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Research Article

ANALYSIS AND MONITORING METHODS OF TECHNOLOGICAL PREPARATION OF THE ADDITIVE PRODUCTION

LEV N. RABINSKIY, ANDREY V. RIPETSKIY, SERGEY V. ZELENOV AND EKATERINA L. KUZNETSOVA *

Moscow Aviation Institute (National Research University), 125993, 4 Volokolamskoe shosse, Moscow, Russian Federation

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ABSTRACT

The driver for this research is the consideration of actual processes in the additive production, then the geometry of model may contain various types of mistakes to which led various processes. In order to exploit the potential benefits of this emergent technology, new design, analysis and optimization methods are needed. This paper presents identification of similar mistakes by all available methods extremely important at technological preparation since finally any mistake in geometrical representation of model involves mistakes fiber representation. The results demonstrate that using the considered control devices at each stage of technological preparation it is possible to reveal mistakes to an exit to the press that will allow to save time and material.

INTRODUCTION

Preparation of the additive production – the complex technological process consisting of several stages: preparation of geometry, projection of sustentaculums, calculation of fiber representation, drawing up the operating teams.

At each stage, there is a work with various types of data presentation. So, geometry is transferred in a type of space grids, layers are presented in the form of perimeters, the operating teams in the form of a set of broken lines (Panesar, *et al.*, 2015). The program components of preparation are responsible for each stage of a data conversion. So, the slayser counts fiber representation, supports are based automatically or is automated, programs of filling of layers are responsible for training of the operating teams.

In approach of producers of an inventory preparation process for printing as a rule becomes simpler to the level of the novice user and it is represented in the form of prime operations: loaded model, correctly arranged in the camera, sent to the press. It certainly works at the prime, ideally prepared for the press models and an inventory of a consumer segment (Ripetskiy, *et al.*, 2016). In actual practice the geometry of model may contain errors of various types and an origin, and the choice of the technological modes, projection of supports on the production inventory demands experience and the technologist's intuition.

So, if to consider actual processes in the additive production, then the geometry of model may contain various types of mistakes to which led various processes and the main thing that for each type of mistakes there is the method of its identification.

MATERIALS AND METHODS

Mistakes in geometries and ways of their identification

This Not sewed sides result from triangulation errors at the level of CAD systems, owing to incorrect broadcast of formats or mistakes in topology did at its projection by the designer. Mistakes can be not visible at visual viewing, but lead to problems at creation of fiber representation (Fig. 1).

***Corresponding authors email: lareyna@mail.ru**

If the model is received by means of scanning, then the "holes" in surfaces arising at a triangulation of zones with a low density of the points (Beyne, 2006) arising owing to a shadowing or just mistakes when scanning is possible (Fig. 2).

Such mistakes will also bring in ruptures of contours at creation of fiber representation and finally to press artifacts.

The model may contain not any mistakes, but all the same to be unprintable (Anamova, *et al.*, 2016). For example, if the model is transferred by the assembly unit containing the internal objects concerning a surface, etc. Even if the slayser will not reveal any mistakes in geometry, we receive excess specification and owing to what time and resources for shortchanging of unnecessary surfaces increases, the operating teams become complicated, time for preparation increases (Fig. 3).

In actual life the technologist should deal not with the models which are ideally prepared for the press, and with actual geometry which already saved up in itself all mistakes which through folly or to ignorance of creators appeared on its course of life.

Fortunately, the majority of the considered mistakes can be revealed at a stage of loading of models and creation of fiber representation by methods of the linear algebra.

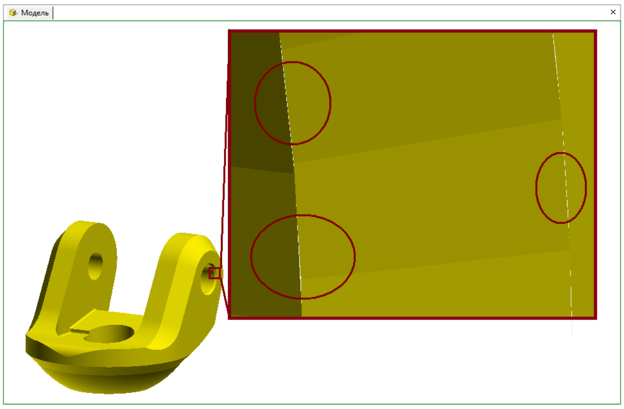

Fig. 1 Model with mistakes in the form of irregularly sewed surfaces.

