Testing the methodology for evaluating the accuracy of the 3d printing

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Abstract. The spread of 3d printing in the industry has led to the need to determine the accuracy of reproducible dimensions on a 3d printer. Precision manufacturing of parts is essential in the manufacture of products. The hardware manufacturer provides the user with information on the positioning accuracy of the 3d printer, but this could be a marketing statement. Also, it is very important to know the accuracy of a 3d printer after its upgrade or under the influence of various external factors (ambient temperature, vibrations) inherent in the location of the printer. The purpose of this work was to check the accuracy of a 3d printer and to develop a methodology for assessing the accuracy of a 3d printer by printing a sample product. As a result of the work done, it was found that by measuring various samples of products, it is possible to determine the quality of accuracy for certain structural elements and the average coefficient of accuracy of products. It was also found that the study of a sample product allows us to determine most of the factors affecting the accuracy of manufacturing products.

1. Introduction
The use of 3d printers opens up new opportunities for production. The spread of 3d printing has led to the need to determine the accuracy of reproducing the dimensions of products [1-9]. The hardware manufacturer provides the user with information about the positioning accuracy of the 3d printer, but this may be a marketing statement. Also, you need to know the accuracy of the 3d printer after its modernization, or under the influence of various external factors (ambient temperature, vibration) peculiar to the location of the printer.

The purpose of this work was to check the accuracy of a 3d printer and to develop a methodology for assessing the accuracy of a 3d printer by printing a sample product.

2. Main part
Assessment of kinematics. Checking the accuracy of 3d printing should begin with an analysis of the kinematics of a 3d printer, this will help in further analysis and search for the reasons for deviations of real dimensions from nominal. The 3d printer used in this work has the H-Bot kinematic scheme.
Sample products for checking. For most FDM 3D printers, the base surface of the desktop is not susceptible to measurements, therefore, it is advisable to assess the accuracy of the printer through control of the shape and size of the sample-product. It is recommended to use PLA material for printing, as it has less shrinkage and deformation during printing from the most common plastics (ABC, PLA) [10-15]. Shapes and sizes of sample-product No. 1 to determine the range of accuracy of manufactured products on a 3d printer Fig.1.

![Figure 1. Sketch of a sample product №1.](image)

The name of the checks carried out:
1. Accuracy of hole shape d: a) roundness; b) longitudinal section profile.
2. The flatness of the end surface of the turned parallelepiped.
3. Parallelism of the end surface of the rotated parallelepiped (only 1 rotated parallelepiped) to the base of the product specimen.
4. Straightness of the side surfaces of the rotated parallelepiped.
5. Perpendicularity of the lateral surfaces of the rotated parallelepiped.
6. Accuracy of the position of the surface inclined at an angle of 5°.
7. Roundness of the outer cylindrical surface.
8. Alignment of holes.

The dimensions of the sample product No. 2 for determining the deviation from the alignment of the holes when printing with two extruders is shown in Figure 2 (the upper lower ring is printed with different extruders).

![Figure 2. Sample product sketch №2.](image)

![Figure 3. Measurement scheme of the main dimensions of the product.](image)

The accuracy of printing and the quality of surfaces are influenced by such factors as the temperature of the external environment, the temperature of the staining head and substrate, do not forget about the
degree and pattern of filling the printed parts. To obtain reliable data on the accuracy of 3D printing, it is necessary to select the same mode for printing product samples, as for products whose production is planned in the future. Do not forget about the storage conditions of printed samples-products, the degree of accuracy of the study depends on this [16-17].

3. Results and Discussion
To determine the quality of the accuracy of the manufacture of products, it is necessary to measure them.

The measurement scheme for the main dimensions of the product is shown in Fig. 3. To measure the deviation from roundness, it is necessary to measure the tested shaft (Fig. 3 dimensions d1, d2) in several sections and select the largest and smallest size, then the difference of these values will be the deviation from roundness. The deviation of 3d printing will be the largest modulus of the difference between the nominal print diameter and the real profile. Table 1 contains the measurement results.

Table 1. Measurement results

| Nominal value, mm | Measurements          |
|-------------------|-----------------------|
|                   | L1, mm | L2, mm | L3, mm | L4, mm |
| 100               | 99.8   | 101.5  | 99.95  | 101.3  |
| d0, mm            | d1     | d2     | d1-d2  | Dn-d2  |
| 70                | 70.8   | 69.85  | 0.95   | 0.8    |

To measure the flatness of the end surface, the part is placed with the reference surface on the surface plate, in this case it is the opposite plane of the parallelepiped being measured. The measuring device is a column-mounted indicator head, which is based on a surface plate. The measurement takes place according to the diagram shown in Fig. 4, which shows the measurement points and the planes to be checked.

