# THE DESIGN OF THE 3D PRINTER FOR USE IN GASTRONOMY

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The research presented in this article deals with the design of appropriate technology and with an implementation of the structural design of the 3D printer for use in gastronomy. A printer concept of RepRap open source project was used and completed with own solution of the extrusion head for printing with chocolate. Chocolate was chosen since it can be easily converted by heat into a plastic-like material and displaced through an extruder on a substrate. Thanks to that, you can print business cards made of chocolate, pralines in shape of whatever the customer desires, or portraits. The printer can also be used for other materials, such as different toppings on cakes, or very complicated structures that would not be possible to create without using 3D printing.

**KEYWORDS**

3D printing, 3D chocolate printing, food printing, additive manufacturing, printing technologies, RepRap

## 1 INTRODUCTION

Currently, the use of the 3D printing in gastronomy is on the rise. A huge range of ingredients has been printed, from pizza dough, meat, pasta, to confectionery products such as sugar, chocolate, decorative cake topping and many others. [Izdebska 2016]. Companies try to overtake each other regarding what their printers are capable of, whose one has an implemented oven, whose one has a chocolate print head with so efficient cooling, that the printer is capable of building 3D objects. Many technologies are a subject of patent protection, and many procedures are considered to be a companies' secret "know-how". [Sun 2015a]

The European Union sees the potential of such printing for provision of food for elderly people and people with swallowing troubles. These people often have a specially prescribed food, which is, in most cases, without any nutritional value and is tasteless. Using 3D printers might solve this problem by preparing of special meals printed accordingly to individual needs of each elderly person. [Jia 2016, Sun 2015a]

Sending of materials and ingredients into space is nowadays very costly. That is why NASA invests considerable amount of money into development of a 3D printer that would be transported to a space station, where it would print food for astronauts using the prepared filling. [Lin 2015, Lipton 2015]

Coffee houses, which use 3D printers to prepare unusual coffee, emerge all around the world. One of the most common 3D printer technologies is a special burning laser head that burns any object that the customer wants from a foam. Another of the commonly used technologies is based on an application of a special coffee extract on a coffee foam. [Pallottino 2016]

Another field of gastronomy, which takes advantage of a huge development of 3D printers, is printing of the pasta. The main goal of the companies, which deals with pasta printing, is to be able to offer pasta that the customer, who comes into their shop, desires. The customer comes with a USB drive that contains a prepared 3D model. The operator processes the model and lets the printer print as much pasta as the customer ordered [TNO 2015].

However, the hugest rise in the 3D food printing is in the confectionery craft. A wide range of materials is used for printing (chocolate, creams, sugar material, etc.), and shapes, which the confectioners are not able to create by conventional methods, are created. [Godoi 2016]

Many shapes and forms of sugar cubes can be made using 3D printers. Printers can be used for any shape, and the fantasy has no limits [3D Systems 2016]. There are two ways to print sugar, both are based on using of heat. Each of them uses a different range of heat. Additionally, the used temperature depends on the type of the sugar and on ambient conditions.

Chocolate is one of the few materials proved to be usable with Fused Deposition Modelling (FDM) technology [Izdebska 2016]. Chocolate can be easily transformed into a creamy state using heat and has therefore similar characteristics to plastic materials, which are commonly used in 3D printing by means of FDM technology [Jia 2016]. Basis for successful chocolate printing is an appropriate mix of the chocolate mass. The priorities are in its colour, taste, but primarily in its consistency. If the chocolate is too thick, it might not be possible to push it through a nozzle. Conversely, too thin chocolate would not be able to keep shape. That is why having a proper mix is very important. Using a correct mix and good cooling, printing of 3D objects from the chocolate can be achieved. This printing method is becoming very popular among confectioners and home users of common RepRap printers [Sun 2015a, Landoni 2014]. The user can simply, quickly, and, above all, cheaply create chocolate business cards, pralines of various shapes or a chocolate gift in a form of the personal portrait.