Not sewed surfaces and "holes" in the planes can be revealed in the analysis of the triangles making grid. The concerning surfaces or the crossed surfaces come to light at a stage of calculation of fiber representation at drawing up closed paths of sections (MacDonald and Wicker, 2016).

Identification of similar mistakes by all available methods extremely important at technological preparation since finally any mistake in geometrical representation of model involves mistakes fiber representation, as a result of a mistake in the operating teams and finally is led to artifacts in a terminating product (Fig. 4).

Algorithms of calculation of fiber representation

In the majority of the modern slayer calculation of fiber representation happens through drawing up closed paths by results of the solution of a problem of searching of section of a triangle the plane in space.

Let the model be presented by a set of triangles.

Part = $\{ t_i \}$, $i = 1,\dots,n$

Then layer Layer(z_s), where z_s – height of a layer consists of a set of the contours set by the closed, not crossed broken lines.

Broken lines of a contour are gathered from pieces which are the solution of a problem of crossing of a triangle of model (t_i) with the equation of the intersecting plane.

$(x_0^{i,zs}, x_1^{i,zs})$ = Cross-section (t_i, plane(z_s)),

where plane (z_s) – the plane in space, perpendicular axes Z, and passing through a point z_s, can be presented by the equation $z = z_s$.

Then the set of pieces will be result of crossing of all model and the intersecting plane $z = z_s$:

Cross-section ($\{t_i\}$, plane (z_s)) = $\{line_j\}$, $j = 1,\dots,m$, $m<n$

Then a layer at the level z_s will consist of a set of the closed not crossed paths, such that

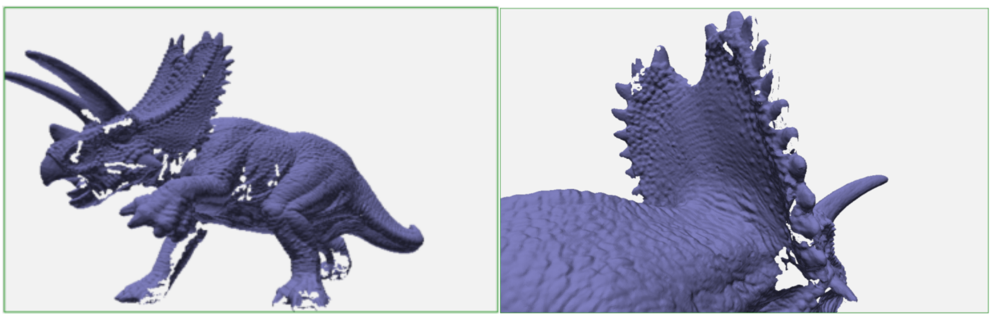

Fig. 2 Errors of a triangulation of the scanned model.

$Layer(z_s) = \{Contour_k\}$, $Contour_k = \{line_l\}$,

$Line_l \in Cross\text{-}section(\{t_i\}, plane(z_s))$

The errors of geometrical representation of model considered in the previous section at creation of fiber representation will lead to what cannot be constructed closed a contour from a set of lines $\{line_j\}$ and, therefore, the part of information which is contained in model will be lost at a stage of creation of fiber representation. It in turn will lead to distortion of geometry of a terminating detail at its manufacture by method of fiber synthesis.

RESULTS AND DISCUSSION

Analysis of fibre representation of model

One of the main features of the additive production is tiny linear dimensions of working elements and large volumes of data. All this complicates the analysis and monitoring on various sites of technological production. So, for example, the operator it is impossible to force to check all layers of model, for the purpose of check of a slaysing or to watch trajectories of driving of a working element the operating teams for the purpose of an assessment of filling of a layer. The quantitative indices of characteristics of layers can serve as a partial solution. For example, distribution of volume of a layer and sustentaculums (Fig. 5).

On the basis of fiber representation layer volume V_{layer} it is possible to count from the area of contours of a layer increased by layer height

$V_{layer} = Square(\{Contour_k\}) * H$,

where $\{Contour_k\}$ – set of contours of a layer,

H – layer height.

The schedule of distribution of volume on layers allows to control dynamics of change of volume of a layer. Existence on graphics of the extremums incompatible with geometry of model has to serve the operator as the alarm system about possible existence of a mistake in a layer and to the management to the padding analysis of a layer of other tools.

As one more tool of the analysis of the relative positioning of layers serves the schedule of change of zones. Those zones of a layer which from above and from below are closed by other layers fall into to the zone Infill. If the zone of a layer is the site of a surface of model, then it falls into to the zone Skin. The zone Skin is divided into Up-Skin – it is not closed by a layer from above and Down-Skin – is not closed by a layer from below (Fig. 6).

