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# Concept of modular 3D printer construction

**M Stopka<sup>1</sup>, R Kohár<sup>1</sup>, P Weis<sup>1</sup> and J Šteininger<sup>1</sup>**

<sup>1</sup>University of Žilina, Faculty of Mechanical Engineering, Univerzitná 1, 010 26 Žilina, Slovak Republic

E-mail: marian.stopka@fstroj.uniza.sk

**Abstract.** The current situation on a field of 3D print does not allow significant changes in the printer's construction. 3D printer's build area is often a limiting factor. The goal of this project is the design of a modular construction of a 3D printer. In the future, that would mean, that after purchase and after query for increasing build area, it would be necessary just to connect another unified block. All the changes could allow rapid modification of the printer's properties without increasing cost or rebuilding construction. As a result, it was able to develop a construction that is able to expand the build area at one axis. It is able to expand the build area with almost no limit in one direction.

## 1. Introduction

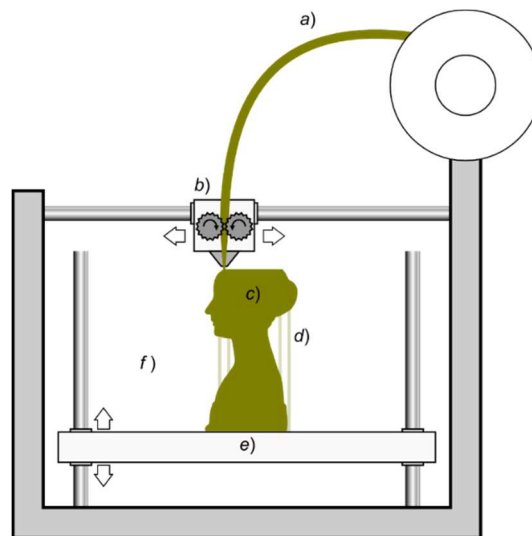
Modern technologies play a very important role in the engineering and manufacturing process. Undoubtedly, 3D print is such a technology. Most manufacturers are focused on production of prototypes, design parts and medical implants. All these items are characterized by small dimensions and high accuracy requirements. This leads to the construction of single-purpose devices, which are not capable of fast printing without need for precision. That fact shows us new market opportunities which are on a field of big-dimensional printing. There are several printers on the market for printing large products, of course, but they are often 'demonstration only' devices. The problem with such large printers is big usage of space. The customer often purchases a printer that is larger than is the really needed to satisfy the potential need for large-scale printing. As a result, space is not used efficiently and causes increased costs. Based on the above, this study was done to design a 3D printer's construction that can change its dimensions according to the actual need. The goal was to make the dimensions change simple, fast, cheap and reversible.

## 2. Choosing a 3D print technology

The first step in the engineering process is the selection of print material. It is important that the material is affordable and inexpensive. It is necessary to avoid complicated processing of material. Therefore, the use of materials such as metals and ceramics, which require the use of a laser and a protective atmosphere, are excluded. [1] Their use places great requirements on the sealing of the workspace (often called build area) as well as the more complicated construction. This could cause problems during engineering a modular system. At this moment we are able to say, that the use of plastic is suitable. [2]

Plastic processing does not impose any special requirements for workspace sealing or protective atmosphere. In principle, it is just needed to melt the material and ensure its application to the required



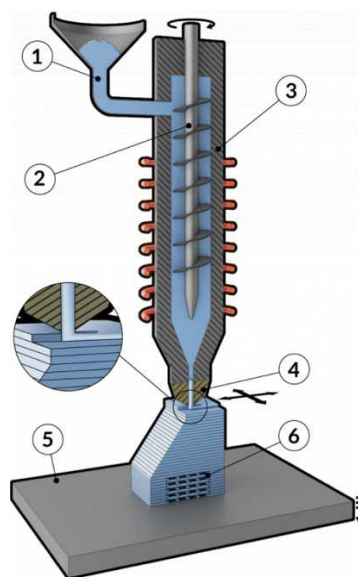


**Figure 1.** FDM (FFF) method principle [4].

place. From this viewpoint it is clever to use FDM (fused deposition modelling) or Fused granular fabrication (FGF) method. [3]