## 2 CONCEPT OF A 3D PRINTER

For this project, the chocolate was selected as a printing material. Chocolate is very suitable for 3D printing, since it can easily be transformed into plastic state allowing printing by extruding the chocolate from a nozzle and consequently applying it onto the workspace. The principle is very similar to a classic FDM technology. Preparation of the chocolate consists of simple mixing and melting of several ingredients.
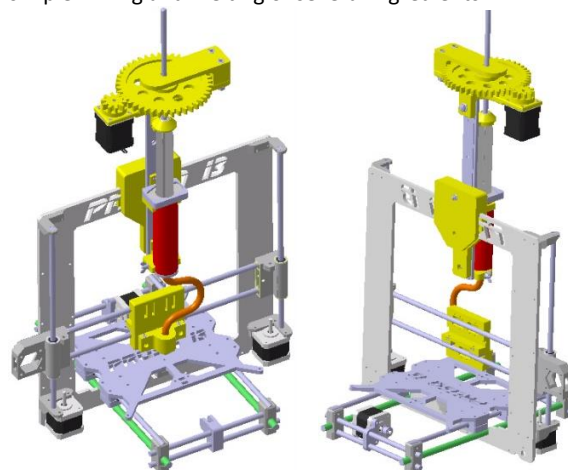


**Figure 1**. Concept design of a 3D printer fitted with extrusion mechanism [Ruzicka 2016]

The concept design of the 3D printer (see Fig. 1) consists of three steps. The first is the frame, which has to be firm enough to withstand the load of moving parts. Also, it must be stable enough to avoid deviating from the equilibrium position. Another step is to design the extrusion head, which is used to

create the required object and is attached to the moving part of the frame. Control elements are an integral part of this printers, which is controlled by a computer. Various software for 3D printer control can be installed into the computer.

For this project, we decided to use Prusa Mendel i3 design, which the Department had already had available in its 3D printing laboratories.

## 3    MATERIAL EXTRUSION METHODS

There are many ways to extrude chocolate. There are complex and simple methods for achieving the uniform extrusion of the medium onto the work pad.

### 3.1    Extrusion by means of rotating screw

This method is very similar to extrusion of plastic materials. Firstly, chocolate granules are put into a hopper above the rotating screw. The screw rotates, conveys the granules into a chamber that is heated from the outer side by heating elements, which consequently melts the chocolate to a plastic-like material. A nozzle (extruder) is fitted onto the end of this chamber, the chocolate is extruded through this nozzle onto the work pad.

### 3.2    Extrusion by means of screw pump

In terms of this project, an extrusion head that uses a screw pump together with an eccentrics screw rotor was designed as one of the variants (see Fig. 2).
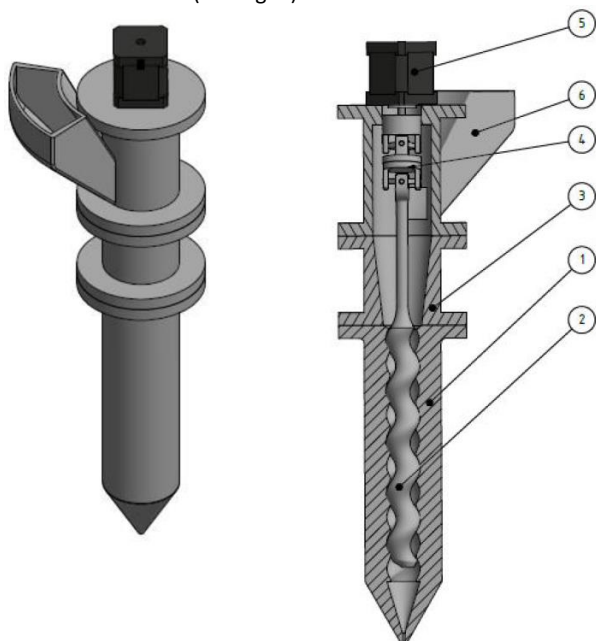
The rotor (2) is mounted into a stator (1) made of elastic material (elastomer), while the stator has a slight overlap. That creates small gaps, though which the chocolate is pumped. The chocolate granules are put into a hopper (6), which is mounted to the device, then they fall into a heated chamber (3), where the chocolate is melted, and afterwards it is collected by the rotor. The rotor is powered by a stepper motor (5). The rotor eccentricity is compensated by a joint mechanism (4).

