RESEARCH ON 3D PRINTING OF GEARS WITH FDM PRINTER

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ABSTRACT: *3D printing technology was patented in the 1980s, but has gained popularity relatively recent. New techniques have been developed and the possibilities of 3D technology have reached a whole new level. However, even today, the technique is not well known in all circles and not everyone knows what 3D printing is. In today's article, we will try to explain in detail and in simple terms what 3D printing is and where it is used.*

KEYWORDS: 3D printing, deposition modeling, laser synthesis

1. Introduction

In short, 3D printing is a technique for making three-dimensional products based on digital models. Regardless of the specific technology, the essence of the process is the gradual reproduction of objects layer by layer. The process uses a special device - the 3D printer, which prints certain types of materials.

3D printing has a wide application, so we can find it in: medicine, construction, creation of weapons, food industry, etc.

There are several types of 3D printers [1], each with different operating criteria such as fused deposition modeling (FDM) [2], laser stereolithography (SLA) [3], selective laser synthesis (SLS), etc. However, in our case, 3D printing is done using fused deposition modeling technology which involves an additive process where successive layers of material are added under computer control.

2. 3D printing industrial aplication

Using the FDM printing technique, we made 4 gear wheels to demonstrate the performance of the method in everyday applications.

The choice of this 3D printing model was inspired by the frequent use of cogwheels in domestic, industrial, transportation and other environments.

Tab.1. 3D printer parts

Printing nr.	Filling(%)	Printer	Score
1	10	Robofun 3D	3
2	30	Anycubic i3 Mega S	2
3	70	Robofun 3D	4
4	100	Anycubic i3 Mega S	1

The score is 1-4, 4 being the maximum score.

Stages of the work:

- Choose the desired model;
- Designing the model to be printed;
- Printing the model;
- Use the model to observe the resistance.

Two printers were used in the printing process, namely Robofun 3D Printer and Anycubic i3 Mega S to streamline the whole process.

Printing nr. 1

Printing nr. 2

Printing nr. 3

Printing nr. 4

Fig.1. 3D printer parts with different types of printers: printing nr. 1 - Robofun 3D; printing nr. 2 - Anycubic i3 Mega S; printing nr. 3 - Robofun 3D; printing nr.4 - Anycubic i3 Mega S

Printing parameters:

-Fused Deposit Modelling (FDM) printing, i.e. printing on layers;
-10%,30%,70%,100% filled 0.4mm nozzle printing;
-width = 40mm, thickness = 10mm;
-Nozzle temperature 220°C;
-Temperature bed 60°C;
-Printing speed 60mm/s;
-Each piece lasted about 30 minutes.
-Used to support all zigzag backing pieces and printing inside in honeycomb shape
-Material used is PLA;

The process of preparing 3D Printers was:

1.Preheat the bed and clean with 90% pure technical or isopropyl alcohol for better adhesion.
2.Preheat the printing nozzle and collect excess material at the time of starting the printing process.

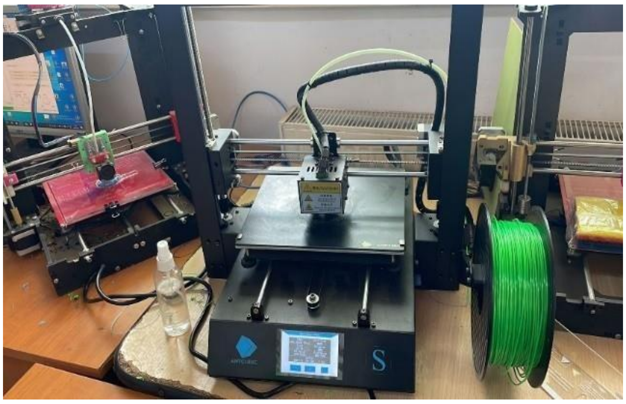

Fig.2. Printing process

Fig.3. Printing defects

The parts were designed in the Fusion 360 program in which the desired dimensions were entered after careful analysis of the part and the appropriate dimensions to fit it into a chain of function, thus forming a digital design of the part in space in order to anticipate the finished product and to determine the exact percentage of similarity with the original part.

In the printing process (fig. 2) we encountered some impediments with regard to air gaps, excess material and wrong sizing due to an error encountered during printing. As a result of that error, we ended up with some rejects (fig. 3).

In order to really see the functionality of these parts we decided to implement them one at a time in a bike's operating cycle to demonstrate their efficiency and to test the material strength.

