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DEMAND FOR RECYCLING FILAMENT IN 3D PRINTING

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Abstract: In the study the brief history of 3D printing is written, how the recent past and present is changing the open source movement. The FDM extrusion technology is reviewed in the text, also the areas where the technology can be used. There is a detailed description about the Creality Ender 5 printer and its printed objects. The study's next main part contains the conceptual design of a filament recycling machine. After the needed market and patent research the functions are established, concepts of the machine are determined. These were evaluated and an optimal sketch was chosen as a result

Keywords: *3D printing, recycling, Creality Ender 5, filament, Ceres (Valdez) principles*

1. INTRODUCTION

3D printing is becoming one of nowadays most popular additive manufacturing technologies. It spreads in wide scales during the past two decades, nowadays many types of 3D printing are existing. Its history cannot look back to a long time instead it began in the 1990s, so its evolution is well documented. With 3D printing three dimensional objects are made first with the help of three-dimensional designing programs, then the models are printed out with the chosen technology.

Specially manufactured materials should be used for 3D printing. These strings are called filaments. Filaments can contain metal, polymer, ceramic, composites, so called smart materials and even special materials like food (pizza). Some other materials can also be mentioned as a printing material such as textile, concrete and their numbers are expanding day by day. Though most of the filaments are polymers, which raises many environmental questions for us.

The application of 3D printing is amusingly vast. This technology is used in aerospace engineering, in the automotive industry, in the architecture industry, in the construction industry, in electronics, in medical areas and in many other fields of science. Today thousands of hobby 3D printers are brought around the world for personal use for those who want to create something unique. Hobby 3D printers are both reasonably priced and available for amateurs. The most common printing materials are polymers with different specifications. A great deal of filaments can be recycled therefore filament recycling machines are needed. The aim of the study was to establish the conceptual design of a filament recycling machine. [3]

2. THE TECHNOLOGY OF 3D PRINTING

The reason for the different kind of printing technologies is the same in case of a regular 2D printing. The following six points are the most defining in connection with what kind of technology we should use for making the objects. These factors are the following: the price of the printer, the quality of the printer, the printing speed, the limitations of the printer, which printer is practical for the print and what are the expectations of the user. The printer should be selected by carefully examining all the parameters, which are required for the printing and the object should be made according to these factors. [4] The steps of the printing processes are quite alike for all the technologies with some minor differences:

- Necessary a three-dimensional designing software,
- Creating the 3D model in the designing software,
- Saving the print in CAD (Computer Aided Design) format, like *.stl, *.step, *.iges,
- Downloading a 3D printing software (Cura, MakerBot Print, PrusaSlicer, Simplify3D), 95% of these softwares can be purchased for free,
- The 3D model should be imported into the program and it must be sliced according to the installed parameters,
- The program saves the appropriate code for the printer then the code is copied to a data storage or transferred directly to the printer,
- The printer reads the code and starts to print the object layer by layer,
- The printed object is finished.

Figure 1
The process of the printing

2.1. Fused Deposition Modelling (FDM) printing technology

Fused Deposition Modelling is one of the most popular printing technologies, because the machines are affordable (relatively cheap) and the required softwares are available easily for everybody, besides the printing materials are also well priced and can be accessed easily. The FDM printing was first introduced by the Stratasys Ltd. in 1980 after Scott Crump developed the process. In most cases thermoplastic polymers are the printing materials. With the help of FDM process functional, accurate prototypes, conceptual models and manufacturing components can be made. Before the printing starts, the user must slice the beforehand designed 3D models, so the printer could translate and execute the commands, after these motions the preheating

of the nozzle and bed must happen before the printing can start. The printer lays the levels on top of each other one-by-one until the model is completely ready. The machine extrudes the melted filament which is after placed on the heated bed. It is important to ensure the proper adhesion on the bed. Like with all technologies, it is important to note that the time of the printing depends on the size and complexity of the object. Postproduction can include the removal of the support material or sand grain grinding so this way the objects get a mirror surface. BMW and Nestlé are also using FDM technology at their factories. [5]

