DESIGN TECHNOLOGY FOR INJECTION MOLD PARTING SURFACE BASED ON CASES AND KNOWLEDGE

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Abstract: On the basis of the comprehensive analysis about the automatic generation of the injection mold parting surface, the parting surface design method which introduces knowledge and case-based reasoning (CBR) into the computer-aided design is described by combining with the actual characteristic in injection mold design, and the design process of case-based reasoning method is also given. A case library including the information of parting surface is built with the index of main shape features. The automatic design of the mold parting surface is realized combined with the forward-reasoning method and the similarity solution procedure. The rule knowledge library is also founded including the knowledge, principles and experiences for parting surface design. An example is used to show the validity of the method, and the quality and the efficiency of the mold design are improved.

Key words: Injection mold Parting surface design Case-based reasoning (CBR) Similarity solution

0 INTRODUCTION

Being one of the important steps in injection mold design, the choice of parting surface has an directly effect on the general frame design, mold making cost, the parting surface machining and the quality of the final plastic parts[1]. So the rational choosing of the parting surface is the precondition of a successful injection mold design and the basis of realizing injection molding part automatic and sophisticated design. In recent years, research work on the parting surface and mold components automatically generation is one of the hotspots and difficulties in the injection molding CAD field, and many researchers around the world have done remarkable works about this issue. But those prior works tend to express the geometry shape and its position relations of parting surface all-around by constructing some numerical models based on the essential analysis of the plastic part's shape[2~5]. Due to the diversity and structure complexity of plastic parts, those methods have some kinds of shortcomings in practice.

With much experience and little theory for molding design, the parting surface design method which introduces knowledge and case-based reasoning (CBR) into the computer-aided design is presented by combining with the design process of injection molding design, so that the molding parts can be generated automatically. Knowledge and case-based reasoning means applying similarity judgment procedure and analogism to handle a new design task by constructing knowledge library and case library and respective reasoning rule on the basis of combining the knowledge and rule of parting surface design and the successful design cases and the successful experience of mold engineers organically[6], thus the new design not only fits the principle of mold parting surface but also includes the successful experience of those former cases. As a result, this approach is more convenient, quick and practical effective compared to analysis and solving the parting surface design by constructing numerical model. Further more the description of parting surface design experiences are easily expressed by the cases rather than the abstract design rules and expressions. So the knowledge and case-based reasoning parting surface design method is very suitable for mold engineer's thought fashion and manner.

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1 FRAMEWORK OF KNOWLEDGE AND CASE-BASED REASONING PARTING SURFACE AUTOMATIC DESIGN

The general idea of knowledge and case-based reasoning parting surface design is to found a case library using successful parting surface designs in term of molded parts' types and geometric character. The main shape features of molded part are indexes of this library. After searching the similar case with the part's main shape feature from the case library, the parting surface can be generated by judging from the similarity principle and the given reasoning strategy. At the same time, the correlative knowledge and principles of parting surface design and the designer's experiences can be summarized into knowledge library, which can be queried and consulted by designers as the assistant information of parting surface design. The case component of the method is used for the reasoning design, while the knowledge one for the guidance of designer's rational selection of parting surface.

The knowledge and case-based reasoning parting surface design mainly consists of the following: ① Constructing knowledge library. Aiming at the practice of injection molding design, a knowledge library of parting surface design rules is founded through concluding and integrating the related knowledge and rules of parting surface design and the designers' experiences. ② Constructing case library of parting surface position. A case library of parting surface position is constructed based on the types of molded parts and the previous successful design cases, which consists of the description of cases and the structure of case library. The key of describing the position of parting surface is to sort and organize the shape features of case models and determine the corresponding position of parting surface according to the variant shape of molded parts. Because the parting surface position is mainly determined by the part's shape feature, the organization of case library should be propitious to the case searching in design process. ③ Identification of molded part's shape feature. The shape features of original part should be identified before determining the position of parting surface. Therefore, the main shape features index need to be founded aiming at the type of molded part structure. Thus the seamless joint between modeling molded part and design module of mold parting surface can be realized. As a result, the inherited characteristic of system is also improved. ④ System reasoning and searching model. Searching and matching the similar shape

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feature of part model from the parting surface position cases is the primary task of the parting surface position case's searching course. Hence building the shape feature indexed model is the core to realize exact case reasoning and quick searching. ⑤ Automatic generation of parting surface. After performing design marching and adjusting about the selected parting surface position case which is similar to the shape feature of molded part, the needed mold parting surface can be generated automatically. ⑥ Storage of cases. The abundant case library of parting surface position is the important foundation to improve the design quality of mold parting surface and reasoning efficiency. The system provides storage judgment and selection based on classification by case features about the finally result of each new design task.

