REPRAP P3STEEL SPATIAL PRINTER CONSTRUCTION DESIGN

Projekt budowy drukarki przestrzennej REPRAP P3STEEL

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Abstract: The introduction describes the purpose of the article, i.e. designing a REPRAP printer. The article includes an overview of additive manufacturing techniques. The next section discusses the definition of a self-replicating REPRAP printer. Then, the example of the method for extruding thermoplastic materials with the use of the FDM / FFF technique served to present the list of parts and the design of the REPRAP P3STEEL spatial printer. Tests were also carried out and the prints were compared with the Zoltrax M200 serial production printer.

Keywords: assembly, 3D printers

Streszczenie: We wstępie został przedstawiony cel pracy, czyli projekt drukarki REPRAP. Praca zawiera przegląd technik przyrostowych. W kolejnej części omówiono definicję samoreplikującej się drukarki RERAP. Następnie na przykładzie metody wytłaczania tworzyw termoplastycznych techniką FDM/FFF przedstawiono wykaz części i projekt drukarki przestrzennej REPRAP P3STEEL. Przeprowadzono również testy i porównano wydruki z seryjną drukarką Zoltrax M200.

Słowa kluczowe: montaż, drukarki 3D

Introduction

Although 3D printers are not a novelty on the market, they are becoming more and more popular. They are used not only for exclusively engineering purposes, but also as a hobby or in commercial applications, e.g. while printing promotional materials for companies.

The scope of 3D printing is not limited to standard plastics such as ABS or PLA. It also includes printing from non-standard materials such as chocolate or concrete.

The price of three-dimension printing machines can still be high, especially when used in professional systems, but after analysing the costs, it can be concluded that their construction can be cheaper and simpler. This article presents a method for constructing an inexpensive open source RepRap P3Steel printer.

Additive Manufacturing Techniques

Extremely fast development of spatial modelling techniques, including solid and surface modelling, allowed making equally dynamic advances in rapid prototyping methods. Taking advantage of the geometry designed in the engineering process makes it possible to form such geometry into a real object. The object is formed by dividing its geometry into individual layers, on the basis of which a machine code controlling the prototyping machine is generated. The machine engaged in the printing process constructs the model in a layer-by-layer manner by combining successive layers [2, 9, 10]. When the term "rapid prototyping" is used in the context of 3D printing it definitely means creating a real object with the use of a digital model [10].

3D printing is, therefore, a visualization of the possibilities of computer-aided engineering. Currently, the use of 3D printing in rapid prototyping is becoming a very popular method helping to check printed models. 3D printing has also appeared in medical applications, where, for example, on the basis of the printed model of an organ or the structure obtained from a tomographic scan, precise consultations and attempts at predicting a course of surgery [3, 4, 5].

3D printing has also found its application at homes as it has allowed ordinary people to visualize their creative mental ideas. Thanks to a huge community interested in it, 3D printing is also a source of infinite ideas, new devices facilitating household chores or gadgets [9].

Stages of three-dimensional printing

The process of developing an idea into a physical object has several stages. The design must be prepared in a virtual three-dimensional space, actually its mesh geometry allowing to map the model, and then it must be exported to CAM software which is responsible for dividing the model into layers and generating motion paths for applying the binding agent, a molten material, or motion paths for the laser beam, in the form of a code understood by a numerically controlled machine tool (CNC). After completing this process, the object is ready for possible finishing, such as smoothing surfaces or removing unnecessary filling. Sometimes it is also necessary to remove unnecessary additional supports [10].

The above description is presented in the form of a diagram in Figure 1.

3D CAD	3D CAM	3D Print	Physical object
The stage involves preparing virtual spatial geometry in the 3D modelling system and its converting into mesh geometry	The stage consists in dividing virtual geometry into layers and programming the movements of how to apply material, a binding agent or a laser beam	The stage involves producing a real object with the use of an additive manufacturing technique in a numerically controlled machine (NC/CNC)	The stage consists in removing the real object from the machine and its possible finishing treatment

Fig. 1. The main stages of the 3D printing process [10]

Printing methods

Additive manufacturing techniques are divided according to the printing method used. They include the following:

- Stereolithography – SLA,
- Laminated Object Manufacturing – LOM,
- Fused Deposition Modelling/Fused Filament Fabrication – FDM/FFF,
- Jetting Modelling – JM,
- Powder-Based 3D Printing 3DP,
- SLS/SLM/LENS.

