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# Вплив розташування об'єкту підчас 3D-друку на якість деталі

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# The impact of object orientation during 3D printing on part quality

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***Анотація. Мета.*** *Дослідження та практична оцінка впливу розташування деталей на столі під час 3Д-друку на витрати матеріалу, час друку, і якість деталей машинобудування.* ***Методика.*** *Проведені практичні випробування у реальних умовах виробництва з попередньою оцінкою результатів друку у середовищі програмного продукту Ultimaker Cura 5.8.1 та наступним друком деталі у 3Д принтері ANYCUBIC PHOTON M3 MAX.* ***Наукова новизна та результати.*** *Практично проведено дослідження реального 3Д-друку фотополімерною смолою деталей після аналізу різних варіантів розташування 3Д-моделі на платформі побудови. З'ясовані дослідним шляхом раціональні положення для 3Д моделей у просторі для зменшення часу друку, витрати матеріалу та усунення дефектів 3Д друку. Виконана оцінка впливу розташування деталей на столі під час 3Д-друку фотополімерною смолою ESUN Hard-Tough Resin білого кольору на витрати матеріалу, час друку, та якість деталей машинобудування. Зафіксовано значущий вплив розташування моделі на платформі побудови – а саме під кутом - на якість друку окремих елементів деталей, особливо дрібнорозмірних, на кількість витраченого матеріалу та час друку.* ***Практична значущість.*** *Проведенні дослідження дозволили більш свідомо виконувати розташування 3Д моделей на платформі побудови, попередньо оцінити витрати матеріалу на підтримки та відредагувати положення моделі у разі невдалого вибору та тим самим зменшити час друку і кількість втрат у наслідок дефектів друку через відсутність підтримок. Одержання практичного досвіду 3Д-друку та формування практичних рекомендацій, що дозволило покращити стан 3Д-виробництва на підприємстві.*
***Ключові слова:*** *Адитивне виробництво, Photon M3 Max, витрата матеріалу, фотопомімерна смола ESUN Hard-Tough Resin, об'єм підтримок, 3Д друк, час 3Д друку.*

***Abstract. Purpose.*** *Research and practical evaluation of the impact of part placement on the table during 3D printing on material consumption, printing time, and quality of mechanical engineering parts.* ***Methodology.*** *Practical tests were conducted in real production conditions with a preliminary assessment of printing results in the Ultimaker Cura 5.8.1 software environment and subsequent printing of the part in a 3D printer ANYCUBIC PHOTON M3 MAX.* ***Originality and Findings.*** *A practical study of real 3D printing of parts with photopolymer resin was conducted after analyzing various options for the location of the 3D model on the build plate. Rational positions for 3D models in space were experimentally determined to reduce printing time, material consumption, and eliminate 3D printing defects. An assessment of the influence of the location of parts on the table during 3D printing with white photopolymer resin ESUN Hard-Tough Resin on material consumption, printing time, and quality of mechanical engineering parts was performed. A significant influence of the location of the model on the build plate - namely at an angle - on the printing quality of individual elements of parts, especially small ones, on the amount of material consumed, and printing time was recorded.* ***Practical value.*** *The conducted research allowed us to more consciously place 3D models on the build plate, pre-estimate the material costs for supports and edit the position of the model in case of an unsuccessful choice, thereby reducing printing time and the number of losses due to printing defects due to the lack of supports. Gaining practical experience in 3D printing and forming practical recommendations, which allowed us to improve the state of 3D production at the enterprise.*
***Keywords:*** *Additive Manufacturing, Photon M3 Max, material consumption, photopolymer resin ESUN Hard-Tough Resin, support volume, 3D printing, 3D printing time.*

**Introduction.** Additive manufacturing technology has opened up new opportunities for creating complex shapes and structures in mechanical engineering. 3D printing is essentially a very important process when it comes to working out the details of design and developing new products. It can easily produce internal sharp corners, complex contours, and even build structures that are completely inaccessible to traditional machining or CNC manufacturing. This is what makes additive manufacturing a powerful tool in the creation of part prototypes intended for casting and machining, as it can handle a wide range of product design features [1].