Figure 4. Scheme of flatness measurements of the end surface of a rotated parallelepiped. 1 - rack measuring device. 2 - measuring device (dial indicator). 3 - sample product. 4 - base surface.

Figure 5. 3D model of a real surface (in the figure these are points at the measurement points) and an adjacent plane (in the figure it is a parallelepiped). 1 - zero count line; 2 - plane adjacent to the real profile; 3 - measurement points.

The maximum deviation from the reference plane to the measurement plane is -0.07 mm.

For product samples, the perpendicularity of the end surfaces was checked; in the considered 3d printer, these deviations were insignificant.
To measure the flatness of the end surface, the part is placed with the reference surface on the surface plate, in this case it is the "top" of the part. The measuring device is a column-mounted indicator head, which is based on a surface plate. The flatness deviation is -0.33mm.

To determine the alignment of the holes in the sample product No. 2 with a diameter of 50 and 40. The part to be measured is installed on the working table (Fig. 6) of a vertical milling machine and fixed with clamping bars. The center finder with the indicator is fixed in the collet chuck of the machine. After that, the dipstick is inserted into a 40 mm diameter hole, and rests on the surface of the hole with slight tension. By rotating the spindle, the deflection of the indicator is fixed. Based on the deviations, the working table of the machine moves to establish the alignment of the axis of the hole with the diameter and the machine. After alignment has been established, the spindle rises until the dipstick moves to a diameter of 50 mm. By rotating the machine spindle, the deviations of the indicator arrow are recorded. On the basis of these deviations (Fig. 7), conclusions are drawn about their alignment.

![Figure 6. Hole alignment measurement diagram. 1-spindle of the machine; 2-center finder; 3-measuring device (dial indicator); 4-sample product No. 2; 5-base surface.](image)

![Figure 7. Deviation of the shape of the holes relative to the reference points (mm).](image)

For the roughness analysis, the base surface was used, since it has a relatively average roughness compared to the rest of the surfaces.

The check was carried out on a profilograph-profilometer with a vertical magnification of 1000 and a horizontal magnification of 40. After measurements on the profile roughness graph, the base length for the analysis was selected, shown in Fig.8. The quality of the surface layer depends more on the parameters of the 3d printing parameters [18].
Figure 8. Section of the roughness graph with analysis. Ln - base length; Sm - step of profile irregularities; yp - height of the i-th largest projection of the profile; yv is the depth of the i-th largest valley of the profile. RMax - Highest profile height; P is the distance between the line of the profile protrusions and the line intersecting the profile of the equidistant line of the profile protrusions.

As a result of measurements at the base length, the values presented in Tables 2 and 3 were obtained.

| Table 2. Step of profile irregularities in mm. |
|-----------------------------------------------|
| Sm1 | Sm2 | Sm3 | Sm4 |
| 0.3 | 0.375 | 0.6 | 1.25 |

| Table 3. Height of profile irregularities by ten points in microns. |
|---------------------------------------------------------------|
| Height of 5 largest profile protrusions | Ypm1 | Ypm2 | Ypm3 | Ypm4 | Ypm5 |
|------------------------------------------|------|------|------|------|------|
| 11                                       | 21   | 16   | 27   | 31   |

| Depth of the 5 largest profile valleys | Yvm1 | Yvm2 | Yvm3 | Yvm4 | Yvm5 |
|----------------------------------------|------|------|------|------|------|
| 12                                     | 5    | 26   | 25   | 31   |

The Rz parameter (the height of the profile irregularities at ten points): Rz=41 μm. The Ra parameter (mean arithmetic deviation of the profile): Ra = 0.0547 / 3.87 = 0.01413mm = 14.13 μm. Rmax =62. The average accuracy factor for a 3d printer is 12.6.

Based on the results of evaluating the accuracy of the 3d printer, it can be concluded that it is necessary to improve the quality of printing products. To do this, you can consider options for adjusting the kinematics, configuring the software, changing the conditions for the equipment's operation [19].

4. Conclusion
As a result of the work done, it was established:
1) By measuring various samples of products, it is possible to determine the quality of accuracy for certain structural elements and the average coefficient of accuracy of products.
2) A detailed study of deviations from the nominal sizes, the correlation of results, in most cases, allows you to determine the influencing factors of these deviations. So, in the tested printer, an incorrect setting of the print head pitch was detected.

3) To obtain reliable data on the accuracy of 3D printing, it is necessary to choose the same mode for printing samples-products, as for products whose production is planned in the future.

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