The method for extruding thermoplastic materials with the use of the FDM/FFF technique was applied in the printer presented below.

Extruding thermoplastic materials – FDM/FFF Fused Deposition Modelling or Fused Filament Fabrication – is an additive manufacturing technology consisting in extruding material through a nozzle along paths. The semi-fluid material bides with adjacent paths, forming a solid model in a layer-by-layer manner [9, 10].

This technique mainly uses thermoplastic materials such as ABS, PLA or nylon. The process involves introducing the material in the form of a fishing line from the spool into the pushing mechanism which presses it into the print head, where in the temperature range suitable for melting a given material (190ºC – 280ºC), it is transformed to a semi-liquid state and extruded through a nozzle of the appropriate size, along the path in the horizontal X-Y axes. After extrusion, the material solidifies, biding with adjacent paths, creating a ready model in a layer-by-layer manner [9, 10].

The general model of the printer construction in the FDM technique consists of two feeders controlling the amount of material pumped into the heated nozzles. The material in them is heated to the melting temperature and pressed directly onto the working platform or the previous layer of the model. The working platform usually consists of a heating table (due to the considerable shrinking of the material when it is cooled and the detaching of the model or its part from the working platform). The nozzles move in the X-Y axes, while the Z axis is responsible for the movement of the platform [10], which is shown in Fig. 2.

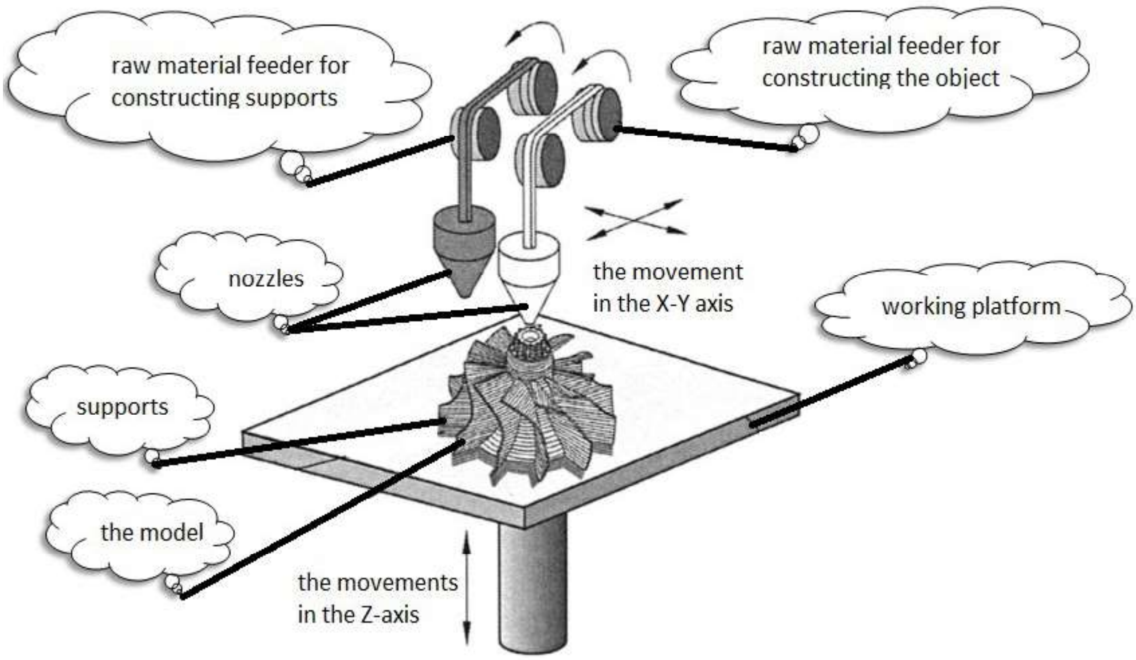

Fig. 2. Model construction diagram according to the FDM technique [10]

Selfreplicating RepRap machine

RepRap is an open, i.e. having sources available for everyone, design of a utility spatial printer. The machines in this design mainly consist of plastic parts printed with the use of one of the additive manufacturing techniques. After a new printer is completely assembled, it is able to produce further parts, enabling self-replication [1, 7, 8].