The flowchart of knowledge and case-based reasoning parting surface designing is shown in Fig.1.

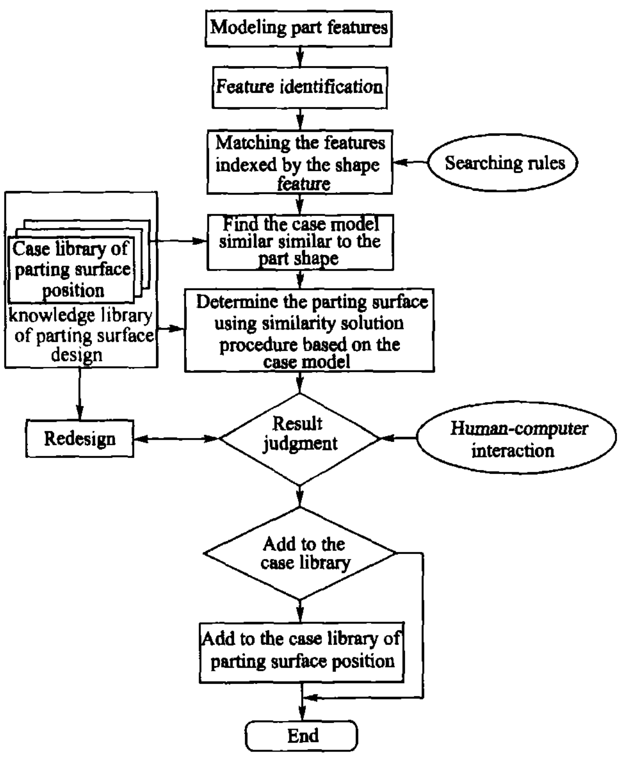

Fig.1　Flow chart of knowledge and case-based reasoning parting surface design

2　BUILDING OF KNOWLEDGE LIBRARY AND CASE LIBRARY

The knowledge library is the important resource that can assist designer to select rational parting surface position. The organization and description of knowledge in the library should fit for the practical mold design process and can be easily queried and consulted by designers. Therefore, the common used knowledge and principles in parting surface design and the designers' successful experiences were concluded and integrated. Some pieces of design rules knowledge, which form the knowledge library of parting surface design, were established and were identified by simple sentences. All of the design rules in library were described and expressed in detail by figure and letter. And the clue is also given in "recommended" and "not recommended" ways in the figure component of design rules, which can help the designers make the rational selection based on particular design case.

Fig.2 shows the parting surface position description given by the system after choosing one of the design rules.

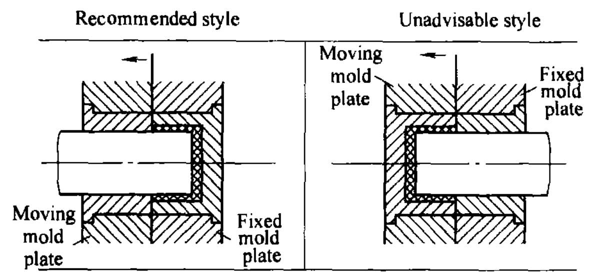

Fig.2　Demonstration of the knowledge library of parting surface design

The parting surface design mainly has relation to the main shape feature of molded part, and the identification of the main shape feature also plays a leading role in case searching. In this regard, the structure of case library should be organized according to the shape feature of part, and the hierarchical feature tree of molded part should be constructed, by which the part cases can be classified stored. Classifying the shape features of parts by their different characters, the common factors of part model can be extracted as the parent node. The child node can inherit all of attributes from the parent node, and contain more features than the parent one. As far as a single case is concerned, along with the inherited relation going through layer by layer, the number of feature attributes will increase. The feature attributes are more apt to describing concretely and by instance, and the complex degree of their relations is also increased. This classified approach can help to search the case library indexed by shape features and to solve the molded part with complex shape.