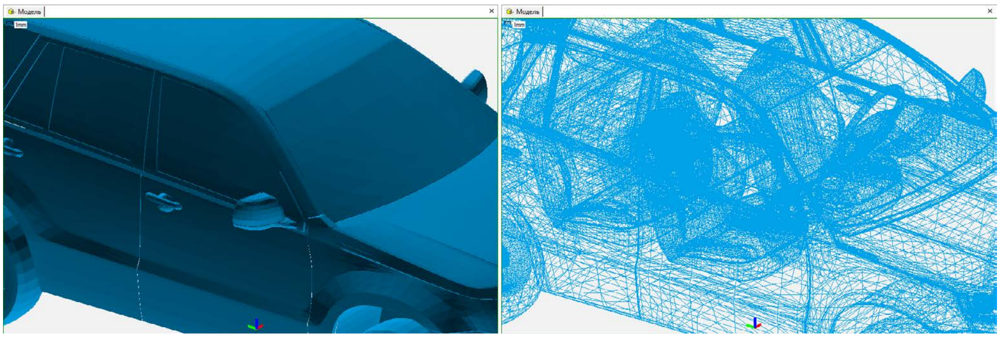

Fig. 3 Model with internal objects.

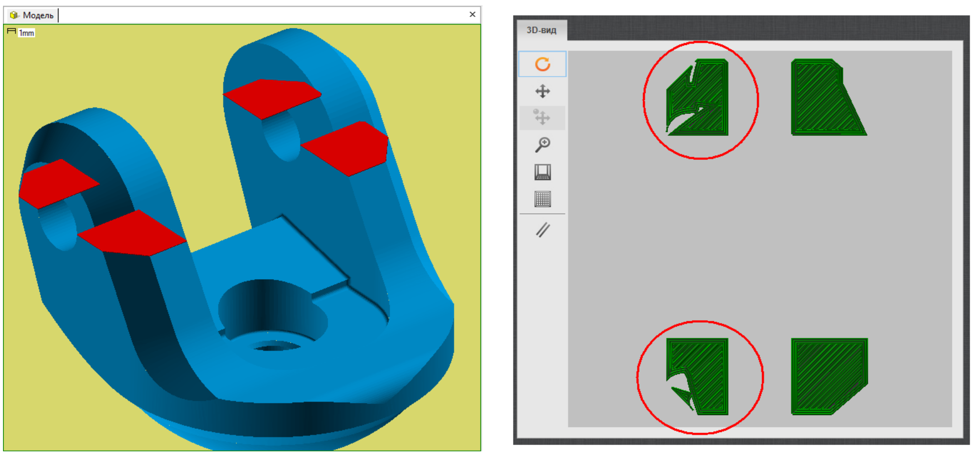

Fig. 4 Mistakes in the operating teams because of mistakes in geometry.

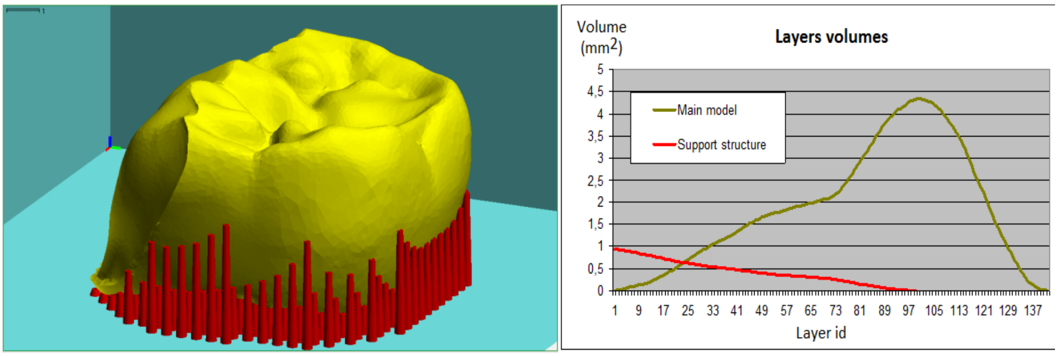

Fig. 5 Distribution of volume of model and sustentaculum on layers Vmodel=265 mm^3; Vsupport=42 mm^3.