RepRap printer design

The growing popularity of 3D printing, particularly the FDM technique, has contributed to the appearance of many printer designs and new concepts for how to construct them. Designs of and modifications to 3D printers which are developed by individual users, who improve structures, and which are made available to the public under a free license are gaining more and more popularity and becoming another well-developed standard for improvement.

The table below shows the parts suggested for the construction of the printer (Tab. 1).

This printer consists of only a few printed parts, because all the fragments of the support frame made in this way have been eliminated. Connecting standard steel parts and additively manufactured ones is carried out without any problems. The assembly of the printer according to the concept presented in the article is shown in figures 3-9.

Table 1. List of parts used for constructing a 3D printer

	Type of parts	Selection
1.	Print method	FDM
2.	Frame	"P3Stell" model
3.	Drive	42BYGHM809 engine by "Wantmotor" was selected Their specifications are: • resolution: 400 steps per turn (0.9 °) • rated voltage: 3V • current consumption per coil: 1.7 A • coil resistance 1.8 Ω • winding inductance: 2,88 mH • moment holding 4.89 kg*cm (0.48 Nm) • outputs: bipolar (four wires) • shaft diameter: 5 mm • weight: 360 g • dimensions: 42 x 42 x 48 mm (without a shaft) - NEMA 17
4.	Extruder	"MK8" by "Geeetech" Specification: • heater: 6 mm, 12 V, 35 W • built-in stepper motor KS42STH48-1684A • motor current: 0.83A • engine speed: up to 40 mm/s • filament diameter: 1.75 mm • nozzle diameter: 0.40 mm • thermistor: 100K NTC • normal operating temperature: 190230°C¬ • supported material: PLA and ABS and other • built-in fan: 40x40 mm • metal construction • net weight: 450 g
5.	Electronic parts	Arduino Mega 2560 microcontroller board paired with RAMPS version 1.4 driver, and drivers for DRV8825 stepper motors, "Full Graphic Smart LCD Controller" display by Reprapdiscount.
6.	Table	aluminium heating table, RepRap Alu-Heatbed MK3
7.	Inductive sensor	model: LJ12A3-4-Z/BX. Its specifications: • output configuration: NPN / NO • range: 0-4.0 mm • supply voltage: 6-36 V DC • operating current max: 200 mA • sensor housing: M12 • number of pins: 3 • cable length: 1.0 m • dimensions: 63 x 12 mm
8.	Power supply	Zalman ZM400-LX
9.	Printed elements	printing of all parts took about 80 hours and was performed on a Zortrax M200 3D printer
10.	Firmware	Firmware used in RepRap machines is a comprehensive program controlling the operation of engines, heaters and sensors. It is controlled by means of common numerically controlled machine codes, the G-code command language. The program works in real time by sampling signals from thermistors. It allows printing from a mass storage device connected to the controller or via computer connection (this solution may cause delays and consequent print quality problems

Source: http://wantmotor.com/product/42byghm.html, http://geeetech.com/wiki/index.php/MK8_Extruder, http://reprap.org/wiki/Arduino_Mega_Pololu_Shield, Kaziunas France A., Świat druku 3D, Wydawnictwo Helion, 2014

Fig. 3. The assembly method with the use of M3 self-locking screws and nuts, P3Steel printer frame [own elaboration]