The FDM method (also known as FFF - fused filament fabrication) is a 3D printing process that uses a continuous filament (a) of a thermoplastic material. This is fed from a coil through a moving, heated printer extruder head (b). Molten material is forced out of the printhead's nozzle and is deposited on the growing workpiece (c). The head is moved, under computer control, to define the printed shape. Usually, the head moves in layers, moving in two dimensions to deposit one horizontal plane at a time, before moving slightly upwards (e) to begin a new slice. Figure 1 shows also workspace (f) and supports (d).

Fused Granular Fabrication (FGF) is an additive 3d printing method in which the 3d model is printed by layer. FGF works by melting granular plastics and feeding the resulting mass at a constant speed through a nozzle onto a platform. By changing the nozzle, more or less plastic can be outputted at a time resulting in higher print speeds or finer details. For each layer printed, the printing platform is lowered (or printhead lifted), allowing for the next layer of the model to be added. [6]



**Figure 2.** FGF method principle [5].

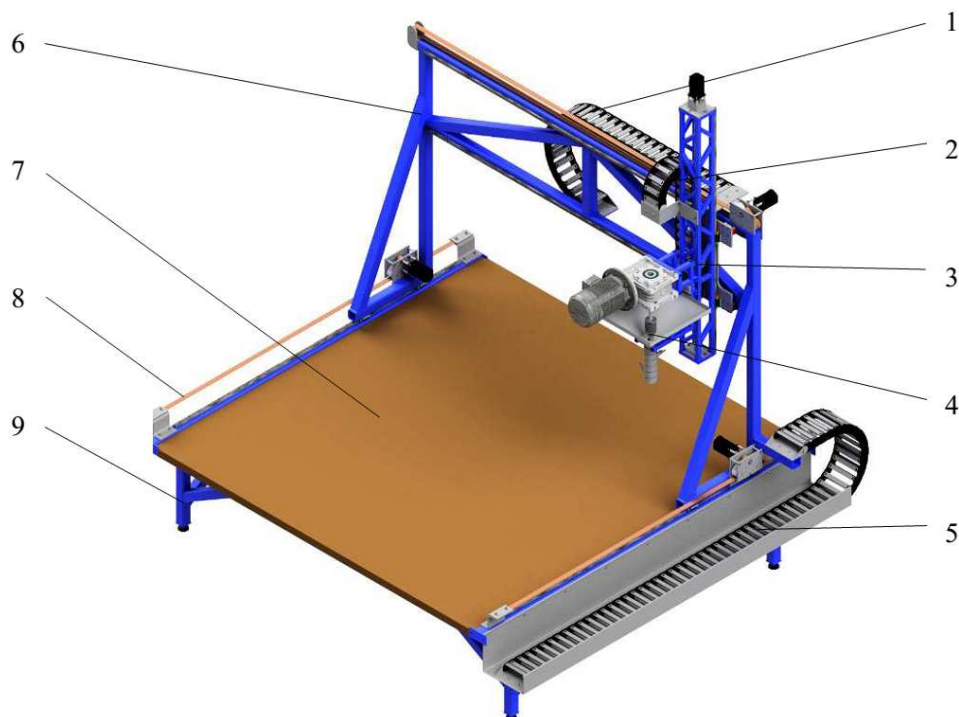
Figure 2 shows main parts of the printing system. The granulated material is placed in a reservoir (1) and gravitationally fed into the extruder (3). The screw (2) pushes material downwards into the heated part. Material is molten here and flows through nozzle (4). Molten material is placed on desired place to be cooled. Cooled material becomes solid and creates final product. The product is placed on workspace (5).

