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Research on the microstructure reconstruction algorithm of titanium alloy materials

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ABSTRACT
Titanium alloy is widely used in national defense, aviation and other fields with low density, corrosion resistance and high tensile strength, but there are also easy deformation, cost and efficiency problems in titanium alloy processing. In this paper, the microstructure of titanium alloy is studied, and an efficient computer reconstruction algorithm based on geometric feature extraction and visual simulation is proposed. Based on finite element simulation technology, the problem of machining deformation can be predicted and improved more accurately, which greatly improves the yield and reduces the cost.

KEYWORDS
Titanium alloy; Microstructure; Two-dimensional reconstruction; Program algorithm

1 Introduction

Titanium alloy is a new material that has developed rapidly in recent years, because it has excellent comprehensive properties such as low density, corrosion resistance, high tensile and compressive strength and high temperature stability, which has made it a key material in the fields of national defense and aerospace. However, it also has the problem of easy deformation in processing. In the case of comprehensive consideration of cost and efficiency, it is necessary to combine the microstructure characteristics of the material and the macro-geometric structure characteristics of the workpiece, based on the finite element simulation technology, for more accurate prediction, analysis and improvement. Therefore, in this paper, the computer reconstruction technology of titanium alloy microstructure is studied deeply and systematically, aiming at the problem of complex machining and easy deformation of titanium alloy whole structure.

There are few examples of two-dimensional microstructure reconstruction of titanium alloy materials at home and abroad. X. D. L developed visual simulation software ProDesign based on Voronoi algorithm. J. Power[1] et al. perfectly combined computer image processing technology with scanning electron microscopy to obtain the microstructure of the material.

2 Theory of two-dimensional reconstruction

2.1 Voronoi graph generation algorithm

1) Generation of random points: First delimit the rectangular area randomly. Then enter the number of random points n to be generated, and obtain the X and Y coordinates of these n points through the random number generator [2]. The X and Y coordinate values of the generated points are judged, the appropriate ones are left, and the inappropriate ones are deleted.

2) Delaunay Triangulation: Scan the coordinate values of all randomly generated points to determine whether all points are collinear. If they are collinear, vertical bisects between each two points are made after they are arranged in ascending order, then all the resulting vertical lines form a Voronoi plot of random points. Otherwise, randomly select a point from n points as the starting point, connect all points that can form a triangle with this point, after forming a triangle, draw its outer circle and find its radius, calculate the distance between the center of the outer circle and all points, if less than this radius, these three points will be rounded off, if the distance between all points and the center of the circle is greater than the radius of the outer circle, These three points are connected to form a triangle in the Delaunay triangulation.

3) Generate Voronoi diagram: Draw the middle vertical lines of all Delaunay triangle sides. For triangles that share the same side, the two ends of the middle vertical line are the center of the two outer circles; for triangles that do not share the same side, the middle vertical part of their sides is the center of the outer circle.

2.2 Principle of two-dimensional reconstruction

Two-dimensional reconstruction is the reproduction of two-dimensional microstructure of materials by computer. FIG. 1 is a scanning electron microscope used to photograph the microstructure of titanium alloy samples. When extracting the orientation diagram, the instrument will automatically output the synchronous data file of the orientation diagram, which only contains the grain information, but not the grain boundary information. Therefore, the basic data of two-dimensional reconstruction of titanium alloy microstructure can be read from the synchronous data file output by scanning electron microscope, which can greatly reduce the complexity of program writing and greatly save the workload.

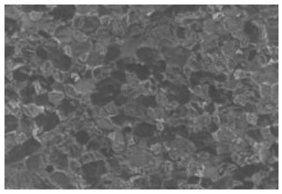


Fig.1 Image extracted by scanning electron microscope

3 Program Algorithm

The Main program Main() consists of several subroutines. The program mainly includes three parts: first, the pre-processing of data; Second, processing of grain boundary geometry data of titanium alloy grains; Third, visualization of the processed titanium alloy grain shape. The program uses a modular design, with three parts belonging to three different modules. In this program, the grain information in the microstructure of titanium alloy obtained by SEM images is processed by Deal() function. Then, the subprogram Draw() calls Select Stock Object() to select a brush from the database to visualize the grain geometry of the titanium alloy microstructure.

In this paper, the basic principle of the two-dimensional reconstruction program of titanium alloy microstructure is as follows: First, all the data obtained from the continuous slicing experiment are scanned to determine the data information of titanium alloy grains; Then, according to the principle that convex polygon represents grain shape, all titanium alloy grains judged as concave polygon are clipped to achieve convex polygon of concave polygon. Finally, all convex polygons representing titanium alloy grain shapes can be visualized to complete the two-dimensional reconstruction of titanium alloy microstructure.

4 Processing of grain boundary geometry data

The grain shape of titanium alloy is identified based on the graph storage data structure, that is, the concavity of grain shape is identified. The data structure uses Simpson area formula to calculate the concavity of polygon.

4.1 Storage data structure

The data structure stores data in a way that stores the information that constitutes the line segment of the polygon. Each polygon is bounded by a group or groups of line segments, each of which defines a simple polygon. The topological cohesion between polygons is formed in the form of left polygons and right polygons, the left polygon refers to the left polygon in the direction of the line segment from the start to the end, and the right polygon is called the right polygon. When scanning line segments, it is required that the same polygon area is the same side polygon that makes up the polygon line segment. In order to achieve this effect, for complex polygons with "holes", the direction of the line segment constituting the "hole" must be opposite to the direction of the outside line segment.

