A NEW METHOD TO AUTOMATICALLY DETERMINE PARTING LINE IN INJECTION MOLD DESIGN

SHAO Jian*, LU Zhen†, WEN Heping†

* College of Mechanical Engineering, Hangzhou Dianzi University, Hangzhou, 310018, China
† Zhejiang University City College, Hangzhou, 310015, China

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Abstract

A new method was proposed to automatically determine parting line for molded part which includes undercut features and free form surfaces in the product model. The brief procedure included: 1) simplifying the product model by recognizing the undercut features and transforming the product solid model into the discrete surface model using the finite element method; 2) determining visibility of mesh based on an angle between normal vector of mesh and parting direction, and decomposing complex surface into single surfaces; 3) merging transitional surfaces into visible/invisible surface group based on merge rules and determining parting line by searching the largest edge loop of these two surface groups. Results from demonstration cases show that parting line can be easily determined using this method and efficiency of injection mold design is greatly improved.

1 Introduction

Mold cavity and core are important working parts of mold which directly affect product molding. For a majority of molded parts, design of mold base, gate, runner, and cooling channel are not sensitive to details in shape and structure of product. Therefore, design scheme can be copied from one to another without any changes when the shape and structure of product are similar. However, even a small change in the shape and structure of product will affect the design scheme of mold cavity and core.

Design process of mold cavity and core for a molded part includes three related tasks namely, i.e. determining parting direction, parting line and parting surface. The determination of parting line plays an important role which affects not only parting surface generation but also mold structure and cost. Parting line is easy to be determined for some regular product and hard for some irregular products. In the general mold cavity design process, to determine parting line greatly lies on experience of the mold designer. Although this design method depending on designer's experience also has its advantages, the automatic determination of parting line is still the main content of this research field.

2 Literature review

There are some studies which have been done in this research field. Ravi proposed nine criteria[1] for computer-aided parting line and parting surface design, and an approach[2] for determining parting line by extruding the projected silhouette curves along parting direction and finding the intersected curves of extruded body and part body. Ganter[3] proposed an algorithm on computer-aided parting line design for cast pattern production, which a planar parting line is obtained by sectioning the molded part. Tan[4] proposed a method of generating parting line by triangulating the surfaces of product and classifying the surfaces into visible, invisible and degenerate faces. Weinstein[5] divided the surfaces of product into convex and concave regions to determine parting line and Wong[6] determined parting line by slicing the 3D CAD model of product. Nee[7] divided the surfaces of product into three groups according to their orientation to the parting direction and determined parting line by the largest edge-loop of these surface groups. Zhou[8] improved the Nee's approach and considered the effect of undercut features on the determination of parting line. Meanwhile, the optimization factors were introduced to evaluate the candidate parting lines.

Although these researches presented different kinds of methods for automatic determination of parting line, they are only suitable for the simple product model and will get the unreasonable parting line when the product model is complex which include free form surfaces and undercut features. In this paper, we presented an improved approach for this problem by combining the advantages of all these above methods. In our approach, the first step is to simplify the product model by suppressing the undercut features. After simplified, the product model will be transformed into the discrete surface model using the finite element method. Then the visibility of meshes will be determined based on an angle between normal vector of mesh and parting direction, and the complex surface will be separated into single surfaces. Finally, the parting line will be determined by adjusting all transitional surfaces into visible or invisible surface group and searching the largest edge-loop of these two surface groups.

3 Basic concepts

3. 1 The visibility of surface

The surfaces of product model include plane, conic surface and free form surface. Figure 1 shows these three types of surface, i.e. (a) plane; (b) conic surface; (c) free form surface, where $\vec{P}_D$ is parting direction and $\vec{L}_i$ is the normal vector of surface F_i. Determining the visibility is easy for the plane because the normal vector is exclusive. But it is hard for the conic or free form surface because the normal vector is not exclusive. For the conic or free form surfaces, the entire surface is visible, invisible or hybrid type of visible, invisible and transitional. The visibility of conic or free form surface can be determined as follow expressions[9], i.e. (1) if $\vec{P}_D \cdot \vec{L}_i > 0$, then the surface is visible, (2) if $\vec{P}_D \cdot \vec{L}_i < 0$, then the surface is invisible, (3) if $\vec{P}_D \cdot \vec{L}_i$ can not be determined, then the surface is hybrid type of visible, invisible and transitional.

3. 2 Single and complex surfaces

All surfaces of product can be transformed into 2D meshes by the finite element method. Three types of mesh are defined as (a) visible mesh, (b) invisible mesh, and (c) transitional mesh, where $\vec{P}_D$ is the parting direction and $\vec{L}_{ij}$ is the normal vector of mesh f_{ij}. The visibility of mesh is determined by these follow expressions, i.e. (1) if $\vec{P}_D \cdot \vec{L}_{ij} > 0$, f_{ij} is visible mesh, (2) if $\vec{P}_D \cdot \vec{L}_{ij} < 0$, f_{ij} is invisible mesh, and (3) if $\vec{P}_D \cdot \vec{L}_{ij} = 0$, f_{ij} is transitional mesh. Two types of surface are defined including single surface and complex surface. In the single surface, all meshes are the only one type of visible, invisible or transitional. But in the complex surface, all meshes are hybrid types of visible, invisible and/or transitional. The diagram of these two types of surface are showed in Figure 2, where, (a) represents the single surface whose all meshes are visible mesh, (b) represents the single surface whose all meshes are invisible mesh, and (c) represents the complex surface whose meshes are the hybrid types of visible, invisible and transitional. Symbols of "+" indicates that the mesh is visible, symbols of "—" indicates that the mesh is invisible, and symbols of "0" indicates that the mesh is transitional.

