through the pointer to the container pIPrtCont on-caanewinstance:
   ```
   CATIPrtContainer * pIPrtContOnCAANewInstance = NULL;
   pIPrtContOnCAANewInstance = (CATIPrtContainer*) pNewInstanceDoc->GetRootContainer("CATIPrtContainer");
   ```

3. Interface query for part parameters:
   ```
   rInit * pInitOnDoc = NULL;
   rc = pNewInstanceDoc->QueryInterface(IID_CATInit, (void**) &pInitOnDoc);
   ```

4. Traversing the part parameters:
   ```
   CATISpecObject _ var spSpecName = List Found[i];
   for ( pPub = ListCst[i] ; ) ;
   ```

5. Associate the parameters of the interactive interface with the parameters in the model, complete model update:
   ```
   spPrism = List [i];
   spPrism->__SetRealValue (W[i]);
   ```

Figure 5 shows the pull rod 1-2 before and after the parameterized variation of part features.

8. Conclusion

CAA programming tools are used to develop 3d software CATIA technology. Through object-oriented
programming language, designers' ideas are combined with 3d software to realize variant design of typical aircraft parts, so as to make users more professional and purpose-oriented in product design. Through example modeling, the deformation design of typical aircraft parts can be widely used in CATIA system to improve the design efficiency.

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