Additive manufacturing allows for the production of parts ranging in size from micro to macro scale. However, the accuracy of printed parts depends on the accuracy of the used method and the printing scale. For example, micro-scale 3D printing creates problems with resolution, surface treatment and layer bonding, which sometimes require post-processing methods such as sintering [2]. On the other hand, the limited range of materials available for 3D printing creates problems when using this technology in various industries. Thus, there is a need to develop suitable materials that can be used for 3D printing. Further research is also needed to improve the properties of 3D-printed parts [3].

**Analysis of literature data and problem statement.** Scientific publications often focus on the following issues in the printing field:

optimization of printing parameters to improve mechanical properties;

analysis of the economic efficiency of technology implementation;

elimination of internal defects that occur during the printing process.

– In the article 'Effect of printing orientation on mechanical properties of FDM 3D printed parts' (ResearchGate) [4], three orientations (XY, YZ, ZX) were studied in FDM printing. The results showed that the YZ orientation provides higher tensile and impact strength, while the XY orientation provides maximum hardness. This confirms the anisotropy of the material due to its layered structure.

– The systematic review 'Impact of 3D printing orientation on accuracy, properties, cost, and time efficiency of additively manufactured dental models' (BMC Oral Health, 2024) [5] focuses on dental applications. The authors concluded that the vertical orientation of models allows more details to be placed in a single printing session, but horizontal orientation proved to be more optimal in terms of accuracy, time reduction, cost, and material usage.

The study 'The Influence of Printing Orientation on Surface Texture Parameters' (PMC) [6] analysed roughness parameters (Ra, Rz) in detail. It was found that the smoothest surface is formed at an orientation of 0° tilt (parallel to the working platform). As the angle of orientation increases, the surface parameters deteriorate significantly, which is critical for high-precision products.

– The article 'Influence of Printing Orientation on the Mechanical Properties of Provisional Polymeric Materials Produced by 3D Printing' (Polymers, 2025) [7] analyses samples of dental polymers. The highest bending strength and modulus of elasticity were shown by samples printed at an angle of 90°. This confirms that in dentistry, the choice of orientation has a direct impact on the reliability of prostheses.

– The article 'Why Part Orientation Matters in 3D Printing' (AZoM) [8] explains that orientation affects all key parameters: mechanical properties, printing time, number of supports, surface quality, and cost. The authors emphasise anisotropy as the main factor that makes the right choice of location critically important.

– Similar conclusions regarding the orientation of objects during printing are presented in the article 'Build orientation optimisation of additive manufactured parts for better mechanical performance by utilising the principal stress directions' [9], which presents an algorithm for determining the optimal print orientation in order to increase the mechanical strength of parts.

Some of these issues – defects, uneven mechanical strength due to limited materials, high prices and small production volumes – are being addressed through further scientific research and the development of advanced materials and additive manufacturing methods. There are no specific practical recommendations regarding the placement of the 3D model on the build platform, the placement of supports, and the time required to build the part, nor is there any correlation between these actions. This creates serious problems during the manufacturing of parts using 3D printing, as it is an energy-intensive and time-consuming process that may not produce the desired result. As a result, the part or its individual element is not printed in full. This situation leads to financial losses due to increased material expenses, electricity costs, and working time. Thus, research on this issue is relevant, especially in the current climate of economical consumption.

**Research goal and objectives.** The goal of this work is to study and practically evaluate the impact of the placement of parts on the build platform during 3D printing on material consumption, printing time, and the quality of printed parts for general mechanical engineering.

One of the important elements of design is the location of the part on the build platform of the 3D printer, which significantly affects printing time, material consumption, and the quality of the final product. Let's examine the main factors that affect the placement of a 3D model during printing and how to correctly find the position of the future part on the build platform of a 3D printer, taking all factors into account.

The location of the part can significantly change the printing time due to the number of layers. Orienting the part along the Z-axis (vertically) usually requires more layers, as each layer is added as the object grows. The more layers, the longer the printing time. If the part is printed vertically, the number of layers is at its maximum, which increases the printing time compared to printing in a horizontal position, where there are fewer layers but each layer has a larger surface area.

The orientation of the part often affects the need for supports. If the part has protrusions or complex geometric elements, the layout may require more support structures. Printing complex parts horizontally can reduce the number of supports, while vertical orientation may require more to ensure the strength and stability of the part during printing.