4 The process of determining parting line

4.1 Simplifying the product model

Because the existence of undercut feature will affect on the automatic determination of parting line, the first step to determine parting line is to recognize the undercut feature. The graph-based method is applied in the undercut feature recognition process[10]. The Figure 3 shows the sub-graph of these three typical undercut features, i.e. (a) concave, (b) convex, (c) through. The concave type has one undercut feature attachment face n_1 and all edges in the cut-set A_c are convex edge. The convex type has also one undercut feature attachment face n_1, but all edges in the cut-set A_c are concave edges. The through type has two undercut feature attachment face n_1, n_8 and all edges in the cut-set A_c are convex edges. In the recognition process, the first step is to express the product model with extended face attribute adjacency graph (EFAAG). Then the undercut features can be recognized by matching sub-graph of undercut features with the EFAAG of product model. When all sub-graphs of undercut features are recognized, the EFAAG of product model will be reconstructed to simplify the product model.

4.2 Transforming the product model

After simplified, the product model will be transformed into the discrete surface model using the finite element method. Whatever the plane, conic or free form surface in the product model can be represented by 2D surface meshes. The transforming process is showed as Figure 4. The product model can be described as $\Omega = \{F_i\}(i = 1,2,\cdots,M)$, where Ω represents the product model; F_i is each surface of model; and M is surface number. After the transformation, each surface F_i can be expressed by a series of meshes namely $F_i = \{f_{ij}\}(i = 1,2,\cdots,m; j = 1,2,\cdots,n)$, where m is mesh number in the row and n is mesh number in the column. The triangular or quadrangular mesh is often applied in the transformation process. Although the number of mesh is determined by experience, there are some principles to be complied with. For example, the number of mesh in the surface should be in accordance with the curvature of surface. The bigger curvature the surface has, the larger number of the mesh it has.

4.3 Separating the complex surface

In general, parting line is the largest edge loop in response to a certain parting direction and is composed of silhouette curves in the surface. For a single surface, the silhouette curve is always at the edge of surface. But the silhouette curve of complex surface is not at the edge of surface and generally hard to be determined. In order to separate the complex surface into single surfaces, a certain plane perpendicular to parting direction will be chosen as the projecting plane. The complex surface will be projected into this plane and formed a 2D shape. Then the silhouette curve can be determined by extruding the curve of this 2D shape along parting direction and finding the intersected curve of extruded surface and complex surface. The process of separating complex surface is expressed in Figure 5, where, $\vec{P}_D$ represents parting direction, A represents the projecting plane, S_+ and S_- represent the single surfaces after separated.

4.4 Determining the parting line

The parting line is the largest edge-loop of visible or invisible surface group in the product. Because the existence of transitional surfaces will affect on the automatic determination of parting line, it should be adjusted into visible or invisible surface group. The adjustment rules are listed as follow.

(1) If the largest edge-loop of transitional surface is

surrounding by the largest edge loop of visible surface group, then the transitional surface will be adjusted into visible group. It can be expressed as,

$$\forall f_3^i \in G_3,\ \text{if}\ \ S(f_3^i) \subset L(G_1),\ \text{then}\ \ f_3^i \to G_1$$

(2) If the largest edge-loop of transitional surface is surrounding by the largest edge loop of invisible surface group, then the transitional surface will be adjusted into invisible group. It can be expressed as,

$$\forall f_3^i \subset G_3,\ \text{if}\ \ S(f_3^i) \subset L(G_2),\ \text{then}\ \ f_3^i \to G_2$$

Where, G_1 represents the visible surface group, G_2 represents the invisible surface group, G_3 represents the transitional surface group, $f_3^i(i=1,\cdots,n)$ represents the i surface in G_3, $S(f_3^i)$ represents the largest edge loop of f_3^i, $L(G_1)$ represents the largest edge loop of visible surface group, $L(G_2)$ represents the largest edge loop of invisible surface group. Suppose that P_L represents the parting line, G_3' represents the transitional surface group adjusted into G_1, G_3' represents the transitional surface group adjusted into G_2, then the parting line can be determined by the expression as,

$$P_L = (G_1 - G_3') \cap (G_2 + \overline{G_3'})$$

5 Case study

The approach presented in this paper is applied in a mold cavity design system. The mold cavity design system is built on the Unigraphic CAD/CAE/CAM software. The development tools are VC++ and UG/OPEN. UG/OPEN is a strong development tool kit of Unigraphic which includes UG/OPEN API, UG/OPEN GRIP and etc. The interface of this software is displayed in the Figure 6.

The approach presented in this paper was demonstrated by a molded part as Fig 7. Fig 7(a) shows the product model. In Fig 7(b), the product model is simplified by excluding the undercut features. Fig 7(c) shows the discrete surface model. In this example, the quadrangular mesh is applied and the size of element is 8. Because there is no complex surface in this product, the visibility of each surface can be determined by the visibility of mesh in the surface. When all transitional surfaces are adjusted into visible or invisible surface group, the parting line can be easily determined by searching the largest edge-loop of visible or invisible surface group. Fig 7(d) shows the parting line of this molded part.

6 Conclusion

An improved approach to automatically determine parting line in injection mold design was presented. There are some advantages of this approach, including 1) the graph-based method is applied to recognize the undercut features in the product, and the product model will be simplified before determination of parting line; 2) the product model is transformed into discrete surface model and the visibility of surface will be determined by analyzing the visibility of 2D surface meshes; 3) the silhouette curve of complex surface is located by extruding the projected silhouette curves along parting direction and used to separate the complex surface into single surfaces; 4) the new adjustment rules is presented to adjust all transitional surfaces into visible or invisible surface group and the parting line is determined by searching the largest edge-loop of these two surface groups. The result of a demonstration case shows that the parting line of complex product which include undercut features and free form surfaces can be determined correctly.

