

# Research on the 3-Dimensional Grab Design System Based on Case-Based Reasoning

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## Abstract

With the increasing intense competition of mechanical manufacturing market, companies must shorten products design cycles, improve products' quality, and reduce the costs of products. This paper takes into account the characteristics of grab product design and put forward the method the integrate three-dimensional design and case-based reasoning technology for the grab design, and propose the procedure of grab bucket design based on case-based reasoning and apply the method to grab bucket design field,. In the paper, the 3-D grab case library and explore intelligent reasoning module are established. And case-modified technology through SolidWorks and its secondary development are achieved. At last, a set of three-dimensional grab design system is developed, which can realize grab virtual assembly, kinematics analysis, interference check, finite element analysis and creating engineering drawings so that it makes the applications of intelligence design possibility.

**Keywords** digital manufacturing, case-based reasoning, virtual design, intelligent design, grab

## 1 Introduction

The Grab is a main handling device which is used for loading and unloading staple scattered material. But all countries have not a uniform design rules for grab bucket because of the diversity of the material shape, the type of material or load capacity and working environment. For example in Germany, Various manufacturers have their own reference data and design rules. And in china, there is no similar national standard. The study on the grab design also is less[1].

In the actual design process, the experience occupies a large proportion. In general, designers use the method such as a simple analogy, size, and zoom in or out according to the reference drawings to revise and design new grab products based on the similar types of grab products drawings. But the method is very difficult to avoid interference between the parts of grab and guarantee the products have reasonable dredging rate and so on.

With the increasing intense competition of mechanical manufacturing market, companies must shorten products design cycles, improve products' quality, and reduce the costs of products. To improve the efficiency and quality of grab design,

the paper focus on the method how to integrate both of intelligent design and three-dimensional grab modeling .

In common, the intelligence design method is the process that choosing the design satisfied solution through the RBR (Rule-Base Reasoning) way base on record the product design knowledge and discipline in rule form, through the RBR (Rule-Base Reasoning) way to choose the design satisfied solution. Intelligent design is method which record product design knowledge and law based on the usual rule form, and make the design plan which meet the requirements through the rule-based reasoning (Rule-Based Reasoning, RBR). However in the design field, a wealth of experience and fragmented knowledge are difficult to be summarized in the form of rules. Those problems limit such system application for the mechanical design field in a narrow range. These problems restrict the application of this kinds system in mechanical design field. Recent years, with the intelligence technology studying, case-based design (Case-Based Design, CBD) method has shown haven a good ability to resolve these issues. Along with the studying of the intelligence technology, CBD has show its ability on these problem solving. Case-based reasoning (Case-Base reasoning, CBR) is a form of artificial intelligence from machine imitation to machine thinking[2-3].

The characteristics of grab product design are took account in the paper. Three-dimensional design and case-based reasoning technology are integrated in the grab bucket design field. The procedure of grab bucket design based on case-based reasoning is put forward in the paper. The design system establishes the 3-D grab case library and explore intelligent reasoning module. And achieve case-modified technology through SolidWorks and its secondary development. At last, a set of three-dimensional grab buckets design system is developed, that it makes grab intelligence design come true.

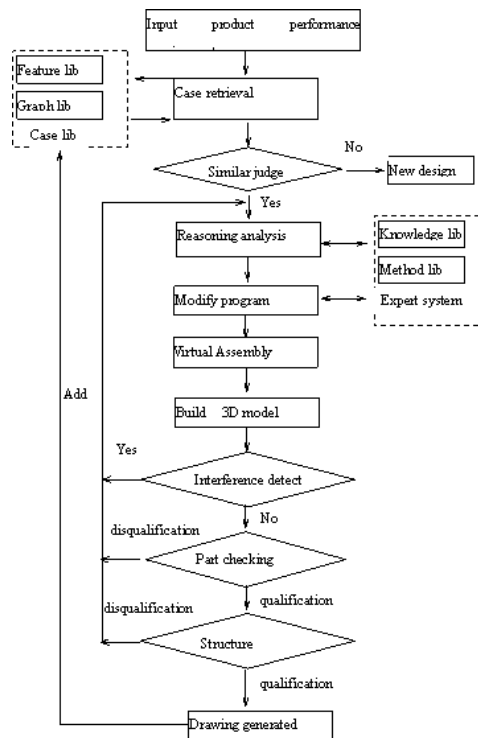
## **2 The Principal of Grab Design Based on Case Reasoning**

Because the foundation of CBR is that similar problems have similar solutions, the case-based design method is very close to the actual design process[4]. Faced to new design requirements, the system first select the case which is most close to design requirements from the past design cases library ,and then simulate to get design program which meet current requirements. The results case also can be modified again as a reference case that means the system has a self-learning ability. The advantages are: (1) No need to build the Rule or Model, but only collect the past cases to establish the CBR system; (2) Only need determine the related case characters. CBR system's case can be improved and enlarged during the using, as long as some examples are added in the system; (3) No need to reasoning from the beginning, only through a completed program which can generate the solution quick; (4) Easy to maintain. The increasing new cases

not only achieve the purpose of the study, but also reflect the customer demand character.