At the same time, increasing the number of supports not only increases material consumption and printing time, but also requires additional time after printing to remove them and further process the part.

After considering and analyzing several positions from different angles, it is possible to find a position in which the printing time and quality will be optimal.

In Fig. 1, the part is positioned completely horizontally, with one of the surfaces serving as a platform for mounting on the table during printing. In this case, there are no supports at all and the printing time is minimal. However, after printing, if the part is thin-walled, there is a risk of damaging the surface when removing it from the table.

In the second case (Fig. 2), the part is positioned vertically and raised 5–8 mm above the platform for stabilization. Due to its cylindrical shape, the print requires supports located both outside and inside the part. This results in maximum printing time, as the number of layers is maximum, and increased material consumption and the need for additional processing after removing the supports.

In Fig. 3, the part is tilted at an angle of 10-20º and raised 5-8 mm above the platform. Supports are only needed on the side attached to the table, which reduces material consumption compared to a vertical position.

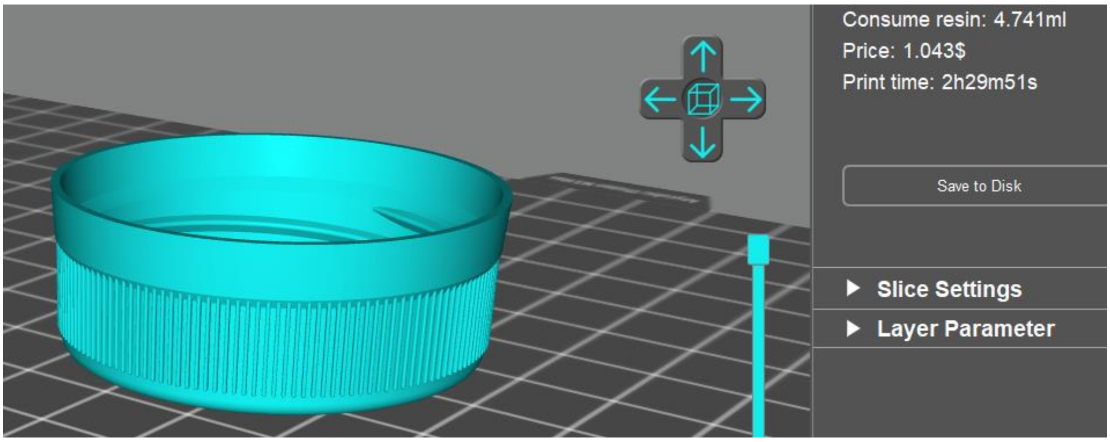


Fig. 1 Horizontal positioning of the part on the 3D printer plate

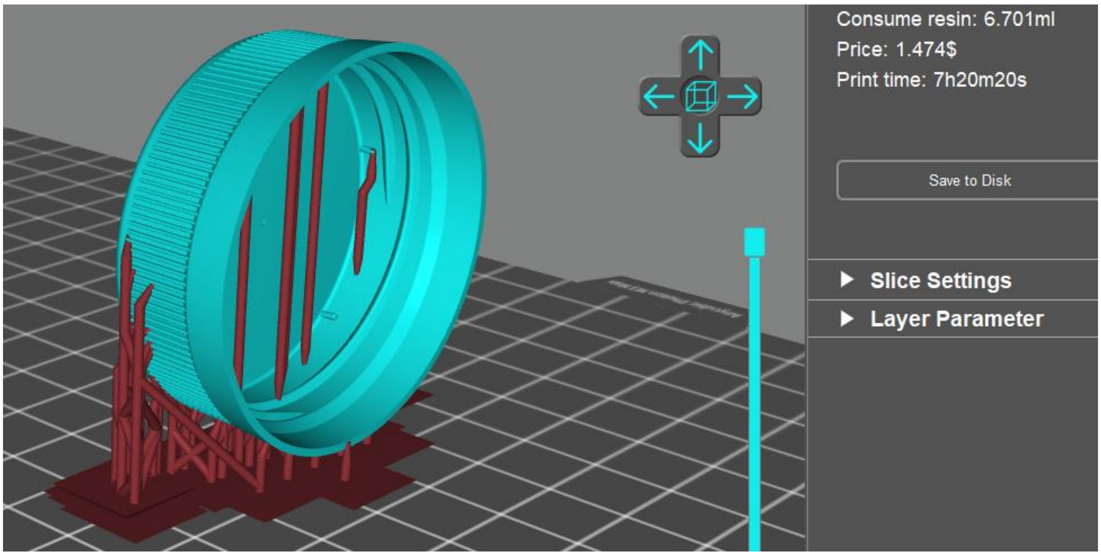


Fig. 2 Vertical positioning of the part on the 3D printer table

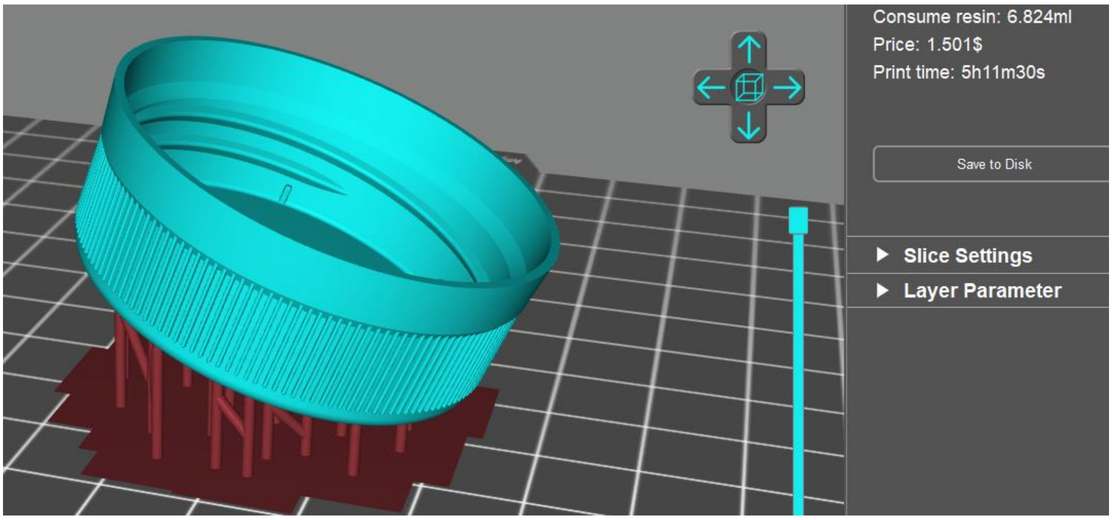


Fig. 3 Positioning of the part at an angle to the 3D printer table