3. THE ENDER 5 PRINTER AND ITS PRINTED OBJECT

The Creality Ender-5 printer, besides being a reasonably priced printer, carries many advantages. It has countless useful functions. This printer is an FDM printer which means that it heats, melts and extrudes the used filament. After extruding the material, it creates layers on the heated bed on top of each other as it was already mentioned it earlier. This work continuous till each layer is done and the model is complete. The printing area is 220 × 220 × 300 mm, so this is the maximum size which the printer is capable for. The printer is manufactured and distributed by a Chinese company. The Ender 5 was priced at 300 dollar in 2019 June, which approximately means 90 thousand forints in Hungarian currency. The Creality company makes a great deal about packaging, it is extremely important for them to transfer the printers to the buyers in perfect condition, buyer satisfaction is always a key component when it comes to choosing manufacturers. The company is labelled according to the users submitted evaluations. Both the ordering and he shipping part was easy and quick. The communication and the problem solving with the buyers is fast and polite. The printer arrived in a complete kit, in cardboard box. The parts were disassembled and placed in protecting sponge material. The printer must be assembled before use according to the instruction manual. The assembling took about 1–1.5 hours, it was not complicated to piece it together. After the assembly and filament filling, only the calibration was left. In this machine the calibration happens manually, the nozzle's height must be adjusted by eye. After the calibration test printing can be started either from the printer's memory (code installed in advance) or we can print anything (own models) we put on the SD card. It is recommended that we make test prints beforehand to install the right printing parameters. One of the printer's advantages is that in spite its price-value rate the printing quality is good, and the printing area is considerably large. However larger models take longer time to print. Long printing time comes with a risk of power break or any other power failure and the printing can stop. This problem is solved by a special function which resets the print from where it stopped before the power break so the printing can continue from the layer the print was suspended. This was the printing can be saved and continued after-wards. The proper printing level is not easy to find, so some practise is needed. There was only one problem with a failing part and that one was the filament extruding part. After a few weeks of printing the polymer extruding element broke and could not extrude the right amount of filament from the nozzle. It is recommended to replace

the polymer part with a metal one or with an even more advanced closed box extruder. Either extruding part can be purchased easily for a few thousand forints. Since this part was replaced there was not any other problems with the extrusion. Another weak point on the printer is the bed which is not supported the right way and it trembles sometimes when a high and slim part is printed. A more rigid framework would not let this shaking happen. This problem can also be solved with some support tools, which can be printed with the 3D printer. Despite these little bumps this printer is quite capable and smooth while working. The printer is also user friendly with an operating screen. All in all, the Ender 5 is a fine choice for a user who is starting to get in touch with 3D printing.