4.2 Simpson's area formula

According to the order of the polygon vertices clockwise or counterclockwise, the trapezoidal area of all sides of the polygon and the X or Y axis [3] is obtained in turn, and then its algebraic sum is obtained, which is the basic idea of Simpson's area calculation formula. Assuming that the polygon consists of n vertices, Simpson's area calculation formula is as follows:

$$S=\frac{1}{2}*\sum_{i=1}^{n}x_i(y_{i+1}-y_{i-1})\Big|_{y_{n+1}=y_1}^{y_0=y_n} \tag{1}$$

4.3 Concave and convex recognition algorithm

According to formula 1, the basic principle of judging the convexity of a polygon by Simpson's area formula can be obtained[4]. Regardless of the positivity of the direction of the polygon, the Simpson's area of the triangle formed by its vertex and the two vertices before and after it is the same as the Simpson's area symbol of the polygon, the vertex must be a convex point. Otherwise, the vertex must be concave.

5 Grain cutting

After recognizing the concavity of the polygon of grain shape, the grain of concave polygon needs to be transformed into the corresponding convex polygon grain. In this paper, the concave polygon grain is transformed according to the polygon clipping algorithm. It is improved on the basis of the Greiner-Hormann algorithm, and the new algorithm uses a single linear linked list data structure to represent all polygons, as shown in Figure 2.

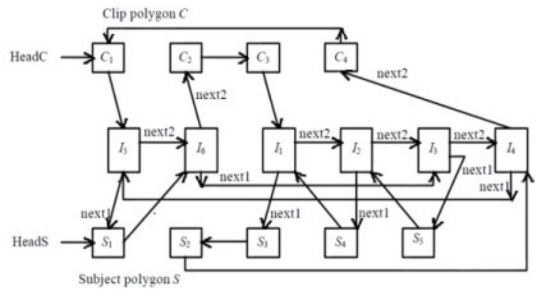


Fig.2 Improve the data structure of the algorithm

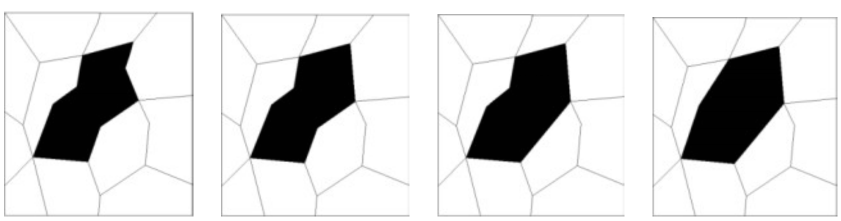
The algorithm is described as follows:

(1) Traverse all input data and scan out the first intersection point between the main polygon and the clipping polygon according to the data input order; Then judge whether the point is the entry point or the exit point, deduce the direction of the two polygons and insert the intersection information into the linear linked list; Finally, according to the input order, a unidirectional pointer is established for the same intersection point between the main polygon and the clipping polygon.

(2) Judging the concave points of polygons and calculating their intersection points in turn according to Simpson's area calculation formula, and then cutting the cut polygon according to the main polygon edge, and saving the new vertex information after cutting into the polygon chain list according to the input order.

(3) Scan all data of the two-polygon linked list, find the first intersection point, and then copy all vertices before this first intersection point to the inner table of the linked list; Then go to the corresponding position in the vertex table of the clipped polygon according to the intersection point position, and then scan the data information in the polygon linked list until the next intersection point, and then copy the vertex table information of the segment to the table in the linked list; The above process is repeated until all the information is scanned, and finally the new polygon after cropping is obtained.

Figure 3 is a schematic diagram of cutting through the algorithm, and the black part represents the result of polygonal multi-wheel cutting of titanium alloy grains.



(a) Grain pattern (b) First cut (c) Second cut (d) Third cut

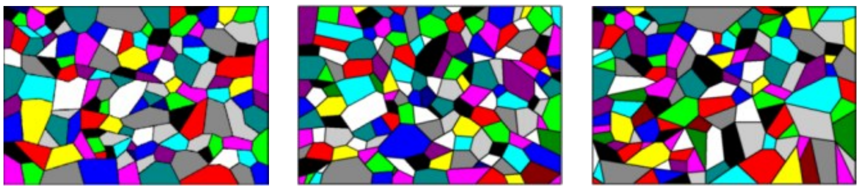
Fig.3 Grain cutting diagram

6 Grain shape visualization

After processing by the above method, convex polygons of titanium alloy grain shape are reconstructed in two dimensions. The Draw crystal() program called Select Stock Object() to select the brush from the inventory to complete the visualization of the titanium alloy grain shape. This program sets a color control variable color by calling 15 different color brush to control the color of the titanium alloy grain filling. The GrainV-isualization() subroutine is used to control the color of titanium alloy microstructure grains, which can effectively distinguish the adjacent titanium alloy grains.

7 Experimental Results

Through continuous slicing experiments of titanium alloy with the developed program, two-dimensional reconstruction of SEM images of titanium alloy microstructure is obtained, as shown in Figure 4. Different colors only better distinguish different grain boundaries and make the distinction between adjacent grains more obvious.



(a) the first layer (b) the second layer (c) the third layer

Fig.4 Two-dimensional reconfiguration of titanium alloy microstructure

It can be seen from Figure 4 that the titanium alloy grains after two-dimensional reconstruction of the titanium alloy microstructure are fully consistent with the images obtained from the titanium alloy continuous slicing experiment in Figure 1 in terms of shape, size and position, and the expected results have been achieved.

8 Conclusions

This paper presents an efficient computer reconstruction algorithm based on geometric feature extraction and visual simulation. Based on the experimental data of scanning electron microscope (SEM) of titanium alloy material, the visualization design of two-dimensional microstructure structure of titanium alloy material based on computer language was carried out on the basis of the separation and extraction of the geometric features of the grain profile. Finally, the computer reconstruction of the two-dimensional microstructure of titanium alloy material with multi-grain topology was realized, which improved the processing deformation problem.

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