It is believed that photopolymer printing is performed at an angle in order to reduce the number of printing failures by reducing the surface area exposed to resin during printing. This orientation of the object on the table reduces the tensile force on the working plate and minimizes the risk of deformation and delamination. Angled printing improves print quality by reducing the visibility of layer lines through more efficient resin runoff and provides better support for overhanging elements, resulting in a surface with less roughness than when printing without an angle.

The printing time is 5 hours, 11 minutes and 30 seconds, which is longer than with a horizontal orientation (2 hours, 9 minutes and 5 seconds), but shorter than with a vertical orientation (7 hours, 20 minutes and 20 seconds). This orientation reduces the risk of damage to surfaces when removing the part from the table.

Thus, selecting the optimal orientation angle allows you to achieve a balance between printing speed and simplifying further processing. The horizontal position is suitable for parts with simple shapes, the vertical position is suitable for compact use of space, and the angular position is a compromise that reduces the risk of damage and defects.

The next parameter affected by the location of the part is the amount of material used for 3D printing. As discussed above, incorrect positioning can lead to the need for a larger number of supports, which will increase the amount of material used for printing. The optimal orientation of the model in the 3D printer space can reduce the number of supports or eliminate them altogether.

If the part is poorly positioned, it may require a significant amount of support structures to ensure printing stability. This not only increases material consumption, but also requires more time for manufacturing and subsequent removal of the supports. Optimal orientation, such as horizontal, can significantly reduce the number of supports or eliminate them altogether.