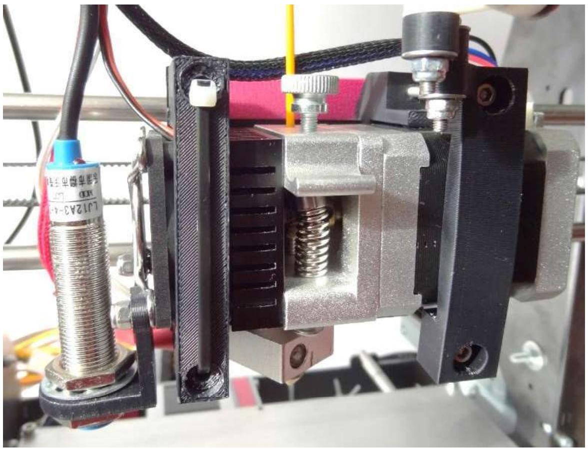

Fig. 6. The complete MK8 extruder mounted with the use of printed parts [own elaboration]

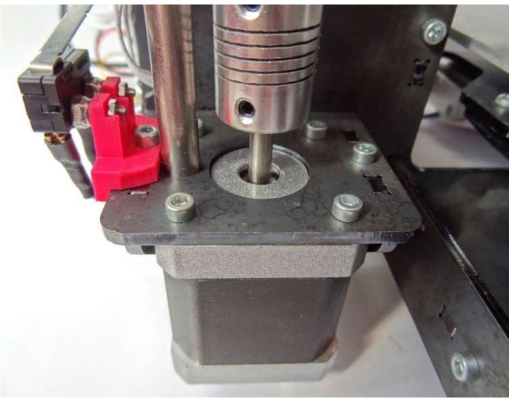

Fig. 4. The complete lower end of the Z-axis [own elaboration]

Fig. 7. The mounted holders for the spool of printer raw material [own elaboration]

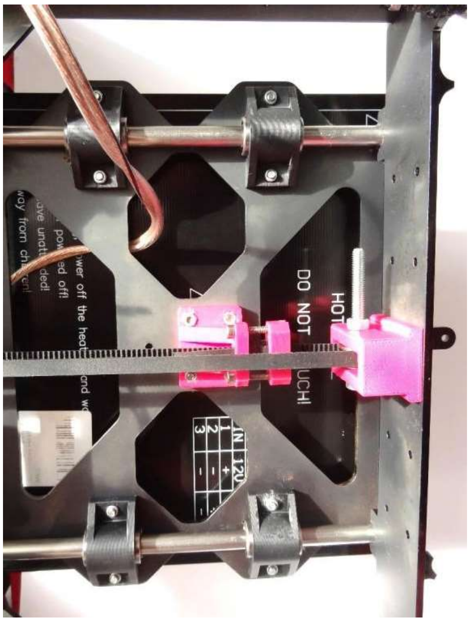

Fig. 5. The assembled Y-axis, bearings mounting, tensioner mounting, toothed belt mounting, and the installed heating plate [own elaboration]

Fig. 8. The holder, the mounting and location of the inductive sensor relative to the extruder nozzle [own elaboration]