### 2.1 Design Workflow of Grab Design Based on CBR

Design workflow is shown as Fig.1. Designer input the parameter of grab first. then the system search the cases library through the key words and find out a number of similar cases and identify and select the most similar one as design reference .the user can get the guidance information to modify the case and establish the three-dimensional geometric model for the product through Human-Computer Interface after a series of steps such as virtual assembly model, kinematic analysis, interference checking, structural analysis, mechanical steps Finally, to generate two-dimensional drawings, at the same time, new product design is completed as a new three-dimensional cases which is stored in the cases library.



**Fig.1** Design flow of grab based on CBR

So that the grab intelligence design depend on the following key technologies: case expression retrieval cases modify case modification.

## 2.2 Case Expression

Because the number of cases and the degree of perfection of case base is the cornerstone of using CBR technology for compute-aided design. The establishment of case library should take the content of the case, the expression of the case and the organization of the case base etc. into consideration. It is Considered that the software SolidWorks has the functions of three-dimensional solid modeling, so that the software and its secondary development are used to the established geometric model can display three-dimensional appearance of entities in actual time[5]. Through the operation of the model the Entitle shapes modification of the model can be concisely completed and the same times. The physical changes slice product model, interference detects, motion simulate, finite elements analyze and so on can be concisely completed.

In view of the characteristics of grab, in order to facilitate search and matching cases, the paper put forward the method to define cases that the cases =cases three-dimensional graphic + case feature the data. Feature data refers to the factors that has a decisive influence on the product design, and can be extracted from the cases. The following is workflow. At first, the three-dimensional graphic of the cases are Set up in SolidWorks, then feature data of the cases are input into the cases library. In practical applications, regarding to different storage requirements of case's three-dimensional graphic library and feature data, different storage management functions are established in system respectively so that they can be integrate into the same interface to be operated. So that a cases consist of a set of three-dimensional graphics include the related sub-components hierarchy and a number of feature date of the case. The method makes the case query and retrieval more easier. Fig.2 shows the three-dimensional graphics, the structure and the expression of feature data in the design system respectively.

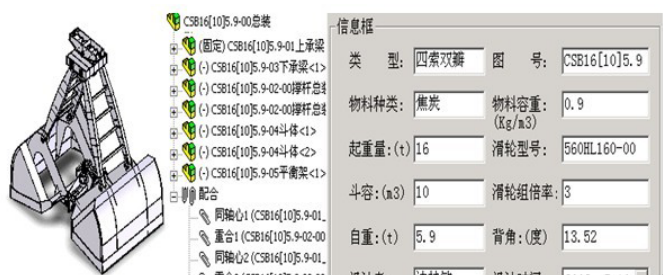


Fig.2 Case expression of grab

In order to make the model more practical, both hands of modeling methods and modeling sequence should be take into; On the one hand, it should be easily modified ,that means the main size of upon -bearing beam , under-bearing beam,

stay bar, bucket body can be stretched and reduced in the corresponding parts through changing the numerical size, and they are easily be matched each other also ); On the other hand, it is easy to establish model, and the model's level and structure coincide with the actual as far as possible. The system use the software SolidWorks, through top-down design methods to establish the model of grab's every part.

Case features are summarized from the case. The description of the case feature is the core of case representation. In the system, the case features are classified three types to be expressed according to different case objects.

1. Every complete set of grab product is a case object. The type of grab as one of case feature will be placed as the first important. In general, there are several types of grab: double-cables two-jaw grab, four-cable double-jaw grab, four-cable grab and four cables multiple jaws and so on. There are also several Special type grab such as hydraulic grab .and then features such as lifting capacity, Material characteristics and work Occasions will be took into account as the design requirements.

- 2 .The main part of grab such as upon -bearing beam, under-bearing beam, stay bar, bucket body also are deal as cases .the feature are expressed according to the range of lifting capacity, shaping feature, mating dimension.

3. The case feature of grab accessory such as pin is geometrical dimensions and processing technology. These features are input into product lib as database. Then the features will be modified by the product data management module and matched with the corresponding three-dimensional drawings .so that the corresponding three-dimensional drawings will be easily got through the feature database retrieval.