For hollow parts, the orientation determines how the internal cavities and stiffening ribs will be formed. Choosing the correct orientation angle can ensure efficient use of the filling material, reduce its quantity, and take into account the location of holes for removing excess material.

Proper orientation allows you to reduce the overall amount of material while maintaining the required strength of the product. This is especially important for complex parts where voids and supports can significantly affect the final cost.

Thus, choosing the optimal part placement minimizes material consumption, reduces printing time, and facilitates processing. This is especially true for hollow products, where it is important to consider the layout of the internal filling and the points of drainage for excess material.

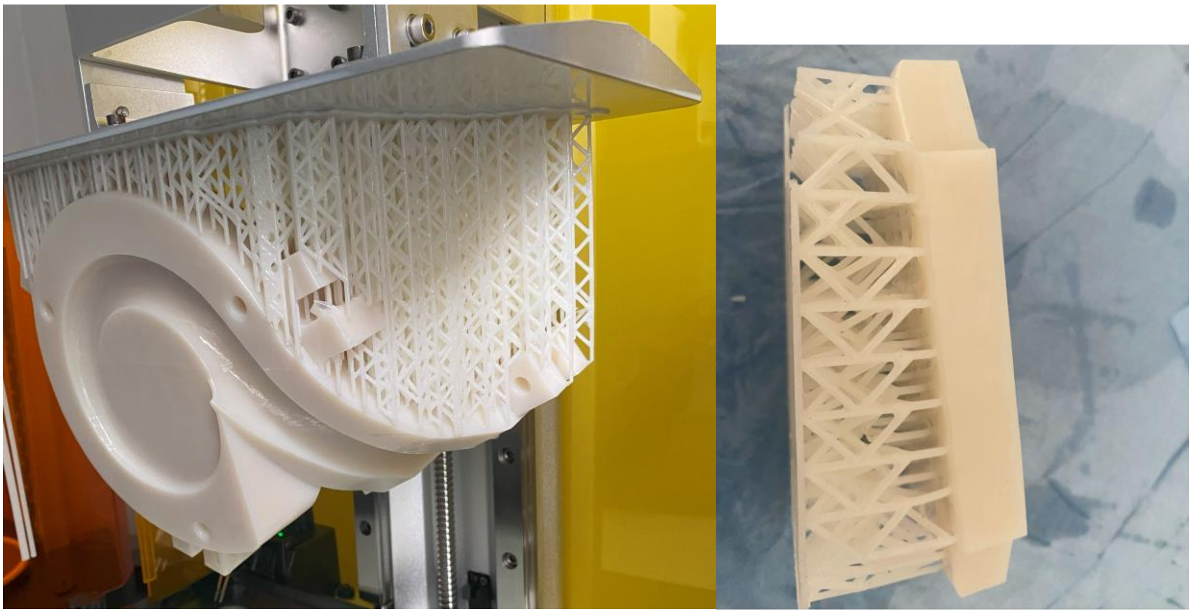

Fig. 4 Examples of supports formed during 3D printing.

The placement of the part affects another important parameter, namely the quality of the printed surfaces of the part. Vertical orientation of parts often results in a noticeable staircase effect on surfaces inclined to the Z-axis. This is due to the technical limitations of layer-by-layer material deposition. To improve surface quality, the part can be reoriented, but this may increase the number of layers and printing time. Surfaces in contact with supports are usually of lower quality, requiring additional post-processing. Reducing the use of supports by correctly orienting the part helps to improve the final appearance of the product.

Parts with detailed features or sharp corners require careful orientation selection to minimize printing errors. Poor placement can result in defects and printing inaccuracies.

Thus, the quality of printed surfaces depends on the correct placement of the part on the platform. Vertical placement is better for parts that require minimal contact with supports, but the risk of defects on the side of

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the platform remains. Horizontal placement is suitable for simple shapes, but complex elements may lose quality.

Saving space on the platform is another parameter that depends on the location of parts on the 3D printer table. If a 3D printer prints several parts at once, correct placement will ensure efficient use of the plate space. This approach will increase the number of objects printed simultaneously and reduce the overall production time.