### 3.3    Extrusion by means of a piston

The most common method of chocolate extrusion in a 3D printing is extrusion of the medium by a piston. A syringe is used in many cases. This is the most affordable and the simplest

method of extruding of the chocolate. We decided to use this method for our project.

By performing experiments, we determined the required extrusion force that has to be applied on the piston. In accordance with this force, gear ratios and required power on a motor, which actuates the extrusion mechanism, were calculated. The selected motor was identical to motors, which were already attached to the printer's mechanism and perform movement of axes. That enabled simpler connection to the printer's control unit.

Most of parts of the extrusion mechanism (Fig. 3) were printed on a 3D printer using ABS material. Standard parts are a threaded rod, bearings, sliding guide rails with carriage and fasteners.
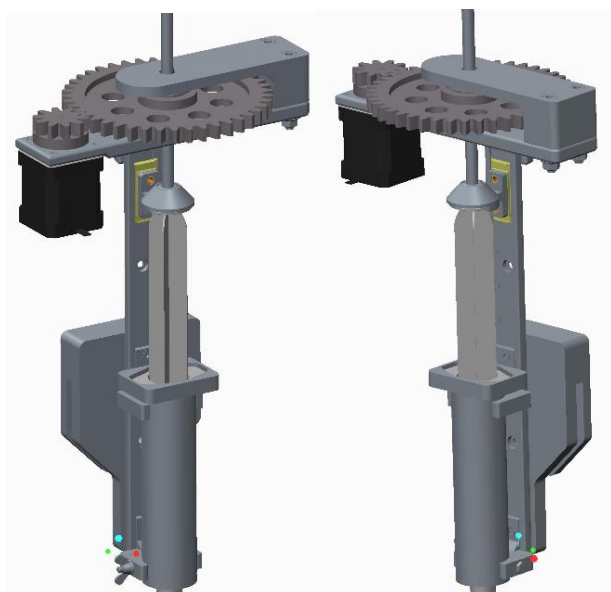


Figure 3. Piston extrusion mechanism

Due to its large weight (1,4 kg), the whole mechanism is mounted to the frame of the device (Fig. 1), and the syringe output is connected with the nozzle via a flexible tube mounted to the printer's carriage instead of the printing head (Fig. 4).
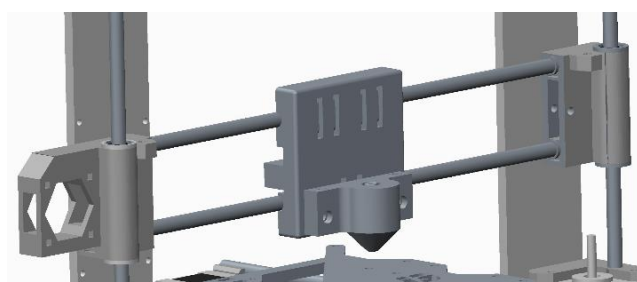


Figure 4. Printing nozzle fitted to the printer's carriage

## 4    PRINTER CONTROL

The Repetier-host was used for printer control. Repetier-host is a freeware available on the developer's website. The software is characterised by easy and simple controllability. The computer with the software is connected to printer's control unit by means of a USB port. The printer's control unit is based on Arduino Mega2560 Rev3 main board.

The preparation of data for printing is similar to data preparation for 3D printing by means of FDM technology. After the printer and the main board with a driver are connected, a Connect button can be pressed. The computer will then identify

the printer and adjust the workspace to dimensions accordingly to the connected printer.

Another step is to add the model into the workspace (Fig. 5). This is carried out by clicking on a button with a plus in the right part of the screen. The model is added in STL format, a universal 3D CAD file, which is very common file type for 3D printing. After the model is imported into the workspace, it can be enlarged and its position can be determined.
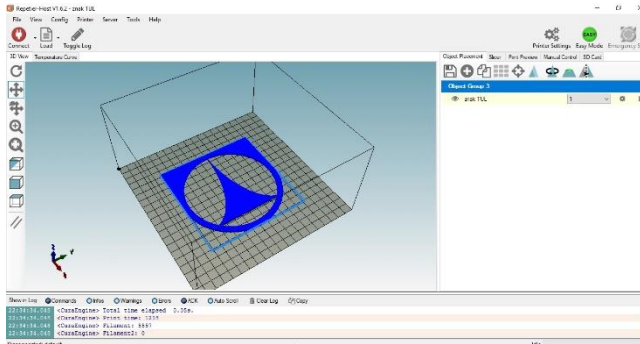