3　CASE DESCRIPTIONS AND SEARCHING

3.1　Case descriptions

The case description is the foundation to perform a knowledge-based reasoning, which turns to describe an existed successful design case as the data information that can be identified and processed by computer. The content and the descriptive ways have relation with the quality and efficiency of solving similar questions.

The case description may be expressed in the following mode, case of the molded part = the index information + position information of parting surface, where the index information is the shape feature of the part. Namely the shape feature of part as an index can search the similar case with the main shape feature, and the respective parting surface position is also given in this case. Thus the cases in parting surface position case library are some typical part shape and the corresponding parting surface position on the part model. The numerical description is

$$\text{case}(F, S) = \text{case}((f_1, f_2, \cdots, f_n), (s_1, s_2, \cdots, s_m))$$

where $F = (f_1, f_2, \cdots, f_n)$, f_i is the child shape feature in the injection molding case, $i = 1, 2, \cdots, n$, n is the number of child features in the case, $S = (s_1, s_2, \cdots, s_m)$, s_j is the solving scheme, i.e. the parting surface position. $j = 1, 2, \cdots, m$, m is the number of available parting surface position of one case model.

A hierarchical case library, which is shown in Fig.3, can be formed according to the number of the shape features in cases. And the next layer contains one more shape feature than the former one. It develops the shape information of case model on the basis of inheriting the former layer's shape features. Fig.4 shows the organizing scheme of complex cases. The scheme is consistent with the model process of molded part, thus it is convenient to performing case searching indexed by the shape feature.

3.2　Hierarchical searching based on the product rule

Case searching is an important component in reasoning mechanism. The essential of searching is the process of searching and matching. So the process of constructing inference mechan-

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ism is also the process of constructing the searching strategies and matching the similarities. The strategies have a great effect on the reasoning efficiency and the result. The purpose of the searching of the parting surface position case is to search the case which has the similar main shape feature with the plastic model. Thus the method is proposed on the basis of product rule according to the organizational structure of case library. The hierarchical searching means that the case library is searched in turn from the head layer to the end in the searching procedure, but which embranchment would be followed should be judged from the product rule.

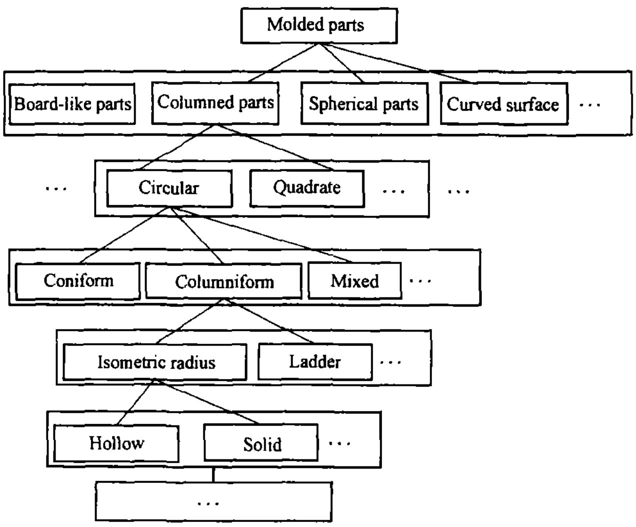

Fig.3 Organization structure of the parting surface position case library

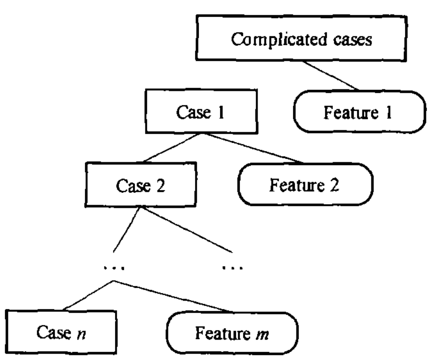

Fig.4 Organization structure of the complicated case

Fig.5 shows a type of ladder like molded parts with the ladder hole feature, which can be obtained by performing Boolean subtraction between two ladder shaft features, and a filleted corner as the assistant feature. The reasoning searching process is, firstly performing the first judgment, if feature 1 is the ladder shaft, then the case 1 with ladder shaft is obtained; then performing the second judgment, if the feature 2 with ladder shaft performs Boolean subtraction with case 2, and the position of its center line is at the same location with the former ones, then the ladder shaft case with ladder hole feature is obtained.