Acknowledgements

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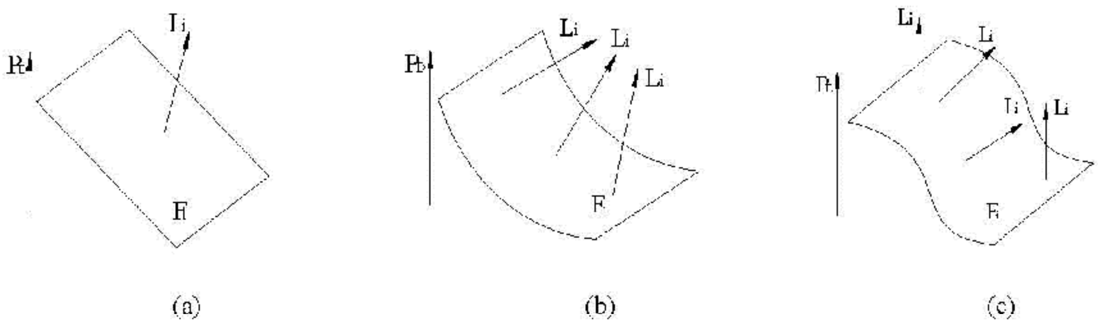

Fig.1: diagram of three types of surface.

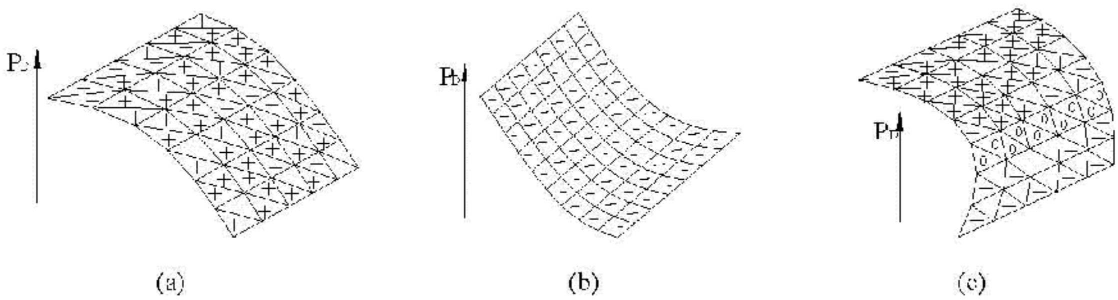

Fig.2: diagram of single and complex surfaces.

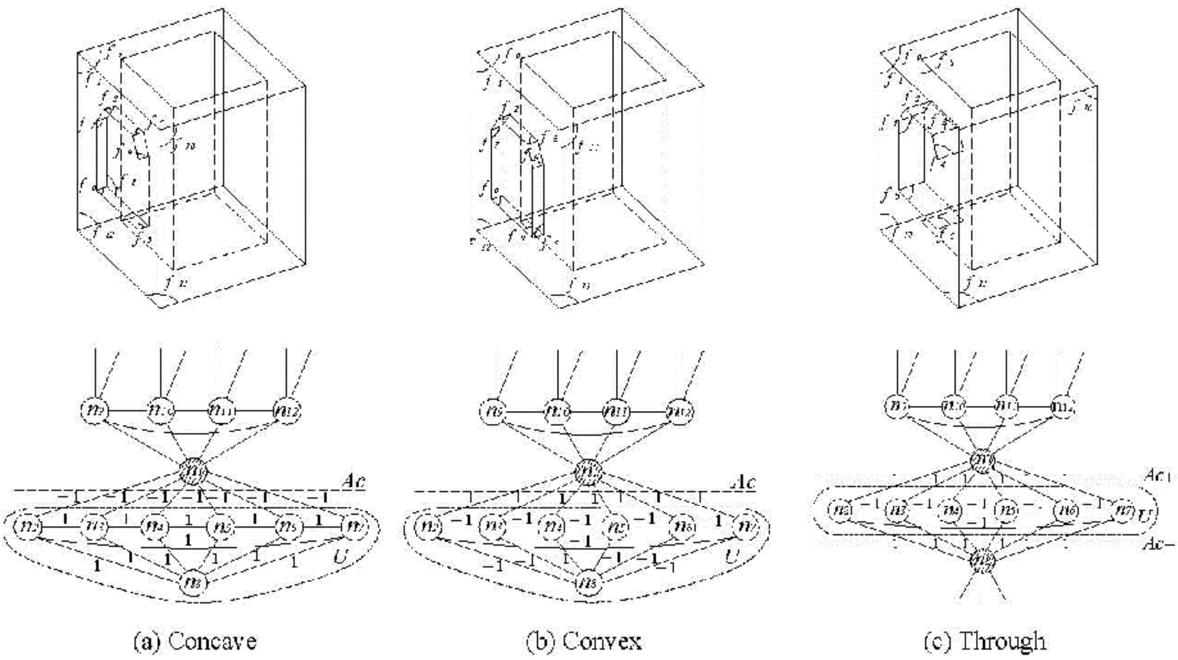

Fig.3: diagram of three types of undercut feature and sub-graph.

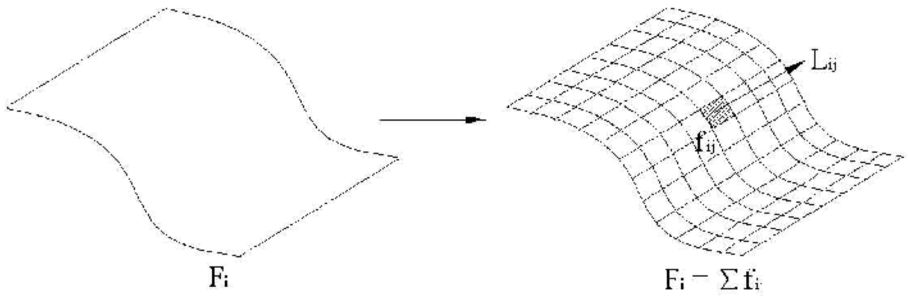

Fig.4: diagram of transforming process.