**Figure 5**. Inserting the model into printer's workspace

After the model is placed, a slicing method of the model is selected, a nozzle path is determined, and G-code is created. The Repetier software offers two model slicing methods – Slic3er and CuraEngine. For this application, we chose CuraEngine method. In its settings, a feeding speed, thickness of the first and the last layer, and many other parameters can be set. The Fig. 6 shows nozzle path generated by the program. It is clear, that the outline of the required object is printed first, and then it is filled with printing material. The right part of the figure shows printing time, number of layers and G-code lines.
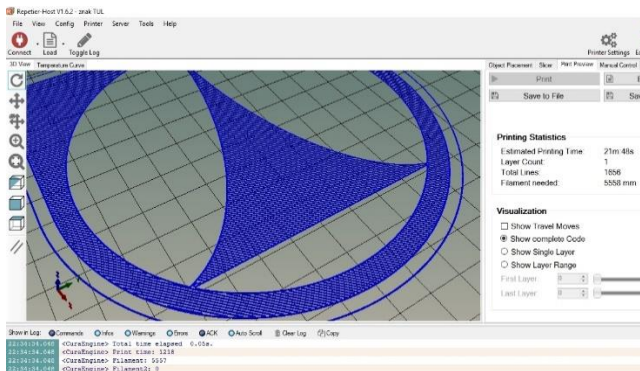


**Figure 6**. Demonstration of nozzle path

The generated G-code can be freely modified. If the user is satisfied with all the properties, he/she presses the button that will initiate the print. The rest of the session is performed automatically. In case of this project, where a chocolate is being printed, it is necessary to choose a model that requires only one syringe of filling. Therefore, the models must be small.

Currently, only one chocolate layer is used. For printing of further layers, an efficient cooling must be designed to ensure immediate cooling of the printed chocolate into a solid state.

## 5    DESCRIPTION OF THE PRINTER

The 3D printer design was based on a RepRap project, which brings enthusiasts from around the world together. A design made by Prusa Research s. r. o. was used, specifically, the Prusa Mendel i3 design. We chose to use already existing design due

to time saving reasons and due to the fact, that the eventual created design would be very similar to the already existing one. The design of the extrusion head is described above. The principle of pressing the syringe lies in its fitting into an aluminium chamber, where it is fixed in a given position; see Fig. 7. The aluminium casing can be wrapped in heating foil to keep the required temperature inside the syringe. The top of the piston is fixed with a special holder, into which a threaded rod is screwed.
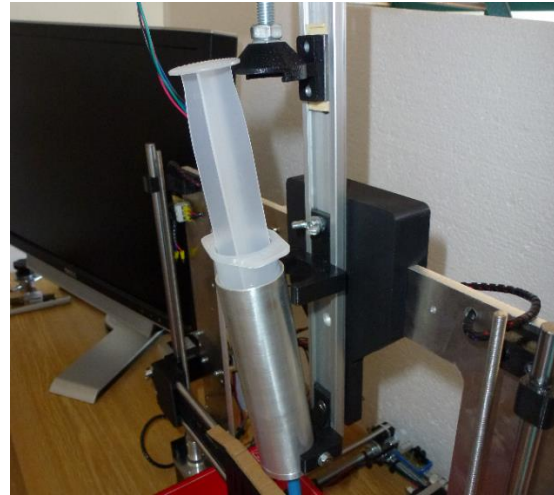