Applying this reasoning method can acquire high efficiency, because searching along one embranchment need not traverse all of case in the library. If the reasoning rules and cases are mature, the similar case with the shape feature of the molded part can be quickly obtained by applying hierarchical searching method based on the product rule. Furthermore, during the process of case-based parting surface automatic design, the case model need not resemble the part model entirely. It only needs that their main shape features are similar and the parting surface positions relative to one of main shape features of the two models are similar. The similarity solution model of parting surface automatic generating is proposed here.

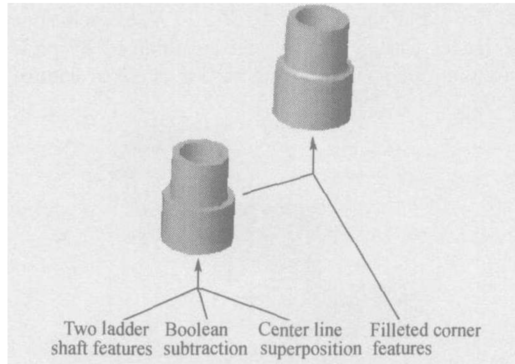

Fig.5 Forward-reasoning based on the product rule

4 SIMILARITY SOLUTION MODEL OF PARTING SURFACE

The parting surface of a case has the special position relation relative to a certain feature. And these relations represent always on a certain surface, a certain section or passing through a certain point of the feature etc. These position relations can be expressed as a 2D vector, that is

$$\boldsymbol{P} = \boldsymbol{X}(p,\ \boldsymbol{n})$$

where $\boldsymbol{P}$——Special position relation
$\boldsymbol{X}$——Vector symbol
p——Point of the feature which the parting surface passes
$\boldsymbol{n}$——Normal vector of parting surface

In other words, the parting surface is represented by a normal vector $\boldsymbol{n}$ and a special point p of the feature. For each parting surface of a case model, vector $\boldsymbol{X}$ is unchangeable. As far as a board-like part case model is concerned, if the parting surface is determined on the top face, then point p is the center point of this face, and $\boldsymbol{n}$ is the normal vector.

Firstly, find the position relation $\boldsymbol{P}$ of the parting surface relative to the case model, and then substitute the position relation into the part model to determine its parting surface position. The solving process can be expressed by the following expression

$$\{(S_{\mathrm{p}}(\boldsymbol{P})f_i) \subset C_{\mathrm{m}}\} \backsim \{(S_{\mathrm{p}}(\boldsymbol{P})f_i) \subset P_{\mathrm{m}}\}$$

where S_{p}——Parting surface
C_{m}——Case model
P_{m}——Part model
f_i, f_j——Feature located in C_{m} and P_{m} respectively

The left item represents the particular position of parting surface relative to a certain feature in the case model, while the right one represents this relation in the part model. Using their similarity we can determine the parting surface of part model. According to the complexity of the structure of the molded parts, the parting surface design may include several aspects as follows.

(1) The parting surface is plane. For those parts whose main feature face is plane, one can find directly point p and vector $\boldsymbol{n}$. Substituting them into the vector expression $\boldsymbol{X}(p,\ \boldsymbol{n})$, the parting surface position of the part mold can be determined. For the part shown in Fig.6, the top face is selected as the parting surface according to the cases in the library. Thus point p is the top face center point of the cubical part model, while $\boldsymbol{n}$ is the normal vector of this surface, and these two values can be found from the feature data, so the position of parting surface can be solved conveniently.

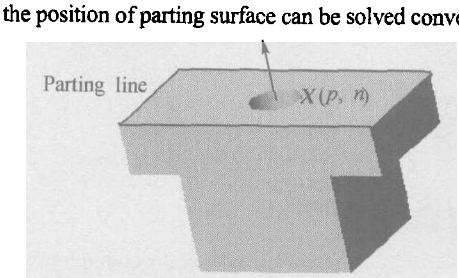

Fig. 6 Plane parting surface

(2) Ladder parting surface. The ladder parting face feature is commonly used in some molded parts. For the part shown in Fig.7,

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one need firstly find the vectors $X_1, X_2, \cdots, X_5$ of each ladder face, then the ladder parting surface can be obtained by performing Boolean union operation with the parting surfaces controlled by these vectors.