For example, let's look at these four mould parts. The size of the plate on which the parts are printed is 300x300x150 mm. Let us consider, for example, these four casting mould parts (fig. 5). The size of the plate on which the parts are printed is 300 x 300 x 150 mm. If the parts are placed horizontally during printing (fig 5), only two parts can be placed on the plate, and the total printing time for the entire mould will be approximately 14.5 hours. This arrangement will affect not only the printing time but also the quality of the working surfaces due to the chosen placement of the supports.

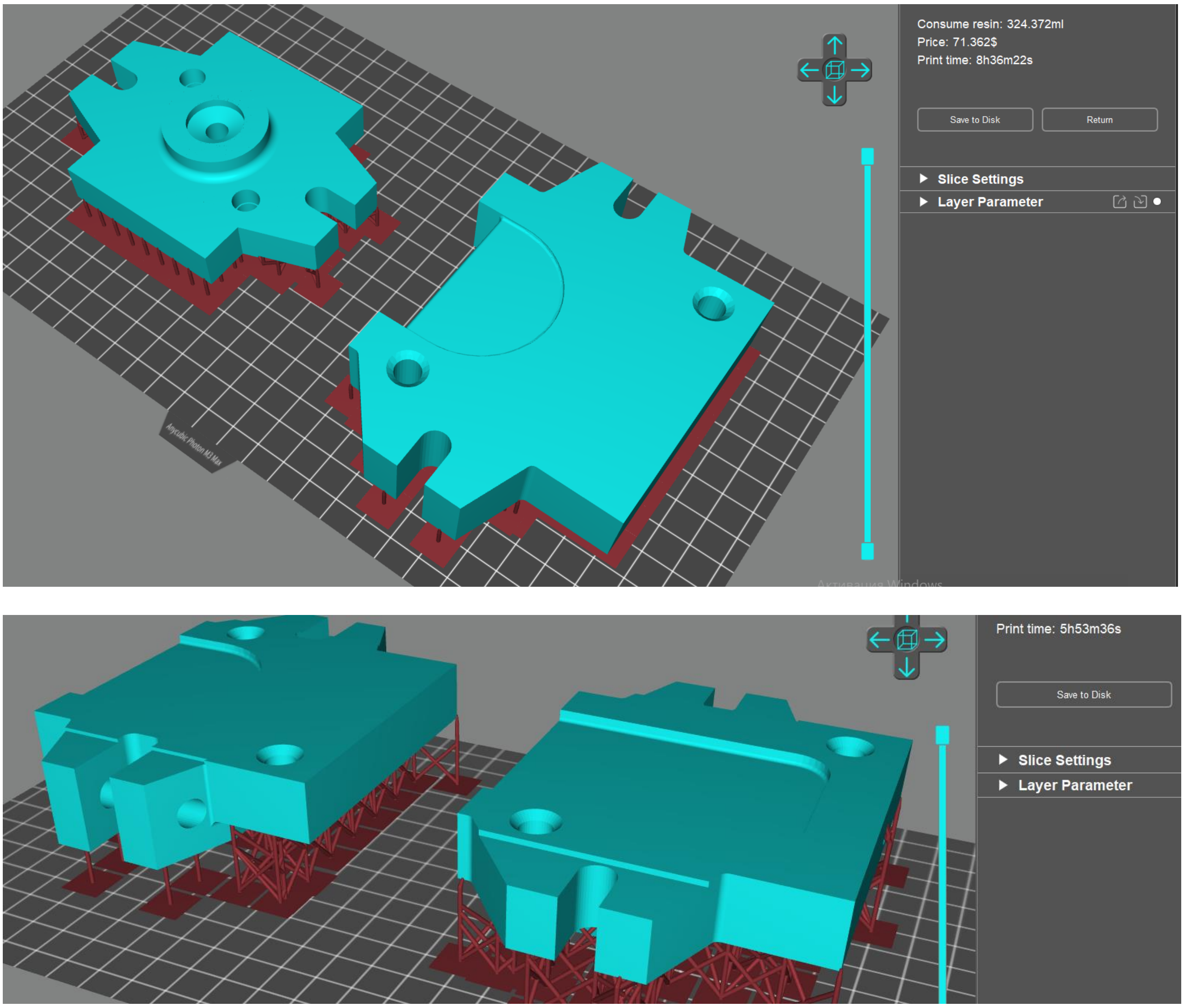


Fig. 5 Different layouts for parts on a 3D printer plate (two parts)

When printing parts horizontally on a 300×300×150 mm plate, only two parts can be placed at a time. The total printing time for four parts in this position is 15 hours. A significant disadvantage of this option is the use of supports that come into contact with the moulding surfaces and affect the quality of the finished products due to the need to remove them later. An important disadvantage of this option is the use of supports that come into contact with the forming surfaces and affect the quality of the finished products due to the need to remove them later.