**Figure 7**.  Mounting of the syringe in the aluminium casing

The rod moves into a gear, which is connected to a nut. Rotation of the gear causes rotation of the nut, consequently the threaded rod begins to move upwards or downwards (depending on the direction of rotation). The rotation of gears is performed by motor which is fixed to the holder together with the gears. The torque is transmitted onto the axial force that compresses the piston of the syringe (see Fig. 8).
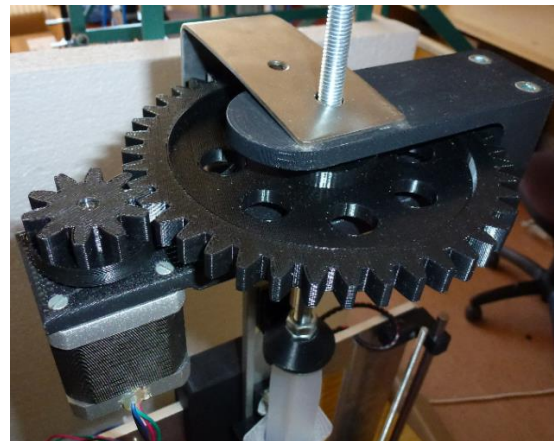


**Figure 8**. Gear mechanism actuating the piston

Due to weight (1,4 kg) of the design, it was decided to place the extruder head onto the 3D printer frame. That eliminated the risk of losing a step of the motor as well as decreasing of the positioning accuracy. Further development will aim to develop a lightweight design or substitution machine base with a platform that can move in X and Y axes.

The chocolate print itself is ensured by a stainless-steel nozzle that is inserted into a preparation mounted to the carriage. Connecting the syringe to the nozzle is performed by a flexible tube that is firmly mounted on both ends to prevent its disconnection (see Fig. 9).
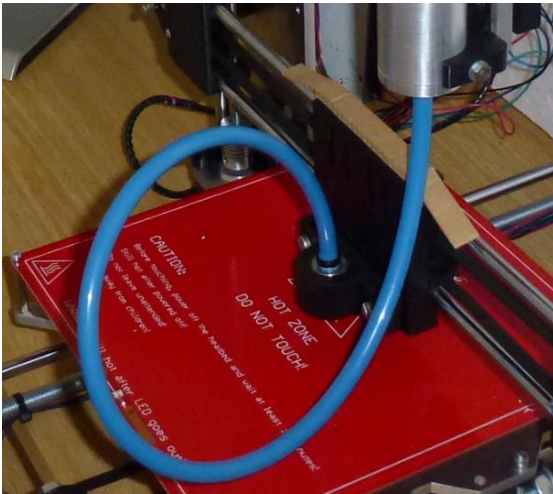
**Figure 9**. Connecting the syringe to the nozzle using a tube

## 6    CONCLUSIONS

Currently, there are ongoing tests and optimisation of building process parameters (see Fig. 10). Printer designed in this project can print planar objects from one layer of chocolate. The design of the printer allows printing using another material than chocolate, for example a decorative topping on cakes or materials with similar consistency. It is suitable for confectioners that want to make something different than their competitors and offer something new, not commonly seen by the customer.
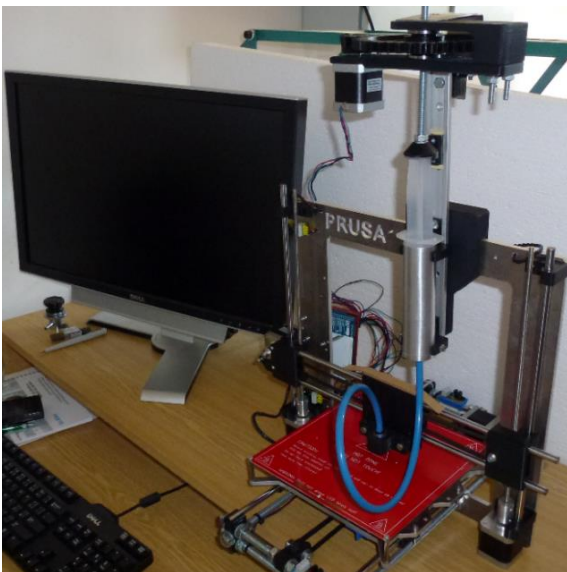


**Figure 10**. Prototype for the 3D chocolate printing

If more layers are to be printed, it is necessary to provide sufficient cooling to ensure that the chocolate solidifies properly to make a solid base for another layer. This goal can be achieved by putting the printer in a cool environment and by heating of the chocolate inside the syringe to ensure that it doesn't solidify before application. Another option of cooling the extruded chocolate is to equip the device with a fan that would cool the air around the printed model so that the chocolate can cool

faster. Solving this issue will be the focus of further development of this design.

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