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Compound scan mode developed from subarea and contour scan mode for selective laser sintering

Y. Shi*, W. Zhang*, Y. Cheng, S. Huang

State Key Laboratory of Plastic Forming Simulation and Die & Mould Technology, School of Material Science and Engineering, Huazhong University of Science and Technology, Wuhan-Hubei 430074, PR China

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Abstract

Scan mode is an important parameter for selective laser sintering (SLS) processing. The improved mode will optimize scan path and improve the precision, strength and fabrication efficiency of a SLS part. A compound scan mode, which combines subarea scan mode and contour scan mode, is proposed. The principle of its hatch (path-planning) algorithm and implementation are presented. To testify the effectiveness of this compound mode compared to that of subarea scan mode, it has been utilized for researches at a SLS machine developed at Huangzhong University of Science and Technique (HUST). The results from the researches indicate that the degree of precision of a SLS part with the compound scan mode is higher than that with subarea one. There is little difference in the tensile strength, flexural strength, shock strength and fabrication efficiency of a SLS part under the compound scan pattern and the subarea scan mode. Therefore, implementation of the compound scan mode is of importance to improve the precision of a SLS part.

Keywords: Selective laser sintering; Improved subarea scan mode; Compound scan mode; Fabrication precision

1. Introduction

Scan mode is one of the important parameters that affect the precision, strength and fabrication efficiency of a selective laser sintering (SLS) part. Therefore, it is very important to optimize scan mode.

Much study on scan mode has been done and many scan modes have been created, and they belong to parallel-line scan mode or broken-line scan mode.

1.1. Parallel-line scan mode

Parallel-line scan mode [1] is also called as type Z scan mode whose scanning paths are parallel to x- and y-axis. Its principle is similar to that of filled regions in computer graphics. Though its algorithm can be simply and easily implemented, it has disadvantages. Firstly, laser has to be continually turned off and on, which shortens its life. Moreover, for a part with holes, cavities have to be spanned frequently and it causes scanners run emptily. Secondly, for the scan direction in layers is the same and there exists shrinkage stress in the same direction, which causes the warp and distortion of a SLS part. Finally, a SLS part with parallel scan mode has anisotropy strength.

For subarea scan mode [2,3], scan lines are parallel lines. Every slice plane of three-dimensional (3D) CAD model is divided into smaller areas and then they are filled by parallel lines. Empty runs are less than those for parallel-line scan mode. Its algorithm is simple, so it is widely used in the SLS process, and it has the following disadvantages: First, some micro-ladders appear on a SLS part with this mode, which causes the precision dependent of the spot size of laser beam. What is more, there exists the warp and distortion of a SLS part with this mode. Especially, in a part with a larger slice plane, there appears great shrinkage stresses and even cracks along the scanning direction because of longer scanning lines.

*Corresponding authors. Tel.: +86 027 87557042; fax: +86 027 87548581.
E-mail addresses: shiyusheng@263.net (Y. Shi), zwxwen@163.com (W. Zhang).

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For emanative starlike scan mode and angled emanative starlike scan mode [4], slice planes are divided into two areas from the center, which are filled with scan lines parallel to x or y axis or at an angle of 45° to the axis from the center to outside. Compared to that with the two scan modes above, the SLS part with these two modes causes less warp and distortion to some extent, but they have disadvantages such as that of parallel-line scan mode.

1.2. Fold-line scan mode

For fractal scan mode [5] scan path has the features of local and whole comparability. When fractal dimensions are 2, the whole slice planes can be filled with fractal scan path. This scan mode overcomes the shortcomings of parallel-line scan mode and makes the temperature field more uniform, which reduces warp and distortion. But it has the following disadvantages: low scanning speed, laser scanners frequently accelerated and decelerated, a SLS part being getting fabricated with low precision, and frequent spanning of the cavities of the slice planes.

Scan paths are spiral lines for spiral scan mode [6]. Though it overcomes the shortcomings of type z scan mode, and shrinkage stresses can be reduced, the cavities have to be spanned frequently.