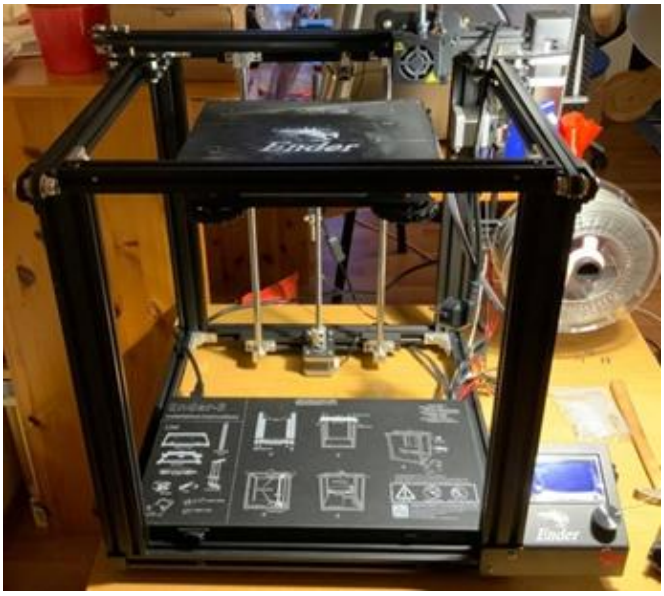


Figure 2
Creality Ender 5

The following pictures demonstrate some of the test prints. Every single printed model is unique in their own way, there are not two models that look exactly alike. Every piece has its own difficulties during the printing process. The little white octopus is a special model because its body is segmented, but it can be printed in one piece, the arm's parts are printed at the same time in the same printing process. This model does not need any further piecing together later on. The satin blue clamp, which as in the printing process during the time the photo was taken serves the role of securing the filament spool in place. The little black boxes play a part in cleaning the filament from dust or any other pollutions before it is extruded. From these objects we can see that hobby printer users have many opportunities when it comes to printing something useful. They can also print such parts which can enhance the printer's capability.

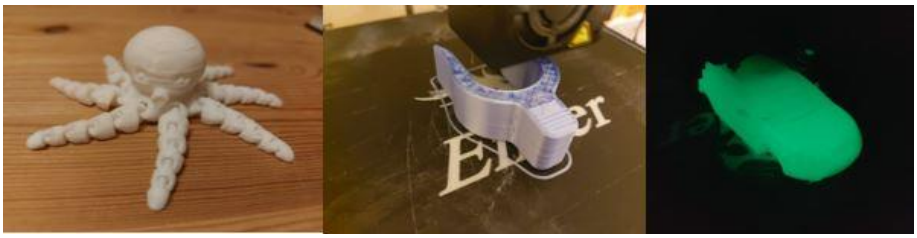


Figure 3
Printed articles for personal use and ornaments

There are special materials among the printing materials, for example there is a filament which changes colour when the temperature changes, it is called thermo filament. There is another material which glows in the dark, we can see a photo of the fluorescent filament where a car is being printed. The last two models to be mentioned are connected to engineering. One of the models is a twin-screw, the other one is a planetary gear which was a great help during the studies.

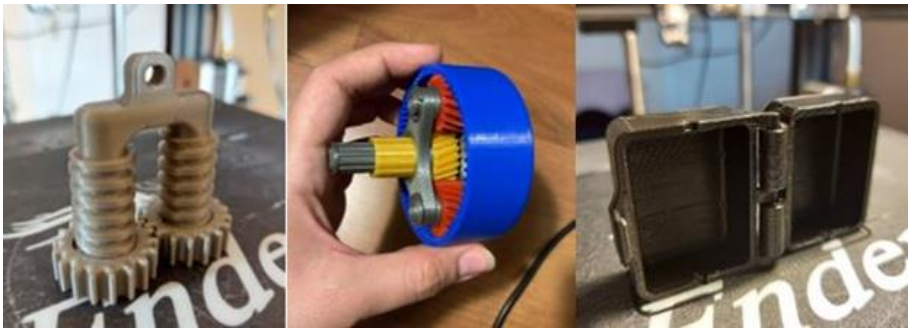


Figure 4
Printed and fitted machine parts

4. CONCEPTUAL DESIGN OF A FILAMENT RECYCLING MACHINE

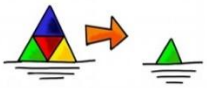
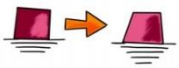
Many of the amateur printers print at home and they learn all the mishaps by themselves, resulting that it is almost impossible to do everything right the first time. Luckily at University of Miskolc students have an extracurricular activity group called Fast Prototyper's Club which is for everyone who is interested in 3D modelling and printing. We can collaborate on different projects with other students and we can also share our experiences with each other. Despite having more and more experiences, we still make mistakes every day during printing and we must learn hundred more facts abouts 3D printing. One thing we definitely have to learn is to prepare less waste. Recycling filaments would be a great possibility for that. It is a fact that the manufacturing of a machine is also harmful for the environment, but the great amount of recycled filament would balance the environmental impacts of a filament recycling machine. [2]

Figure 5
Waste filaments

4.1. Functional subassemblies of the recycling machine

Functional designing can happen through different paths. For a better demonstration, the functional subassemblies are represented with figures. It makes it easier to visualize the functioning mechanism if we see a visual indicator such as a drawing or figure, therefore I choose this method to explain my ideas. [1]