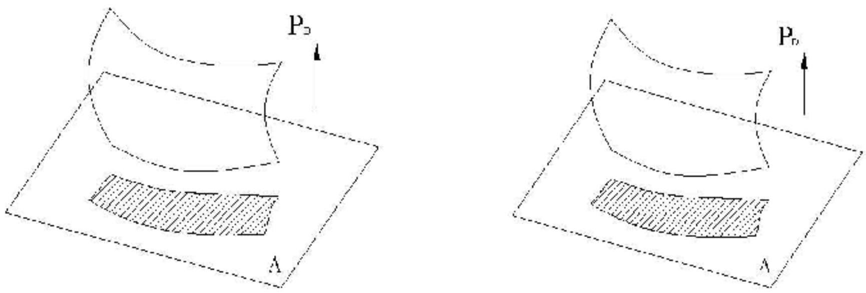

Fig.5: diagram of separating the complex surface.

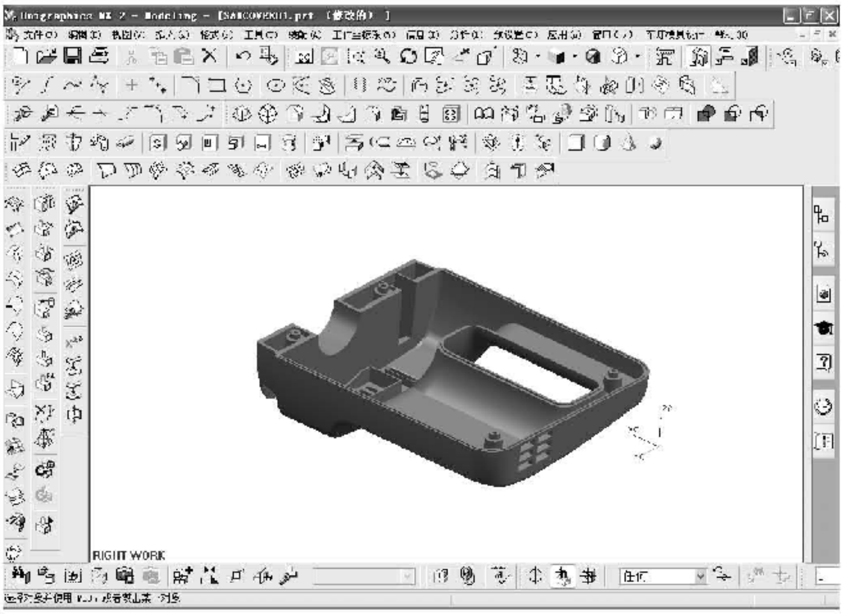

Fig.6: interface of Unigraphic software.

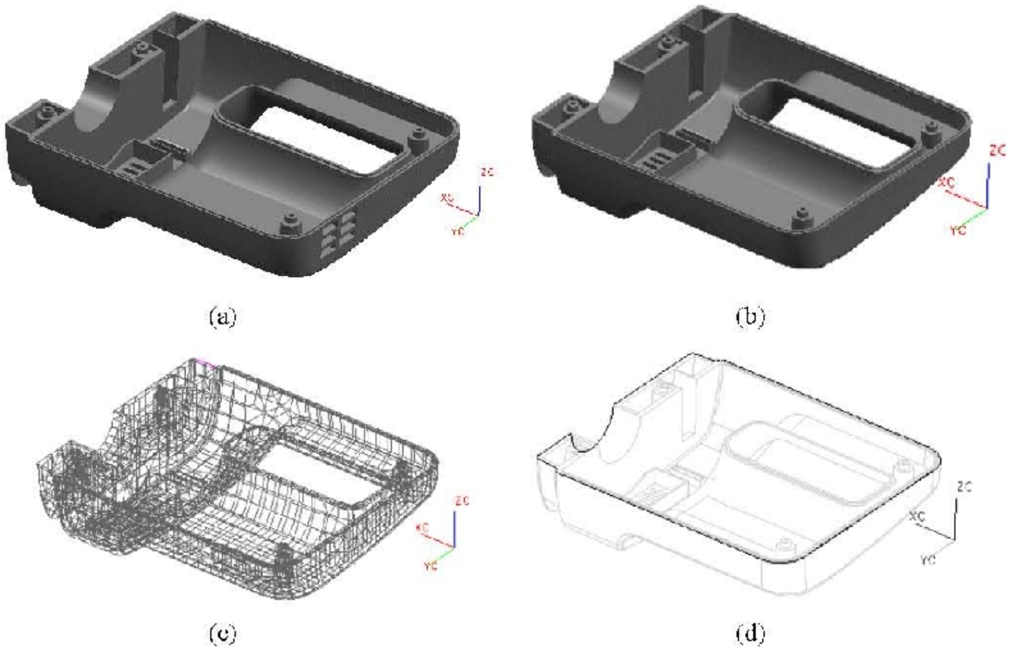

Fig.7: determining the parting line for a molded part.

多自由曲面产品注塑模具分型线的自动确定

邵 健[1]，吕震[2]，柯映林[1]

（1. 浙江大学现代制造工程研究所，浙江 杭州 310027

2. 浙江大学城市学院，浙江 杭州 310015

【关键词】：模具，分型线，特征识别，有限元

【摘 要】：为有效地确定多自由曲面产品模具分型线问题，提出了一种将特征识别技术和有限元方法相结合的模具分型线确定方法。在该方法中，首先，提出了基于图的特征识别方法来对产品中的侧凹特征进行识别，并在识别的基础上对产品模型进行简化；然后，提出了基于有限元的离散方法，对简化的产品模型的所有组成面进行离散，并根据网格面的可视性来判别组成面的可视性；最后，将产品中的所有组成面分成可视面组、不可视面组和退化面组，并通过抽取可视面组或不可视面组的最大边环来确定模具的分型线。研究实践表明，通过该方法可以有效地解决多自由曲面产品模具分型线的确定问题，提高模具设计的效率。

