Control of geometrical parameters of a single layer at additive forming of products by FDM technology

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Abstract: Questions are considered about the accuracy of the formation of the surface layer by additive methods. The analysis of works is carried out on a research subject. High values of the error of forming (approximation) are revealed at forming of surfaces of a complex profile by additive methods. The spatial orientation of a single layer is proposed to reduce the error of forming products by additive methods. Mathematical dependences are proposed to determine the value of the parameters of a single directed layer on the results of experimental studies.

1. Introduction

The term additive technology has been entrenched in the scientific community for a long time and it means layer-by-layer cultivation of objects. These technologies are classified as one of the types of new industries and they allow us to launch new products in a short time. The classification of additive shaping methods may vary in the type of material used, they may vary in the state of aggregation of the materials, they may vary in the way the material is sprayed, etc. Additive methods have a common way of shaping. The object is formed in layers and it is formed from top to bottom, and the quality of the surface depends on the geometric parameters of the cross section of a single layer, that is, the error in shaping (approximation) is high when using additive technologies and this is a significant drawback of additive methods [1-8].

Scientific works have been created in large numbers on the study of the mechanisms of the formation of errors in additive shaping methods, but they are devoted to a greater degree to ensure accuracy at the macro level by minimizing the height of a single deposited layer or they are devoted to the selection of the shaping mode [9-13].

Issues to be considered are also about the spatial orientation of the products during shaping, since the physical position affects the formation of the shape of the transverse unit layer, it also affects its geometric characteristics, and it affects the formation of the accuracy of the formed surface [16-19]. The studies were conducted to find the possibility of minimizing the error of additive methods and they were aimed at establishing the components of their error.

2. Analysis of domain research

A large number of scientific papers devoted to the study of mechanisms of error formation in the formation of subtractive and additive methods.

The problems of formation of errors in mechanical processing are studied in [3] and the error of processing was considered as a result of the action of the relevant components:

\[ \Delta r_0 = \Delta r_{\text{ex}} + \Delta r_{\text{thm}} + \Delta r_{\text{tem}} + \Delta r_{\text{thm}} + \Delta r_{\text{thm}}, \]

where the static component of the processing error; the dynamic component of the processing error; and errors caused respectively by thermal deformation and tool wear; error caused by the wear of parts.
The value of the error of forming (approximation) is one of the values of the static component of the error of processing in the formation of parts by additive methods.

Improving the accuracy of additive forming methods is an urgent task, for which it is necessary to determine the geometric parameters of the unit deposited layer, Orient it in space so that the error of forming (approximation) was minimal [13-15].

3. Experimental study

Dimensions and shape parameters must be defined and described mathematically to provide a rational spatial orientation of a single directed layer.

Samples of single layers were sent according to the experimental plan (table 1.1.) – variable parameters: thickness of a single layer h, mm; temperature of extruder heating t, °C; speed of extruder movement v, mm/sec; sections were made, which were investigated on the instrumental MMI-2 microscope. The coordinates of the points on the curves forming the cross section of the unit layer were fixed, the approximation of these points by the ellipse equation was made – this is the shape of the cross section of the unit layer was observed in the samples (Fig. 3), the difference in the coordinates of the characteristic points on the surface of the cross-section profile of the unit layer were determined by the parameters of the width \(a\) and height \(b\) of the unit deposited layer.

Table 1. The experiment plan.

| №  | X1  | X2  | X3  |
|----|-----|-----|-----|
|    | Код | Код | Код |
| 1  | +   | 0,22| +   |
| 2  | -   | 0,38| +   |
| 3  | +   | 0,22| -   |
| 4  | -   | 0,38| -   |
| 5  | +   | 0,22| +   |
| 6  | -   | 0,38| +   |
| 7  | +   | 0,22| -   |
| 8  | -   | 0,38| -   |
| 9  | -1,215| 0,2| -1,215|
| 10 | +1,215| 0,4| +1,215|
| 11 | 0   | 0,3 | 0   |
| 12 | 0   | 0,3 | 0   |
| 13 | 0   | 0,3 | 0   |
| 14 | 0   | 0,3 | 0   |
| 15 | 0   | 0,3 | 0   |

Table 1. The experiment plan.
The direction of a single layer was carried out on the additive installation of modes. Model Makerbot Replicator 2, single layer material abs plastic.

![Figure 1. Samples of a single deposited layer](image)

The combination of the values of geometrical parameters (width and height) was obtained during measurement of the parameters of a single lateral layer.

| № | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| a, mm | 0,545 | 0,8 | 0,65 | 0,8 | 0,565 | 0,845 | 0,595 | 0,755 | 0,65 | 0,605 | 0,615 | 0,6 | 0,615 | 0,6 |
| b, mm | 0,29 | 0,38 | 0,2 | 0,29 | 0,25 | 0,29 | 0,23 | 0,37 | 0,15 | 0,51 | 0,28 | 0,32 | 0,32 | 0,32 | 0,32 |

Processing of the experimental results for the mathematical description of the geometric characteristics of the directed unit layer was made and reflecting the influence of elements of the modes of additive shaping on the width $a$ and height $b$, mathematical dependences were obtained:

$$a = h(356h + 8,536) - t(0,043h - 0,02) + v(0,0002t - 0,04) - 3,87 \quad (2)$$

$$b = h(4267 - 5,595h) - t(0,0006h - 0,028) + v(0,000312t - 0,065) - 31,45 \quad (3)$$

where $h$ (mm.) - is the thickness of a single layer; $t$ (°C) - is the heating temperature of the extruder; $v$ (mm/sec.) – moving speed of the extruder.

Graphs of the influence of elements of the regime of additive formation on the value of the parameters of a single layer were built on the results of the analysis of the empirical dependences.

![Graphs](image)
Figure 2. Graphs of the width of the unit deposited layer a, the height of the unit deposited layer b on the elements of the modes of additive shaping:

a - graph of the height of a single layer b, mm temperature t, °C, v, mm/s, at a constant value of the layer thickness h=0,2 mm;
b - graph of the height of a single layer b, mm temperature t, °C, v, mm/s, at a constant value of the layer thickness h=0,3 mm;
c - graph of the height of a single layer b, mm temperature t, °C, v, mm/s, at a constant value of the layer thickness h=0,4 mm;
d - graph of the width of a single layer a, mm temperature t, °C, h, mm, at a constant value of the layer thickness v=10 m/s;
e - graph of the width of a single layer a, mm temperature t, °C, h, mm, at a constant value of the layer thickness v=35 m/s;
f - graph of the width of a single layer a, mm temperature t, °C, h, mm, at a constant value of the layer thickness v=60 m/s.
The results of the analysis revealed the nature of changes in the parameters of width and height of a single deposited layer. The width of a single layer $a$ does not depend on the value of the heating temperature of the extruder $t$ at the thickness of the directed layer $h=0.3$ mm, which is observed.

4. Conclusion
Mathematical relationship showing the effect of additive elements of modes of formation on the parameters of the cross section of single-directional layers obtained according to the results of the research.

The development of methods and devices to ensure the dynamic spatial orientation of the final link of the forming system of the additive installation is the next stage of research and their application allows to provide the spatial orientation of a single directed layer and the least curvature of the approximated sections of the single layer profile of the forming part. The value of the error of shaping (approximation) will be able to reduce and improve the accuracy of shaping by additive methods.

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