### *2.3 Case Retrieval*

The key to case-based reasoning achieved successfully is the case retrieval and matching .the function of the case retrieval and matching is that the most similar cases will be retrieved and used as the template of new design program. To cases which be retrieved, there are two requirements: 1) The cases should be less as possible. 2) The cases are most similar with new product. so that the retrieval algorithm is the core of cases retrieval. At present there are three kind of retrieval algorithm: Nearest Neighbor Method, induction indexing method, knowledge inducting method. Because the feature of grab can be classed according to grab parameter such as dimension, type of grab. The system uses a knowledge-guided strategy and the recent adjacent strategy. The Nearest Neighbor Method and the knowledge inducting method are used in the system .those grab parameter are define as feature key word and are given weight value .after calculating case similarity according to the weight, the most similarity case is selected and modified.

The following equation is similarity formula

$$sim(l, k) = 1 - \sqrt{\sum_{i=1}^n W_i \times \left( \frac{f_{ki} - f_{li}}{f_{li}} \right)^2}$$

Where *sim* means the similarity between objective design and the case, the more value of *sim* is large, the more similarity is close.  $f_{li}$  means design requirement feature item  $l$  includes attribute variable  $i$ .  $f_{ki}$  means the case feature item  $k$  includes attribute variable  $i$ . If  $f_{ki}$  and  $f_{li}$  is same, then  $f_{ki} - f_{li}$  value is 0, otherwise is 1).  $W_i$  is weight of the attribute variable  $i$ . For example, when the case is searched, considering the design requirement and the using condition for the grab, its feature array is (the grab type, lifting capacity, material, bucket cubage), the weight array is (0.4, 0.2, 0.3, 0.1).

#### 2.4 The Case Modification Base the Knowledge

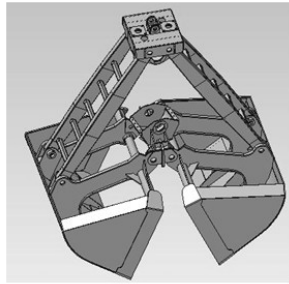
It is a key problem to propose the advice about the modification through case reasoning. After the system concluded the experts' design experience on grab, it establishes knowledge base. The knowledge base has concluded the main parts' design experience and data on different types of grabs, modify suggest on overall geometric parameters and the related reasoning calculate formula. If there is a difference between the case base is the grab capacity when a new grab is designed, you can propose the suggestion that modify the grab's width in a certain range firstly according to the ratio between the two grab capacity in the case base and then the modified modules are called to the grab three-dimensional model can be modified.

Because the application of the interface with SolidWorks and the top down design theory, the function can be applied that the grab three-dimensional model could automatically update as the parameter changes. Top-down design means the ability to design the relevant sub-components in the assembly environment, not only the relevance between the size parameters, but also realize the automatic and total relevance between the geometry appearances and parts. The user can design some other parts on the case that the assembly layout diagram is already, and make sure that the assembly layout diagram and the parts' size are totally automatic relevance, so to make the system's modified modules in three-dimensional model more convenient. As long as the key sizes are modified on the matching position, the relevant parts can be automatically modified and updated.

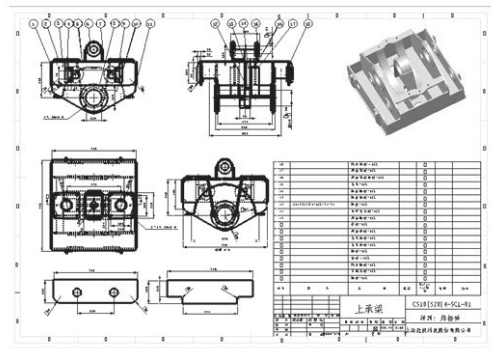
### 3 Application

To design a double-cable double-jaw grab, whose load capacity is 12t, grab material is sand, bucket capacity is  $1.6t/m^3$ , After retrieval the similar grab

bucket case from the three dimensional case library. In the case library, one which loads capacity is 10t, grab material is sand, bucket capacity is  $6m^3$  can be got. Considering the difference with the objective product, keeping the same bucket area, the bucket wide is modified from 2.05m to 2.46m, and then it can satisfy the capacity requirement. The new capacity is  $7.2m^3$ . After the accordingly adjustment for other components, the 12t three dimensional model and drawing can be got shown as Fig.3 and Fig.4 respectively.



**Fig.3** Grab model



**Fig.4** Grab part drawing

#### 4 Conclusion

The intelligent design process of the grab based on the CBR and three-dimensional entity's model technology is introduced in this paper. The basic structure of implementation, the expressions of cases and their retrieval method are also described. An intelligent design system is developed using SolidWorks and its secondary development. The application of the system has shortened the design cycle and improved the design efficiency. At present improving the knowledge

library is still in progress.

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