中图分类号：T P391 文献标识码：A

1 引言

模具型腔的设计过程一般包括脱模方向的选择、分型线的确定和分型面的生成 3 个步骤。其中分型线的确定是非常重要的一个环节，不但影响到后续分型面的生成，还对整个模具的结构和成本有很大的影响。对于一些规则产品，模具分型线的确定是比较简单的，但对于一些包含自由曲面的产品，模具的分型线往往难以确定。在一般的模具型腔设计过程中，分型线往往由模具工程师通过一些经验的方式来判断确定。但通过这种方式来确定模具的分型线，设计效率不高，同时由于设计者的疏忽也有可能造成分型线确定失误的问题。因此探索分型线的自动生成技术是模具设计自动化的一个重要研究内容。

2 相关研究

对分型线的确定，有 3 类典型的方法：(1) 文献[2] 等提出的通过拉伸零件最大投影轮廓线的方法来确定产品的分型线；(2) 文献[3] 等提出的通过对塑件模型切片来生成分型线的方法；(3) 文献[4]等提出的通过对注塑件表面进行分组并抽取最大边环来自动生成分型线的方法。在这 3 种方法中，都没有考虑产品中的侧凹特征对模具分型线的影响，对于多自由曲面产品，无法有效地确定模具的分型线。文献[5]等虽在文献[4] 的基础上进行了改进，但对于多自由曲面产品，也无法有效地确定模具的分型线。

为此，本文提出了一种将特征识别技术和有限元方法相结合的模具分型线确定方法，不但考虑了侧凹特征对模具分型线确定的影响，提出了基于图的特征识别方法对产品中的侧凹特征进行识别，还提出了基于有限元方法对包含自由曲面的产品模型的表面进行离散，以解决自由曲面在模具分型线的确定过程中可能产生的歧义，加快模具分型线的自动确定过程。与前述的3类分型线确定方法相比，该方法的主要特点在于：1. 在确定模具分型线前，首先对产品中的侧凹特征应用提出的侧凹特征识别方法进行识别，并根据特征识别的结果简化产品模型，从而避免了侧凹特征对模具分型线的影响；2. 型简化后，应用有限元离散方法对产品模型的表面进行离散，并根据网格面的可视性来综合判断产品模型表面的可视性，消除自由曲面在判断面可视性时的不确定性。

3 基本概念

3.1 表面的可见性

产品，其表面则既包含平面，也包含自由曲面。对于平面来说，因为其法向惟一，所以一定为可视、不可视或过渡面中的一种。但对于曲面来说，由于其法向并不惟一，既有可能全为可视或不可视，也有可能部分可视、部分不可视。因此，要判断曲面的可视性，必须应用有限元方法。在有限元模型中，产品模型的表面往往离散为一些小的单元模型。由于这些单元的表面都为平面，可以方便地判断出这些单元的可视性。设 $\vec{P_D}$ 表示模具的脱模方向，$\vec{L_i}$ 表示面 F_i 的法向，则可根据如下规则来判断面的可视性：如果 $\vec{P_D} * \vec{L_i} > 0$，则 F_i 为可视面；如果 $\vec{P_D} * \vec{L_i} < 0$，则 F_i 为不可视面；如果 $\vec{P_D} * \vec{L_i} = 0$ 则 F_i 为过渡面。

3.2 单一表面和复杂表面

所有表面的产品可以转化为二维网格对各组成部分进行有限元分析。网格包含以下三种类型：(a)可见网眼(b)无形的网(c)过渡网格。设 $\vec{P_D}$ 表示模具的脱模方向，$\vec{L_{ij}}$ 表示面 F_i 的法向，则可根据如下规则来判断网格的可视性：如果 $\vec{P_D} * \vec{L_i} > 0$，则 F_i 为可视网格；如果 $\vec{P_D} * \vec{L_i} < 0$，则 F_i 为不可视网格；如果 $\vec{P_D} * \vec{L_i} = 0$，则 F_i 为过渡面。

一些简单的产品往往都由平面组成，但一些外形和结构复杂的产品，其表面则既包含平面，也包含自由曲面。对于平面来说，因为其法向惟一，所以一定为可视、不可视或过渡面中的一种。但对于曲面来说，由于其法向并不惟一，既有可能全为可视或不可视，也有可能部分可视、部分不可视。因此，要判断曲面的可视性，必须应用有限元方法。在有限元模型中，产品模型的表面往往离散为一些小的单元模型。由于这些单元的表面都为平面，可以方便地判断出这些单元的可视性。一般情况下 P_D 表示模具的脱模方向，L_{ij} 表示单元面 F_{ij} 的法向。如图2 所示，图2a 为可视表面，所有的单元面均为可视单元面；图2b 为不可视表面，所有的单元面均为不可视单元面；图2c 为可视、不可视同存表面，在其单元面中，既存在可视单元面，又存在不可视单元面和过渡单元面。其中"+"表示可视单元面，"-"表示不可视单元面，"0"表示过渡单元面。

4 确定分型面的过程

4.1 简化的产品模型

因为侧凹特征的存在会直接影响到模具分型线的正确确定。因此，在确定模具的分型线前，首先要对产品中的侧凹特征进行识别，并对产品模型进行简化。识别特征的方法较多[7]，本文提出了一种基于图的特征识别方法。在识别过程中，首先将产品模型用面属性邻接图(FaceAt tribute Adjacency Graph，FAAG)[8]的方式表示，然后通过在产品FAAG 中搜索侧凹特征子图的方式来识别侧凹特征。

图1 所示为3 种典型类型的侧凹特征的子图。图1a 为一凹类型的侧凹特征及其子图U，该侧凹特征只有一个特征生成面(侧凹特征附着的面) n1，在割集(将侧凹特征的子图从产品FAAG 图中分离出来的一组边) A c 中，所有的边都为凸边，在子图U中，所有的边都为凹边；图1b 为一凸类型的侧凹特征及其子图U，该侧凹特征也只有一个特征生成面n1，在割集Ac 中，所有的边都为凹边，在子图U 中,所有的边都为凸边；图1c 所示为一通孔类型的侧凹特征，该侧凹特征有两个特征生成面n1 ，n8 ，在割集Ac 中，所有的边都为凸边，