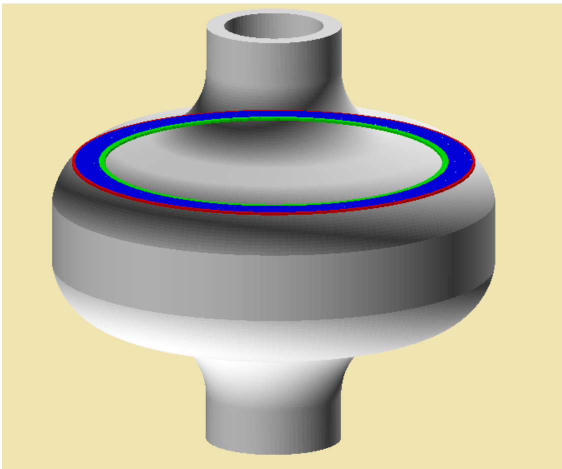

Fig. 6 Model of a hollow solid of revolution and one layer with division on the zones infill (blue) up skin (red) and down skin (green).

Schedules of distribution of volumes of layers and volumes of the zone Infill on layers depending on a slaysing step are given below. (Ponche, *et al*., 2012). For an example, the model of a hollow solid of revolution from the drawing is taken above.

According to the provided schedules it is possible to draw the following conclusions:

1. For bodies of not having levels with decrease of a step of a slaying the volume of the zone Infill aspires to the total amount of a layer.

2. The zero volume of the zone Infill (the first schedule) says that two next layers are not connected among themselves in any way, and, therefore, at the exit we will not receive an integral detail (Fig. 7).

Control methods of filling of a layer

The following stage of technological preparation is calculation of the operating teams. At this stage, the geometrical problem of a round of a contour, equidistant shift and shading of area, a restricted broken line is solved.

Actually, operating commands can be considered as a set of two dimensional trajectories of driving of the printing element (a spot of the laser or an extruder). Trajectories represent polygonal lines with the given accuracy the approximating zones of a layer calculated at a slaysing (Fig. 8).

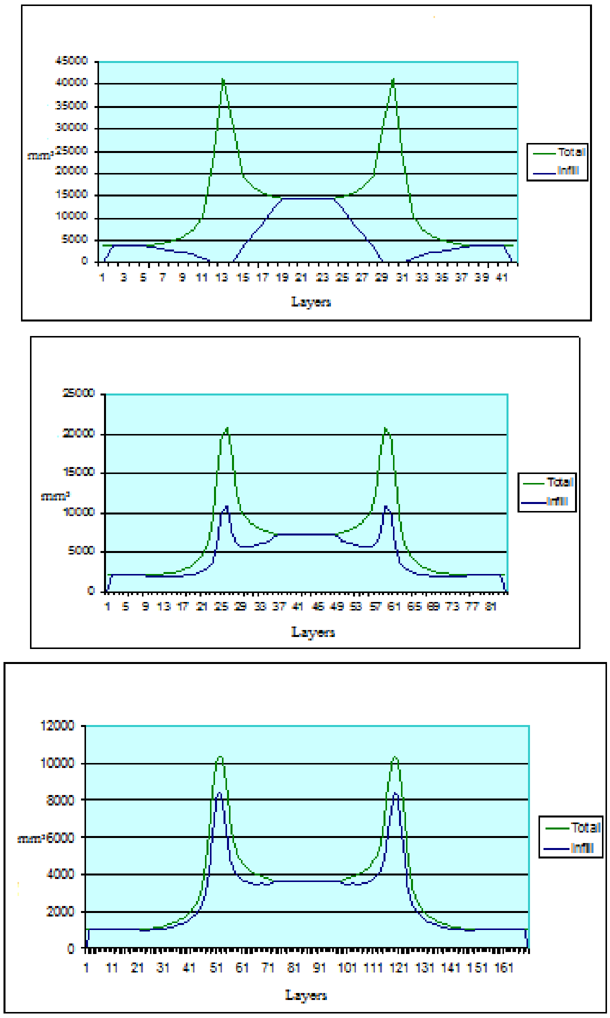

Fig. 7 Distribution of volumes of layers and volumes of the zone Infill on layers. a) Step of the slice 2%; b) Step of the slice 1%; c) Step of the slice 0.5%.

For the majority of technologies of the additive production filling of a layer consists of one or several equidistant rounds of perimeter and filling of contours with shading. However technological features of some printers' demand more difficult filling of a layer. For example, the layer zones which are falling into to various Shell/Infill segments can be shared with various density of filling. Or for prevention of emergence of tension at the press on SLS technology various approaches of distribution of heating when filling a layer can be used (Sigmund and Maute, 2013).