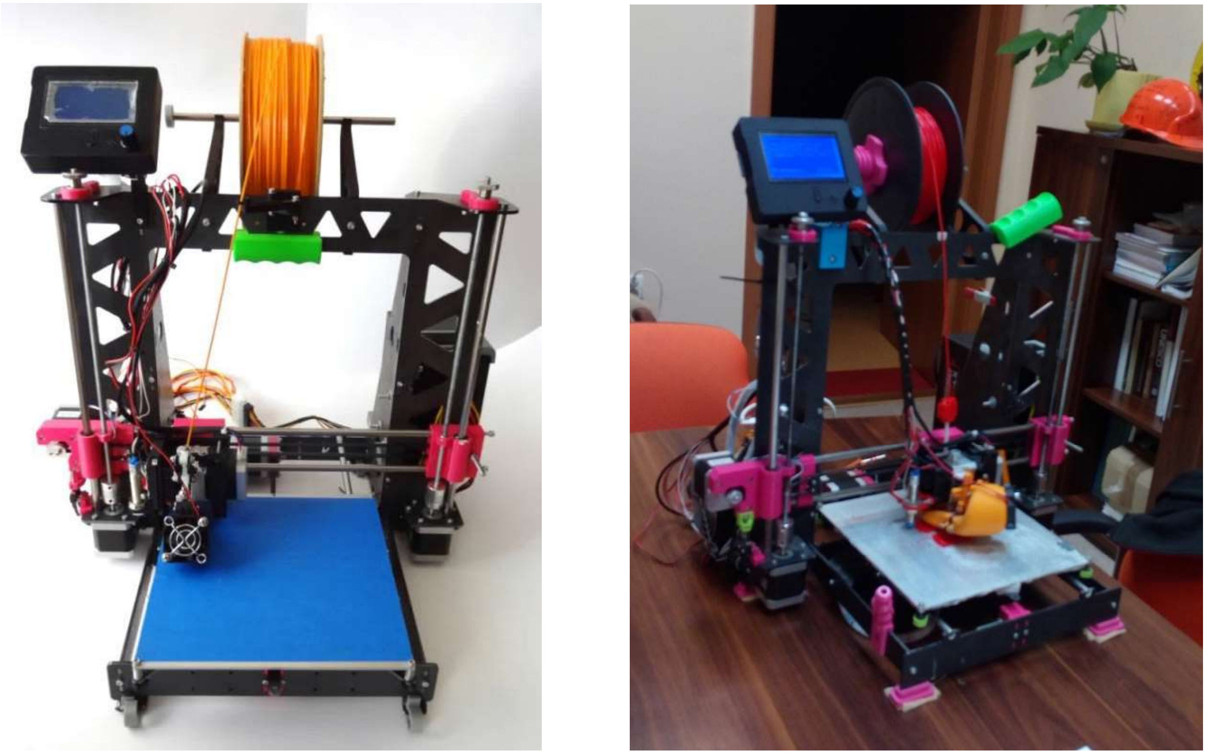

Fig. 9. The complete RepRap P3Steel device – on the left-hand side, The 3D printer during the test – on the right-hand side [own elaboration]

Comparison of printout quality

In order to verify the printouts generated by the RepRap printer presented in the article, the quality of its printouts was compared with those generated by the Zortrax M200 printer, as shown in Figures 10 and 11. There were no significant differences in the quality of printouts from both printers in terms of resolution and the surface itself.