在子图U 中，所有的边都为凹边 °在子图匹配的过程中，如果对产品的FAAG 应用遍历方式进行搜索，则搜索的时间将会非常长 °因此，在实际的搜索过程中，总是先找到产品中所有的特征生成面然后再确定子图的割集，并利用割集将产品的FAAG 图分解为两部分，一部分为产品FAAG，一部分为侧凹特征FAAG °侧凹特征识别后，为了方便模具分型线的确定，还需要对产品模型进行简化，简化的过程即产品FAAG 重构的过程 °

4.2 产品模型转化

简化模型后,产品将会被转换成采用离散曲面模型,采用有限元分析方法 °无论怎样的平面,曲面或自由曲面产品模型可以表示为2维表面网格 ’转换过程如图4所示 °该产品模型可以描述为$\Omega = \{F_i\}(i = 1,2,M)$;其中Ω代表了产品的模型 ;F_i代表模型的每个表面 ;M代表表面的号码 ’这样一来 ’每一个外表面即可表示为

$F_i = \{f_{ij}\}(i = 1,2,\ldots,m; j = 1,2,\ldots,n)$;其中m表示横向的网格数量 ’n表示纵向的网格数量 °三角形或四边形网格是当前常用的转化过程 °虽然网格的数量是由经验确定的,有一些原则是可以照办 ’例如网格的数量的多少表面与表面的曲率有关 °网格的数量越大,其表面曲率越大 °

4.3 分离复杂表面

产品中可视 `不可视同存的表面，称为复合产品表面，而对于单一的可视面或不可视面，则称为单一产品表面 °在确定模具的分型线前，必须将复合产品表面分解为单一产品表面，从而在将这些产品表面归入可视或不可视面组时，就不会产生二义性 °在对复合产品表面进行分解前，首先要获取这些产品表面对应脱模方向的最大外轮廓线，以最大轮廓线为界，复合产品表面就可以分解为单一产品表面 °在分解过程中，首先要做1个垂直于产品脱模方向的平面为投影平面，并将产品表面投影到投影平面上 °投影后，首先找到产品表面在投影平面上的投影轮廓线，然后沿脱模方向拉伸投影轮廓线并与产品表面相交，则所确定的交线即为该产品表面的最大外轮廓线 °如图3 所示为复合产品表面的分解过程示意 °图中的P_D表示产品的脱模方向，Λ表示投影平面 °S_+ 和S_- 为经过分解后的单一产品表面,S_+ 表示可视表面，S_- 表示不可视表面 °

4.4分型线的确定

模具的分型线即为产品中可视面组和不可视面组的最大边环，因此，为了正确地确定模具的分型线，首先要将产品中所有过渡面调整到可视面组或不可视面组中去 °在调整过程中，首先要判断过渡面最大轮廓线与可视面组或不可视面组最大边环的关系 °

(1) 如果过渡面的最大轮廓线在可视面组的最大边环内，则将过渡面调整到可视面组中去，调整规则表述为

$\forall f_3^i \in G_3, \text{if} \, S(f_3^i) \subset L(G_1) \text{ then } f_3^i \rightarrow G_1$

(2) 如果过渡面的最大轮廓线在不可视面组的最大边环内，则将过渡面调整到不可视面组中去，调整规则表述为：$\forall f_3^i \in G_3, \text{if } S(f_3^i) \subset L(G_2) \text{ then } f_3^i \rightarrow G_2$

其中，G1 表示产品中的可视面组，G2 表示产品中的不可视面组，G3 表示产品中的过渡面组，$f_3^i(i = 1 \ldots n)$ 表示过渡面组G_3 中的第i个面I ’ $S(f_3^i)$表示f_3^i的最大轮廓,$L(G_1)$ 表示可视面组的最大边环,$L(G_2)$ 表示不可视面组的最大边环 °设过渡面组G3中调整到G [illegible] 中的面组为 [illegible]，调整到G [illegible] 中的面组为 [illegible]，则最后确定的模具

的分型线为$p_L=(G_1+G_3')\cap(G_2+\overline{G_3'})$ 。

5 实例研究

本文提出的多自由曲面产品模具分型线的确定方法已在注塑模具型腔设计制造系统中实现，系统的开发基于U G 平台，开发工具为VC+ + 和UG/Open，U G/ Open 是基于UG 平台的一组2 次开发工具，包括U G/ Open应用程序界面(A pplicat io nPro gramming Inter face，API)，UG/ Open Grip 等 °该开发工具可以使用户方便地对产品B- r ep 模型中的几何和拓扑信息进行操作，实现用户的自定义功能 °

图4 所示为某汽车车灯产品的产品模型 °在产品模型中，不但存在侧凹特征，同时模型表面也存在自由曲面，因此在确定零件的模具分型线前，首先要对产品模型中的侧凹特征进行识别并对产品模型进行简化 °因为确定的脱模方向为Z 轴方向，所以在产品模型中，实际的侧凹特征为产品侧壁的通风孔 °产品中另外的特征，由于其特征方向都与脱模方向一致，并不构成真正的侧凹特征 °图4b 所示为经过简化后的产品模型 °产品模型简化后，即可应用有限元方法对简化产品模型的表面进行离散 °本例中采用的网格为四边形网格，网格单位为8，离散后的产品模型如图4c 所示 °对所有的网格面确定其可视性，并由此来判断模型表面的可视性 °由于在该产品模型中并不存在复合产品表面，可以直接将所有的产品表面归入可视面组 `不可视面组和过渡面组中 °在将所有的过渡面通过调整规则调整到可视面组和不可视面组之后，即可确定模具的分型线 °图4d 所示为最终经系统自动确定的该测试产品的模具分型线 °

6 结束语

本文提出了一种将特征识别技术和有限元方法相结合的模具分型线确定方法，可以有效地确定多自由曲面产品的模型分型线的问题，从而缩短模具设计的周期，提高模具设计的效率 °通过对数十个多自由曲面产品的测试表明，系统自动确定的模具分型线与设计师依据经验判断确定的模具分型线的情况完全吻合 °目前，该方法已经应用于笔者所开
发的注塑模具型腔设计制造系统中，运行情况良好 °

