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METHODS OF FORMING SURFACE LAYER OF AN FDM PRODUCT AT POST-PROCESSING STAGE

In recent years, additive technologies have become an integral part of modern manufacturing, evolving from a prototyping tool to a full-fledged mass production technology. However, issues related to the surface layer, its roughness, and geometric accuracy remain unresolved.

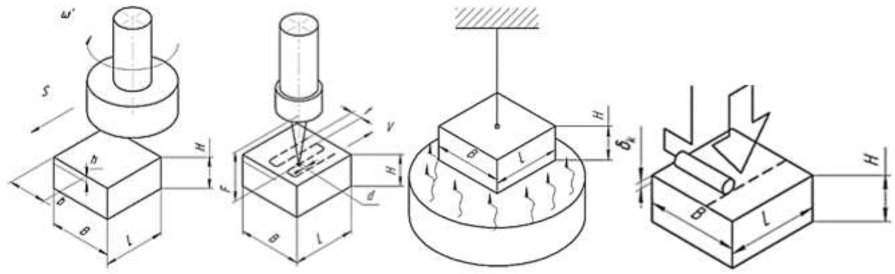
Gradual multi-cycle reproduction of products leads to them being characterized by a certain anisotropy of properties [1], as well as errors in shape and size [2], which in most cases are determined by the conditions and means of product reproduction, the quality of the plastic used, the purity of the environment, etc.

Post-processing methods used for FDM products: mechanical impact (cutting or grinding), Fig. 1,a, physical and technical processing, Fig. 1,b, or chemical processing, Fig. 1,c.

During mechanical processing of a workpiece with dimensions $L \times B \times H$, for example with a milling cutter, Fig. 1,a, rotating at a frequency ω and contacting the workpiece at a width b with a gradual feed S, material is removed to a depth h; as a rule, the surface layer is removed, ensuring the mutual arrangement of the base and mating surfaces, however, defects are not eliminated, since during cutting, the material, which has a certain porosity (from 1.5 to 3...5%), perceives a mechanical load that can destroy the loose places of the joints of the printed product structure, especially when the density of the latter is insufficient.

A type of mechanical processing is grinding, in which the microcutting process is accompanied by significant heat release, so that at the same time as the mechanical load is applied, the workpiece is subjected to significant thermal effects.

Laser scanning heating of the workpiece surface allows changing the state and structure of the surface layer due to intense local heating with the transfer of the heating zone, Fig. 1, b, as a result of which it is possible to achieve complete or partial remelting of the surface layer. In this case, the workpiece $L \times B \times H$ is subjected to a high-intensity focused irradiation spot with a diameter d on one edge of the workpiece during scanning at a speed v. The scanning step t is set based on the condition of overlapping the tracks subjected to thermal exposure. Typically, this can eliminate surface defects such as delamination, threading, over- or under-extrusion.



a b c d

Figure 1. Post-processing options: a – mechanical; b – physical and technical; c – chemical methods; d – application of films (adhesive)

Chemical treatment of the workpiece, for example, in a chamber above a bath with ketone liquid (acetone), allows chemical exposure across the entire outer surface (for a prismatic body $L \times B \times H$, Fig. 1,c, practically across all six faces, with the exception of the workpiece attachment point; a variation of this treatment involves applying an adhesive reagent in strips or by immersion; this results in the formation of an adhesive layer with a thickness of T_k. This forms a sufficiently dense and closed surface structure (in the form of a film), which, provided that it has high wettability, ensures the tightness of the product and its ability to resist the development of microdefects from cyclic loads.