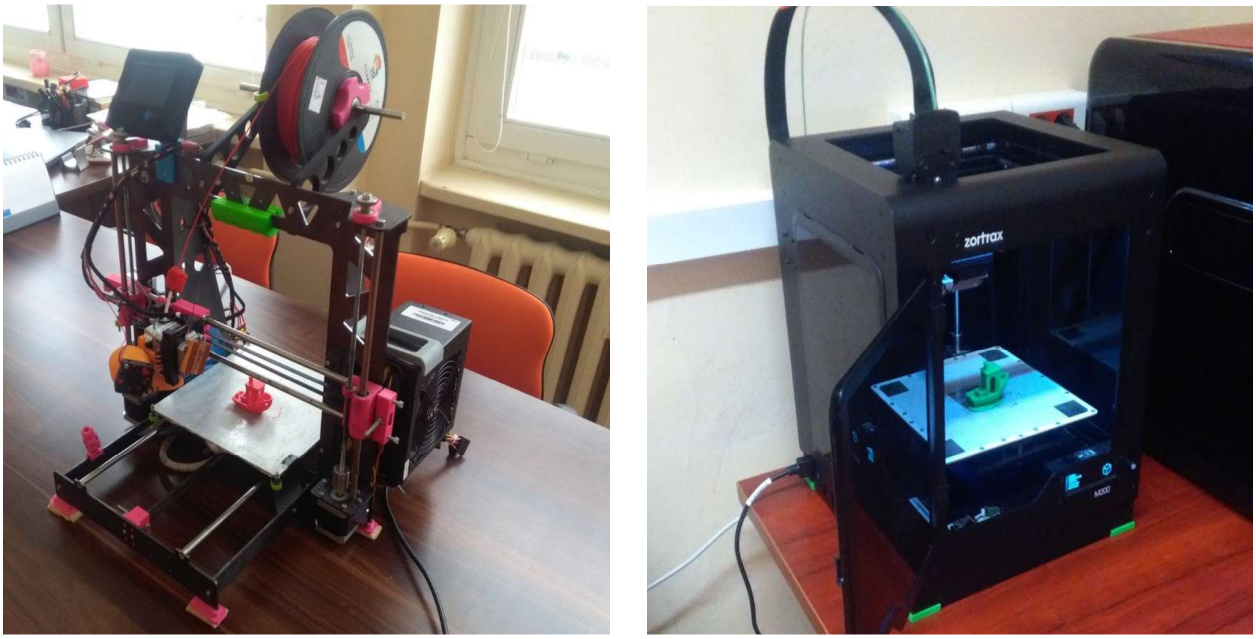

Fig. 10. The printout of the model generated by RepRap P3Steel and Zortrax M200 [own elaboration]

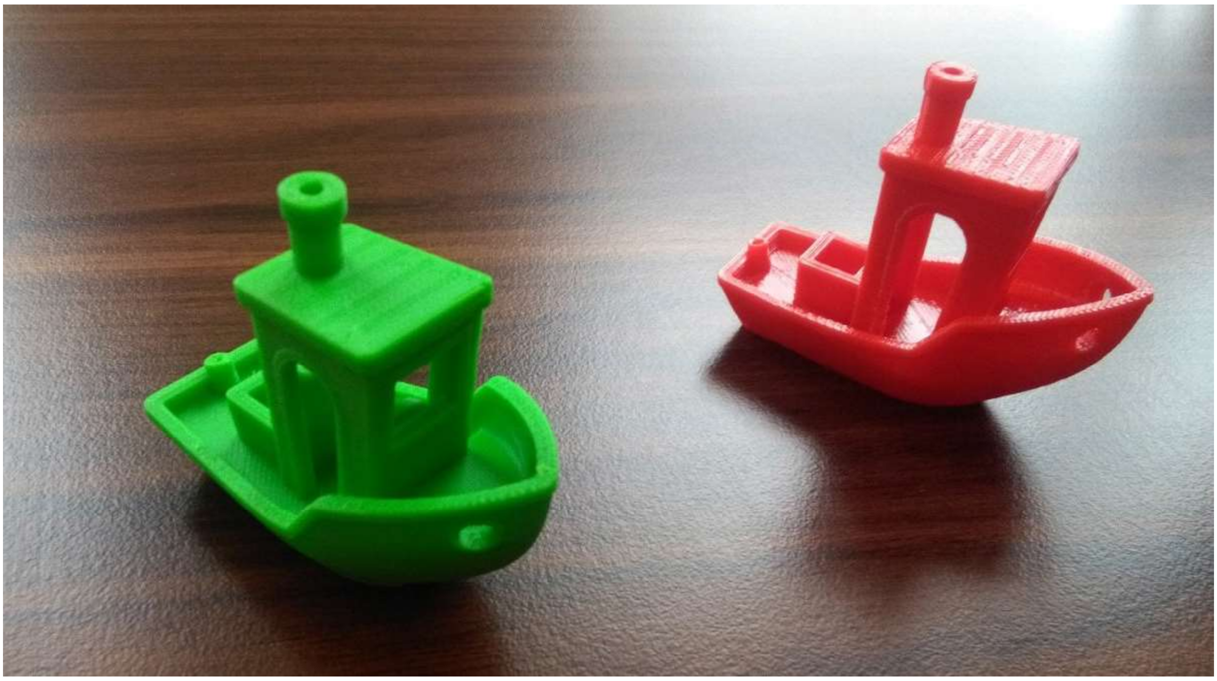

Fig.11. The prints from RepRap P3Steel and Zortrax M200 [own elaboration]

Conclusions

The increase in the popularity of 3D printing, in particular the FDM technique, has contributed to the emergence of many printer designs and new concepts. Projects and modifications developed by individual users, who are constantly improving their own designs as well as constructions available to the public under a free license, are gaining popularity and are becoming another well-developed standard for community improvement.

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