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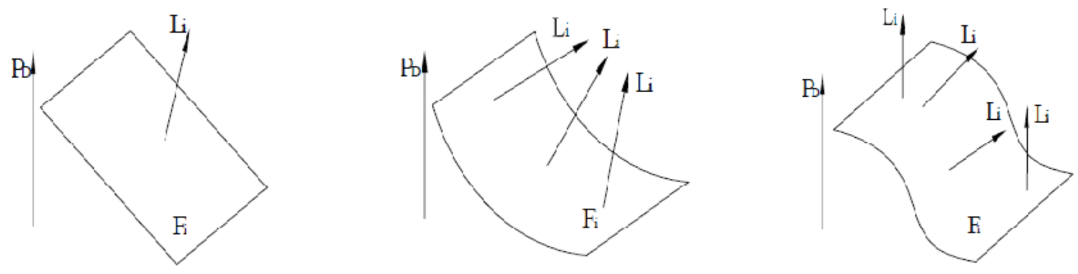
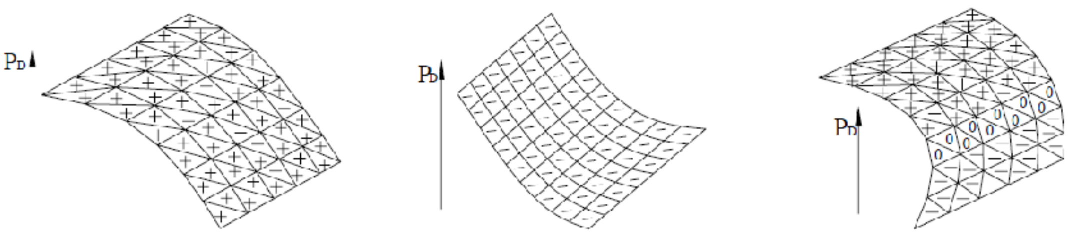


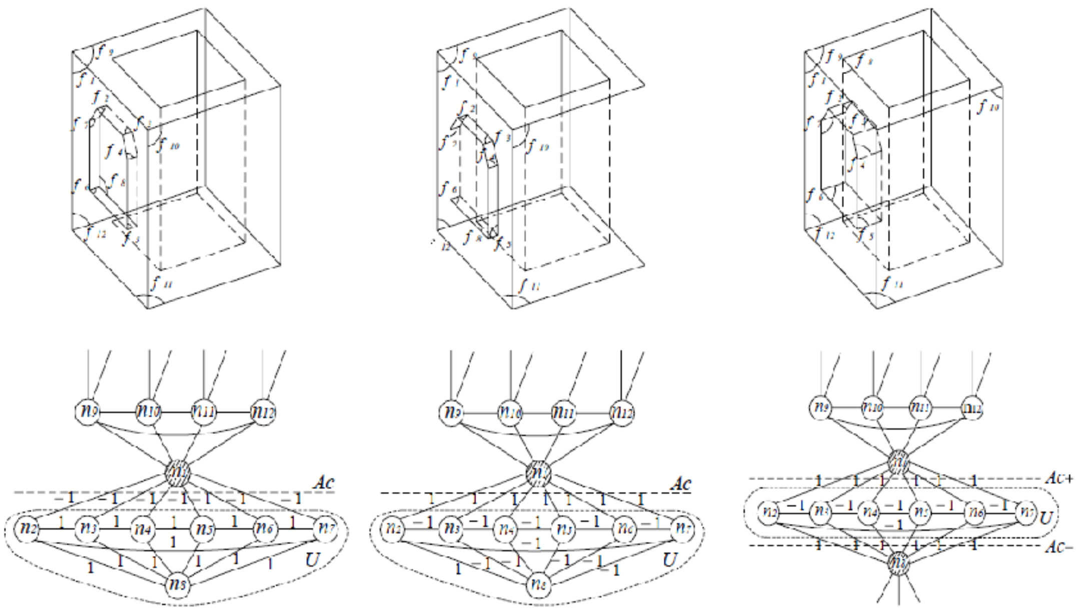
(a) (b) (c)

图1　三种类型表面



(a) (b) (c)