Table 1
Functional segments

Storing box		Spooling mechanism	
Feeding unit		Modular function (changeable extruder size)	
Chopping unit		Forwarding, moving unit	
Heating unit		Size monitoring unit	
Temperature controlling unit (temperature check)		Power source	
Cooling unit		Controlling unit (the machine's "brain")	
Extruder			

4.2. The optimal concept

The presented concept is full of functions, the complexity itself means compact performance, because the whole system is automatic from placing the filament in the machine to receiving the finished filament spools. The power source and the controlling unit is managed with a micro-controller platform. The polymer placed in the container box is moved from the feeder unit to the chopping unit. The machine chops the polymer into pieces for the easier heating. The material pieces are transferred to the heating unit where the polymer is melted down. The temperature controlling unit is responsible for keeping the material at the right temperature through the process. The melted polymer leaves through the extruder, where it goes under size verification and cooling. After cooling down the filament, the machine cools the spool down, rolls it up and stores it inside. The special function of this concept is that the extruder head is modular which means that it can be changed into a different size. The two preferred filament sizes are 1.75 mm and 2.85 mm. This solution is complex, but its production is fast and easy thanks to the automatic working.

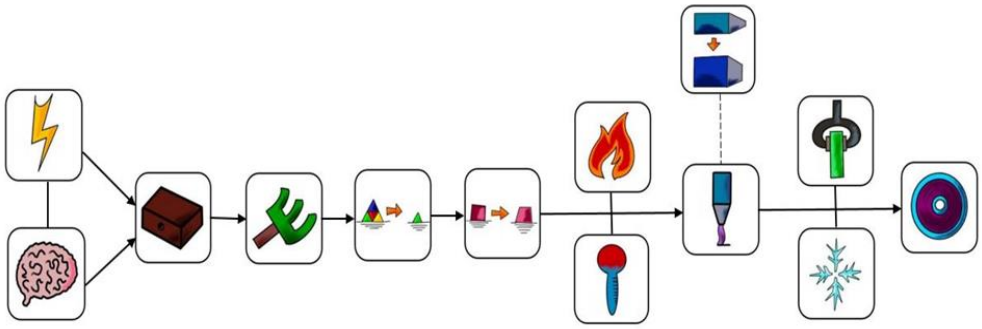


Figure 6
The optimal concept

5. SUMMARY

The study focuses on getting acquainted with the 3D printing technology. The technologies widespread-functionality and usability is mentioned in the paper. The Fused Deposition Modelling technique is introduced and there is a brief explanation about the 3D printing process as well. Following these topics, the own experiences of a Creality Ender 5 printer and a few printed models were introduced. After establishing the need for filament recycling machines, the last main part of the article deals with the conceptual design of such a machine. The functional units were also illustrated and explained in detail. In the near future the construction of this filament recycling machine will be worked out.

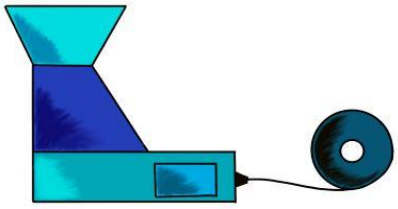


Figure 7
Sketch of the filament recycling machine

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REFERENCES

[1] Otto, Kevin N., Wood, Kristin L. (2001). *Product Design*. Techniques in Reverse Engineering and New Product Development, Prentice Hall Upper Saddle River, New Jersey, USA.

[2] Jayatilleka, S., Okogbaa, G. (2014). *Accelerated Life Testing, 2014 Workshop on Accelerated Stress Testing and Reliability Conference*, Saint Paul, Minnesota, United States, pp. 1–21.

[3] https://3dinsider.com/3d-printing-history/

[4] https://www.sculpteo.com/en/3d-learning-hub/basics-of-3d-printing/the-history-of-3d-printing/

[5] https://3dsourced.com/guides/history-of-3d-printing/