If the parts are placed vertically (Fig. 6), all four objects can be placed on the platform at the same time. In this case, the supports do not come into contact with the critically important surfaces of the parts. The total printing time is reduced to 13 hours, which improves the productivity of the process. However, the possibility of deformation due to thermal stresses should be taken into account. The upper layers cool more slowly, creating additional pressure on the lower ones, which can lead to distortion of the shape.

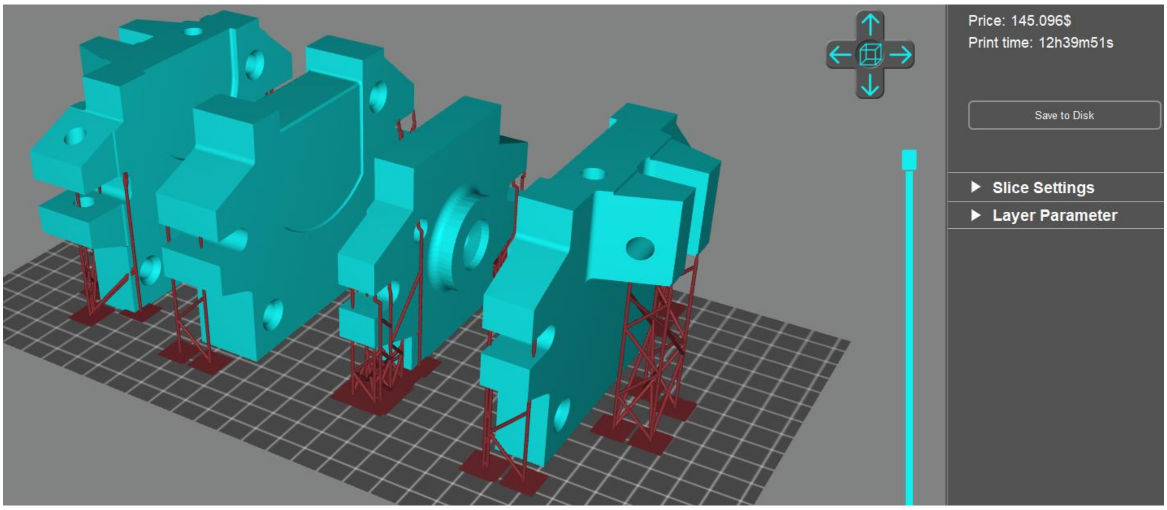


Fig. 6 Different layouts for parts on a 3D printer plate (four parts)

The orientation of a part can also affects its deformation due to thermal stresses. Vertical orientation can lead to more pronounced deformation, as the upper layers cool more slowly and can put pressure on the lower layers.

**Conclusion.** Optimizing the placement of parts in 3D printing helps to balance the following parameters:

Reducing printing time by reducing the number of layers and the volume of supports.

Saving material by minimizing the volume of supports and efficiently utilizing the filling of the part's cross-section.

Improving surface quality by correctly orienting the part relative to the Z-axis.

Minimizing defects by reducing the likelihood of deformations and errors.

Designing and preparing for 3D printing does require specific knowledge and approaches that differ from conventional manufacturing methods such as machining or casting. There are certain specifics and limitations that must be taken into account when 3D printing. Parts should be positioned to minimize the need for support. This will reduce material consumption and post-processing time. Parts that will be under load are best printed in an orientation where the layers do not weaken key areas, i.e., avoid placing load areas along the planes of the layers. For smooth surfaces, place important areas of the model parallel to the platform plane. Position parts at an angle of 15–45° to the print plane and 8–12 mm away from the table to reduce the effect of sticking to the platform and avoid defects.

Thus, the optimal placement of a part is a compromise between quality, time and material consumption.

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