Mistakes when calculating of the operating teams can lead to the fact that some zones of a layer will be heated-up insufficiently, and some is on the contrary exuberant. Both will have an adverse effect on a bed detail and will lead to loss of strength characteristics or to excess internal stresses (Fig. 9).

Check of filling of a layer can be carried out by recovery of geometry of a layer on set of managing directors of teams. Knowing the physical sizes of a working element (a spot of the laser or extruder size) it is possible to restore a layer, modeling driving of a working element (Fig. 10).

Comparing geometry of the initial and restored layer in a combination to a speed of driving of a working element it is possible not only to check a correctness of calculation of the operating teams, but also to reveal zones of an overheat or underheating.

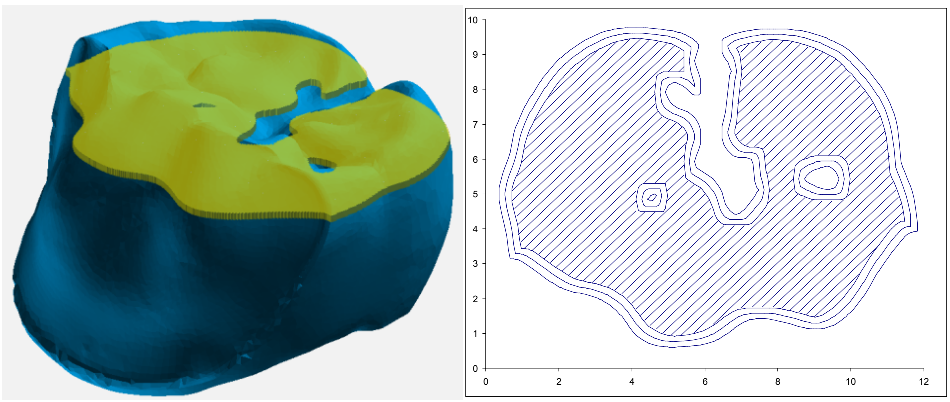

Fig. 8 Model with the allocated layer and the example of filling of a layer consisting of perimeter and shading.

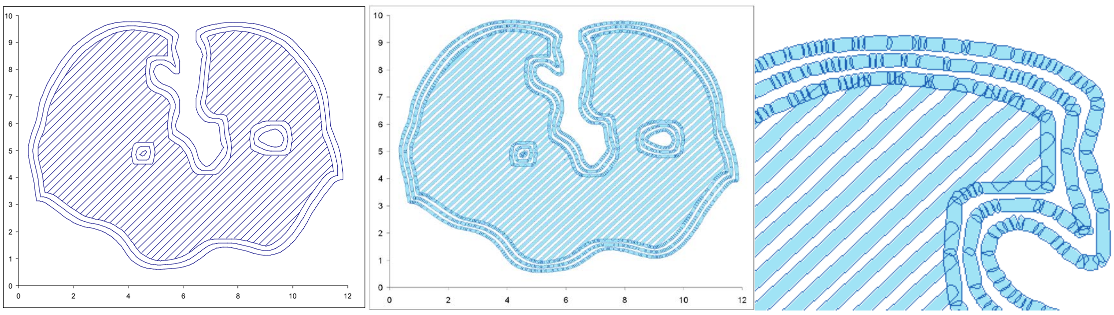

Fig. 9 Example of restitution of a layer according to the operating teams.

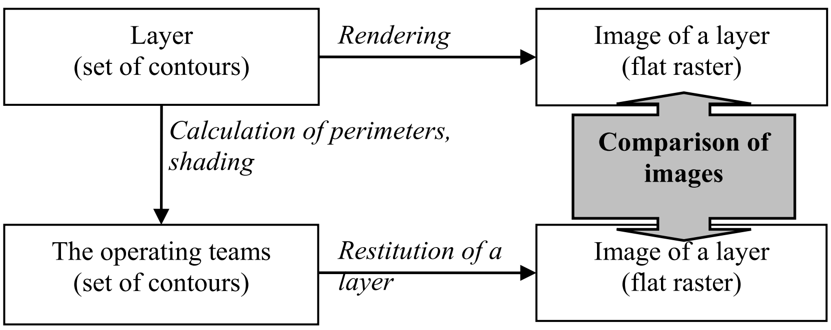

Fig. 10 Algorithm of verification of the operating commands.

CONCLUSION

Process of technological preparation consists of a set of computing processes and strongly depends on quality of input data. Mistakes which can arise both owing to the improper technological modes and owing to incorrect input data lead to marriage in terminating products. Using the considered control devices at each stage of technological preparation it is possible to reveal mistakes to an exit to the press that will allow to save time and material.

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