Several tests were carried out on each sprocket until each one failed, after which we came to certain conclusions about the handling and efficiency that each of them had.

Fig.4. Printing nr. 1

Fig.5. Printing nr. 1 in the bicycle system

The experiment itself consisted of putting the sprocket in the bicycle system (fig. 5) under the action of a constant force over a fixed distance, observing the moment of breakage under the action of the same parameters, the force of pressure on the bicycle pedal being the same, the only parameter we were able to measure that made a difference in each situation was the distance the bike travelled before the sprocket was damaged or broke. We set up a 600metre circuit and started experimenting with each sprocket, the first being the printing nr. 1 (fig. 4) with 10% PLA material.

From the very beginning we can see the imperfections of the piece in terms of shape as well as printing imperfections where there are air voids, but also excess material especially in the lower part, surplus from the support created in the printing process.

All this leads to errors in the experiment and additional interventions in terms of grinding teeth and deepening the wheel pitch. For these interventions we used batteries, sandpaper and a biax (fig. 7).

After performing the experiment on the first model we could observe that the operating distance before breakage was 600 meters, exactly one full circle of the pre-determined route.

Fig.6. Printing nr. 1 after the test

Fig.7. The biax used

We can observe the damage of the teeth under the continuous tension of the chain on the surface of each tooth but also the breakage in the area of the axle (fig. 6) which led to the appearance of a play and a permanent trembling of the chain.

The next piece that was fitted to the bike's shifting assembly was the printing nr. 2 (fig. 8), with 30% concentration. We can also see on this piece the printing defects that led to the deformation of the surface of the piece, the teeth of the wheel not being perpendicular to the surface, having a small elongation towards the outside that led to the incorrect positioning of the chain on the wheel. This wheel also underwent some external work on the teeth and tooth pitch.

Fig.8. Printing nr. 2

Fig.9. Printing nr. 2 after the test

After performing the same experiment, under the action of the same parameters, the result did not differ much from the first test, the distance that the bike was able to achieve was just over 600 meters and the breaking point was still in the area of the central axis (fig. 9), noting that this area is subject to the greatest stress. Being a softer material, wear can also be seen on each tooth.

The printing nr. 3 (fig. 10) with 70% concentration was the piece with the fewest printing defects, the air voids being significantly reduced, the surplus of material existing only in the lower area where the support of the piece was created but also in some areas of the central axis. We can also notice the lack of imperfections in the teeth, being very close to the original piece.

Fig.10. Printing nr. 3

Fig.11. Printing nr. 3 after the test

With the increase of the concentration, the strength has increased significantly, coping with 3 cycles of operation,1800 meters, before it deteriorates and breaks, the breaking area being the central shaft area (fig. 11).

The last piece subjected to the experiment was the printing nr. 4(fig. 12) with 100% concentration. In this case we encountered difficulties in terms of sizing and printing defects. You can see the lack of material in the area of the central axis, which led to a premature breakage of the piece. Also in this case we noticed the same problem we faced with the 30% concentration piece, and in this case the teeth are not perpendicular, having a degree of elongation outwards. This problem with the wheel teeth may be due to the use of a different type of printer for the two parts.

Following the placement of the 100% concentrated part in the bike assembly the result was disappointing. The part only lasted 1200 meters, and even with maximum concentration, the gap in the axle area had a significant impact on the load resistance (fig. 13).

Fig.12. Printing nr. 4

Fig.13. Printing nr. 4 after the test

The appearance of that gap in the central axle has led to low resistance in the use of these wheels, even if we have increased the concentration of each, that gap area in the axle has remained fragile, leading to breakage. Thus the erroneous conclusion arises that the part with 70% concentration resists more to stress, because that part had a low degree of defects and a correct printing in the axle area.

In the course of the experiments we noticed another design flaw: wrong dimensioning of the spindle, with a play between the inner cylinder walls and the spindle leading to the excessive inner cylinder walls (fig. 16). The wrong sizing of the inner cylinder led to errors in the outer cylinder, making it impossible to place a protective sleeve on both the lower and upper side, in order to reduce friction of the part with other surfaces.

Fig.14. How it should look

Fig.15. How it should look

Fig.16. How it looks on the printing nr. 3

3. Conclusions

The experiment itself had an unexpected result given the design flaws as well as the printing defects. In conclusion it can be said that 3D printed parts cannot completely replace "traditional" parts, but, with a quality printer and material, they can contribute significantly to the development of certain products. What is certain is that 3D printing technology is constantly developing and the quality of the models will get better and better.

4. Bibliography

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