For contour equidistance path [7,8] no empty run appears which prolongs scanners' life. The frequent changing scan direction and shorter scanning lines disperse the shrinkage stresses and reduce warp and distortion. Its algorithm is complex and it needs more CPU time. Besides, the algorithm is not reliable and some unfilled regions appear, which affects the strength of the SLS part.

This algorithm of the scan path based on Voronoi map [9,10] is suitable for multi-connected domains in slice planes, and enhances the scan efficiency to some degree. But it has the same shortcomings as the contour equidistance path.

As for scan mode using Pythagorean hodograph as filling lines [11], the intersecting parts of slices are separated into some subareas by the Delaunay triangle, and then they are filled with Hilbert curves [12]. However, it is suitable only for regular parts, except the fabrication of parts with complex contour. Besides, there are also other similar slice filling modes presented by Wasser et al. [13], Tiller and Hanson [14], Ganesan and Fadel [15], Pham [16] and Takashi [17].

To overcome the shortcomings of the scan modes above, a compound scan mode combining subarea scan mode with contour scan mode is presented in this paper, and it has not been reported in the literature.

2. Subarea scan mode and contour scan mode

The compound scan mode, based on the subarea scan mode and cotour scan mode, is presented. Therefore, we firstly discuss these two scan modes before the compound one.

2.1. Subarea scan mode

A subarea scan mode is presented in Ref. [2] in order to improve quality of a SLS part. Strategies for it are as follows:

The first step is that the slice planes are divided into subareas without holes shown in Fig. 1.

The second one is that the slice planes are divided into subareas in terms of the number of intersecting points that the scan lines parallel to x or y-axis intersect with their contours. Fig. 1 is taken for an example. The scan lines within area 1 form two intersecting points with the contour. The number of intersecting points increases into four when they are within area 2. In the same way, the number in area 4 is six, the number in area 7 is eight, and the number in area 11 is six. So the whole slice area is subdivided into 16 subareas.

The third one is that subareas are scanned in the fixed order from top to bottom, and from left to right. For example, the scan order in Fig. 1 is: area 1→ area 2→ area 3→ area 4→ area 5→ area 6→ area 7⋯ ⋯.

Finally, these subareas are filled with parallel lines, but there is an α angle between two neighboring scan layers in order to reduce shrinkage stress along the same direction. Generally $\alpha = 90°$.

According to the above strategies, we can implement it by the following procedure:

Initially, intersecting points where (at which) the scan lines are intersecting with the contours of a slice plane are obtained, and in the order they can be stored in pairs, such as(P_0, P_1),(P_2, P_3), (P_4, P_5),$\cdots$,(P_{2n-1}, P_{2n}). If these scan lines are in a connected domain, it can be filled with lines consisting of point pairs. And those lines are called the filling lines.

Then the filling lines can be grouped. For the set$\{C_i, 1 < i < N\}$, the filling lines in the whole slice can be grouped into m groups from Eq. (1).

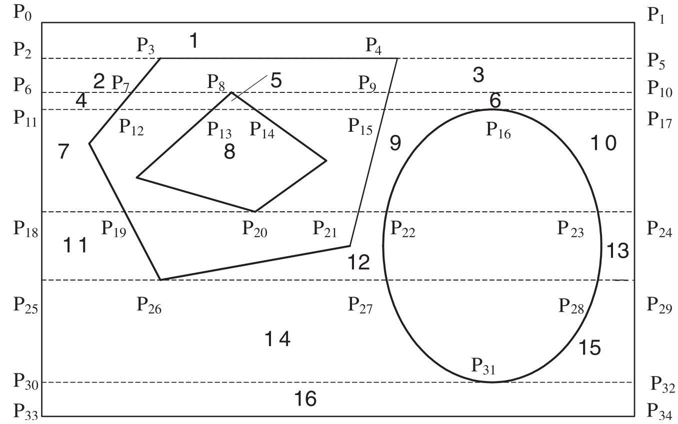

Fig. 1. Subarea scan mode.