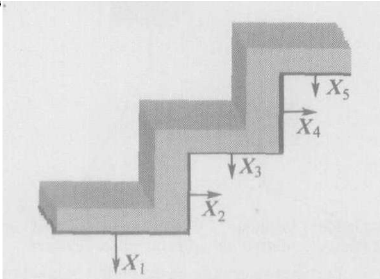

Fig.7 Ladder parting surface

(3) The parting surface is curved face. The solving process is complicated when the parting face is curved face. Take the part shown in Fig.8 as an example, the key feature parameters, such as the radius arc, the position of center line and its distribution, should be found according to the shape of the curved face. Then the solving model can be constructed. After substituting these parameters into the solving model, the parting line can be generated, and then the parting surface also can be obtained. If the parting surface is free-form surface, the solving model will be more complicated.

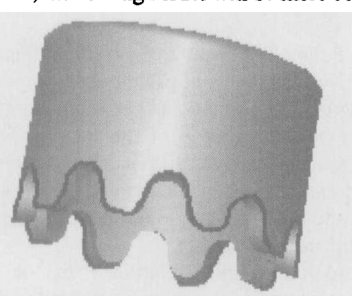
Fig.8 Curved parting surface

(4) Molded parts with complicated structure. The more complicated part model is the one that its similar case does not exist in the case library of parting surface position, and the case model resulted from the reasoning procedure also has a significant difference. This kind of case model should be solved directly at this time, for the general structure of the part is complicated, but the position of parting line may be similar.

Take the part shown in Fig.9 as an example, which consists of several structure factors, there is not the similar case in the case library. But its parting face also can be designed using the case shown in Fig.6, and the top face of the part would be chosen as the parting surface because their positions of parting surface are similar. If the similarity solution procedure does not work, the human-computer interaction will be chosen to determine the parting surface and the result will be stored, thus the case library of the parting surface position will be enriched.

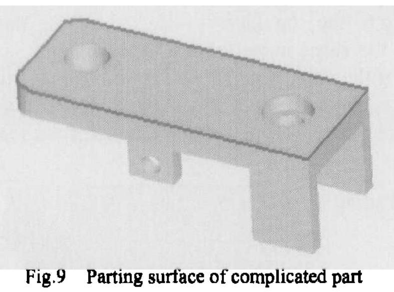
Fig.9 Parting surface of complicated part

5 DESIGN EXAMPLE

Our algorithm has been realized by programming with Visual C++ on the platform of AutoCAD 2000. ObjectARX serves as the developing toolkit because of its great efficiency. Fig.7 is used as the test part model, and the result of the determination of parting surface is shown in the figure. It is a kind of typical ladder parting surface. In the process of the parting surface selecting, the knowledge library, the cases library, and the forward-reasoning method are used. The similarity solution method and Boolean unite operation among the child parting surfaces are used to generate the final parting surface. Fig.10 is the 2D illustration of parting surface of this part model.

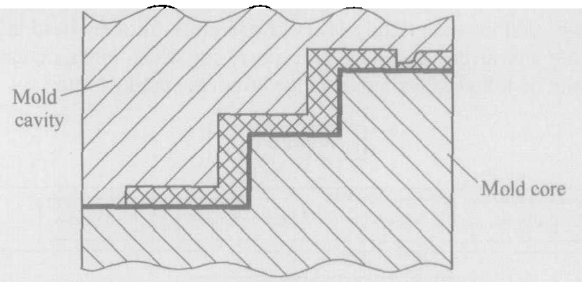

Fig.10 Final parting surface of the test part model

6 CONCLUSIONS

The knowledge and case-based reasoning design of mold parting surface is to reason the similar case with the original part indexed by the shape feature of the part and to determine the position of the mold parting surface employing the similarity solution method. This approach has high design efficiency and reliability on the basis of the abundant knowledge library and case library. It also has several characteristics as follows:

(1) The hierarchical case library of parting surface position is constructed based on the number of the features in the case, which makes the searching more convenient.

(2) Indexed by the shape feature, a hierarchical searching method is employed based on the product rule. It has high efficiency and can quickly reason out the case model which main shape feature is similar to the molded part.

(3) Using the similarity of the shape features between the case model and the part model, the similarity solution model of parting surface is founded, which can determine the position of the mold parting surface quickly and exactly. As a result, the quality and the efficiency of the mold design are improved.

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