The corresponding post-processing methods are as follows: D_m^i – mechanical cutting (D_m^1 – turning, D_m^2 – milling, D_m^3 – drilling, etc.); D_a – abrasive processing; D_f – physical and technical processing; D_h – chemical processing. Then, ensuring the set of properties of the finished product described by the array G will correspond to the transformation of the initial parameters of the part R by the corresponding methods D_j, which are manifested through the corresponding components P_k.

$$R \cap D(P_k) \rightarrow G \ .\mathrm{R} \cap \mathrm{D}(\mathrm{P_k}) \rightarrow \mathrm{G} \qquad (1)$$

Here, for each D_i, the set of components P_k will be unique, determined by the mechanisms and characteristics of their flow during post-processing. For example, D_{mi} will be determined as follows:

$$D_m^i \subset (P_1, P_3, P_4, P_9)\,. \qquad (2)$$

Other post-processing methods:

$$D_a \subset (P_1, P_2, P_3, P_4, P_9)\,. \qquad (3)$$

$$D_f \subset \left(P_4, P_5, P_6, P_7, P_9\right). \quad (4)$$

$$D_h \subset \left(P_4, P_5, P_7, P_8, P_9\right). \quad (5)$$

From the above expressions, it becomes clear that the task of achieving the required quality of the finished product as the formation of initial indicators according to (1) is possible in several post-processing options; thus, D_{mi} is aimed primarily at correcting the shape, while D_f and D_h are aimed at changing the state and properties of the surface. Thus, the full range of quality indicators is ensured by the condition

$$G \subset \sum_{i=1}^{4} R \cap D_i(P_k), \quad (6)$$

which is quite expensive from an economic point of view and requires a significant amount of auxiliary equipment.

Improving the efficiency of post-processing involves finding methods that eliminate duplicate actions that lead to changes in the state or parameters of the surface and near-surface layers Fig. 2.

Modeling of the processes and phenomena occurring during the processing of additive-manufactured workpieces was carried out.

The assumptions for modeling were as follows:

1) the workpiece has a regular structure, consisting of symmetrically arranged fibers of regular shape, connected to each other and layer by layer;

2) the strength of the joints corresponds to the maximum permissible stresses that can occur at the contact boundary of the material;

3) all joint areas have the same strength and there are no internal defects;

4) the material is not dense, gas or liquid permeation is possible in the inter-fiber and interlayer gaps; the permeation area is the same for the main fibers and is stable across the cross-section.

The modeling was performed in Solid Works with the appropriate calculation modules. The analysis was performed for low-temperature plastic such as ABS.

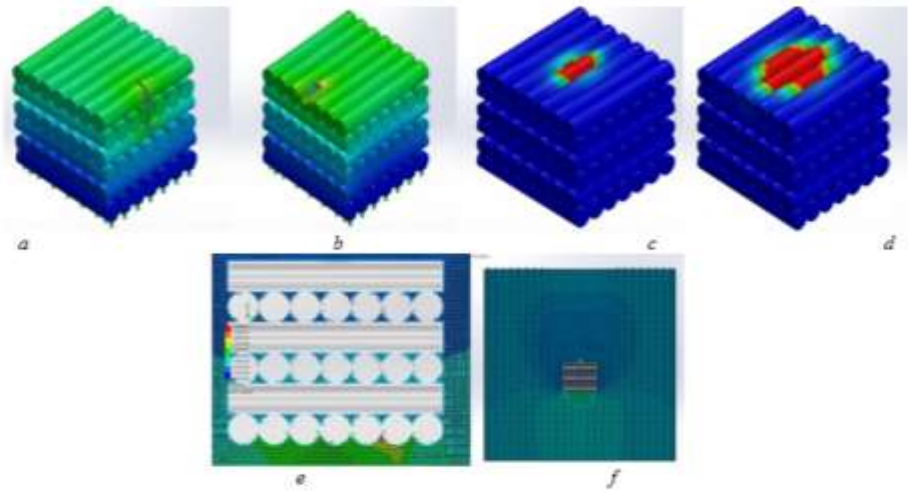


Figure 2. Post-processing simulation: a – force load from the cutting wedge across the fibers; b – force load from the cutting wedge along the fibers; c – effect of laser radiation pulse on the surface; d – heat propagation in the workpiece; e – fiber vapor flow; f – workpieces as a whole

During the modeling of mechanical interaction, attention was drawn to the fact that mechanical cutting satisfactorily removes the surface layer, but new defects in the form of cavities, delamination, and detachment may appear; the products proved to be quite sensitive to the accuracy of the cutting mode settings.

References

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