图2　单一表面及复杂表面



︵a︶凸　(b)凹　(c)穿透

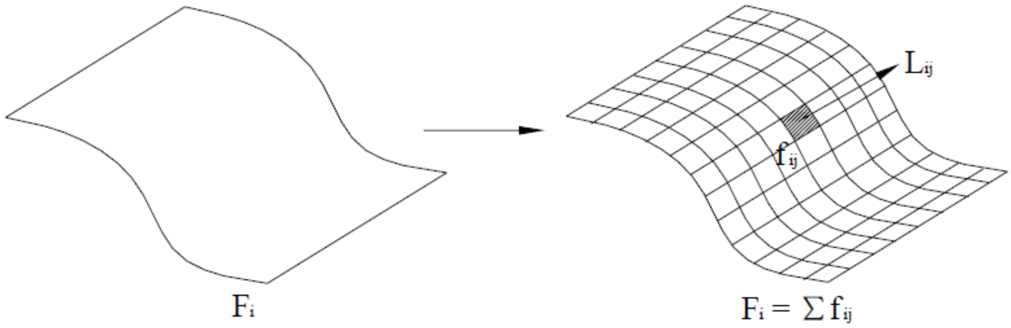


图4　转化的过程

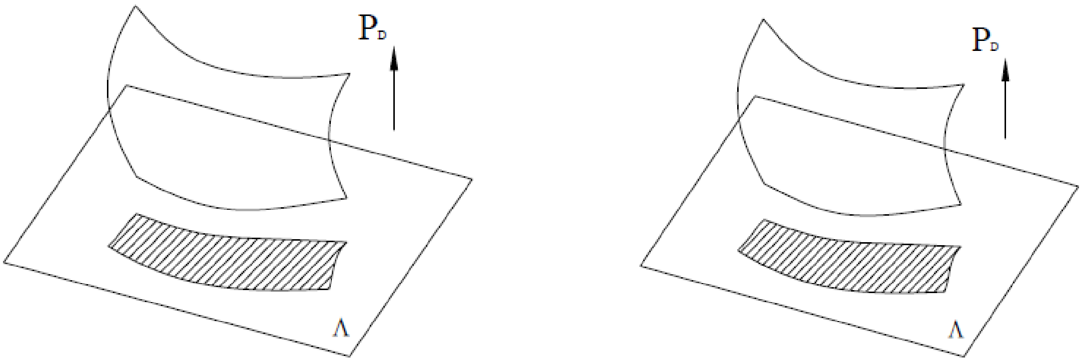


图5　复杂表面的拆分

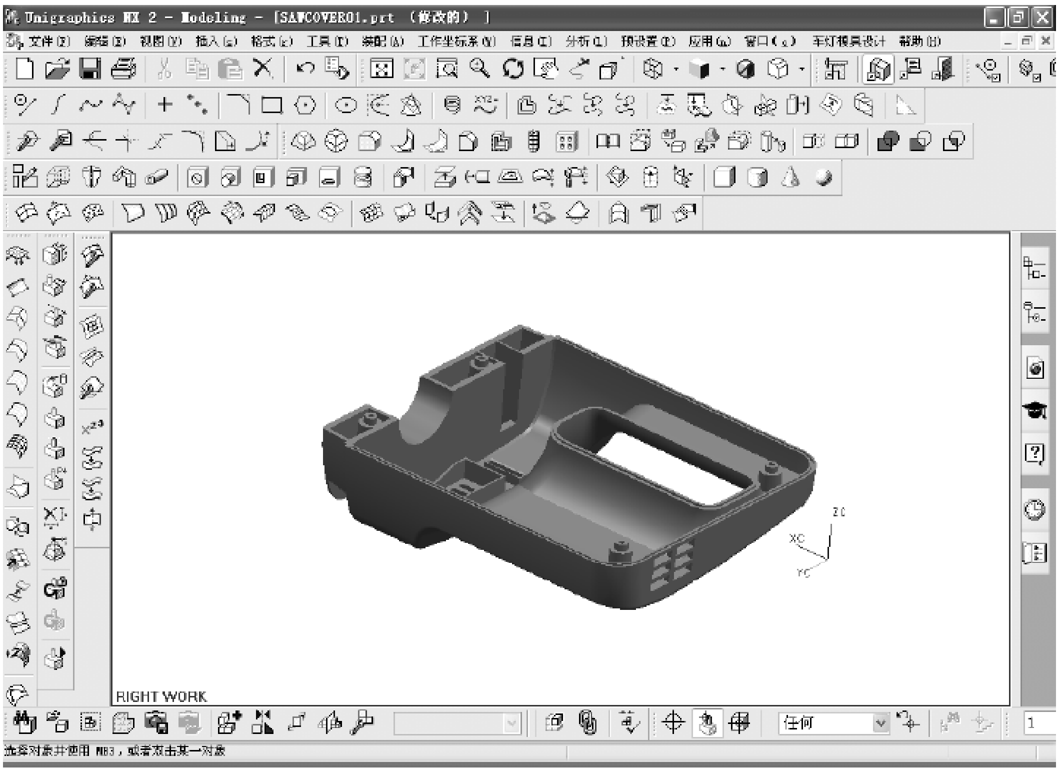


图6　UG软件的界面

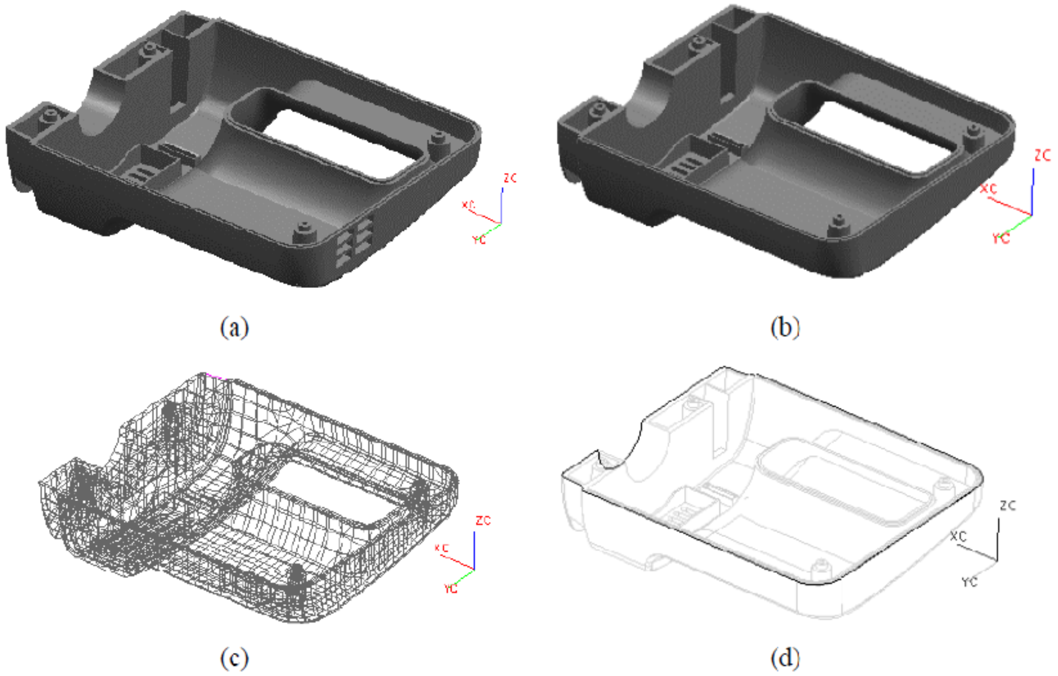


图7　一个塑造部分的分型线确定