Overall, it is possible to say that these methods are equivalent and differ only in the way how material is fed. Since the FGF method uses a granular material, its transport is practically uninterrupted. This leads to shorter downtime and simplified operation. According to the mentioned advantages, the FGF method was selected as a starting method for the engineering process. [7]

### 3. Description of construction

The base build area should have dimensions of 2 x 2 meters to a height of 1 meter. According to these relatively large dimensions, it is desirable that the construction will be made of steel beams welded together. Welding technology does not allow detachable connections, so it is necessary to remember the modularity of the solution when designing the structure. Changing printer dimensions needs to be resolved by replacing or adding whole part of the device. [8] The construction change is expensive and takes long time, so it is needed to avoid of it. After defining these conditions, the engineering process was started. This resulted to a design of base structure shown.

The device consists of a base frame on which linear guides are placed. These guides allow movement of portal in the X-axis direction. There are linear guides on the portal in the Y-axis direction, those allow Y-axis movement of a mounting plate. On the mounting plate is mounted support. The support allows the extruder to be fixed and it is able to move in Z-axis. The extruder is a container in which the plastic granulate is placed. The screw moves the granulate into the heating section where it melts. The molten material is pushed through the nozzle into the required space. [10] Movement of each axis is provided by the servomotor. All of the servomotors are controlled by the computer. Flexible connection of moving parts is realized by energy chains, to transfer energy.



**Figure 3.** 3D printers construction overview [9]: 1 – Y axis energy chain, 2 – Z axis energy chain, 3 – extruder support, 4 – extruder / printer head, 5 – X axis energy chain, 6 – portal, 7 – workspace, 8 – X axis toothed belt, 9 – unified base frame.



**Figure 4.** Unified extension unit equipped by linear guides [9].

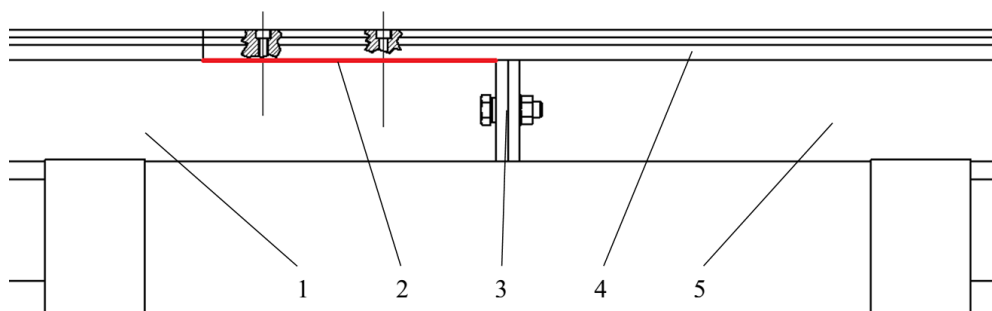
A unified extension unit can be used, if workspace expansion is needed. This unit is structurally identical to the base frame of 3D printer. It is designed to be able to adjust the frame position using adjusting feet independent to the position of the table. This allows it possible to adjust the plane of the workspace precisely. The extension unit is connected with screw connections after setting level of the workspace. The portal can be moved from one frame to another on the linear guides then. The only change that needs to be made when expanding the print area is the use of a longer toothed belt. The process of extending workspace follows these steps:

- place unified extension unit on desired place
- manually level frame using adjusting feet on the bottom of frame
- tighten connecting screws to the base frame
- use set screws under the table to level workspace into one plane with plane on base frame
- place linear guides overlapping from extension unit to base frame
- cut longer toothed belts to desired length and use them instead of original ones
- (use longer cables for X axis when extending to bigger dimension than 2 x 4 m)

The design of X-axis driver uses “open ends” timing belts (toothed belts) instead of endless belts as usual. This design is more flexible when expanding workspace and also decrease the number of needed pulleys. Belts are tensioned during assembly, so there is no need of using additional tensioning pulleys.



**Figure 5.** Extended workspace to 2 x 4 m configuration [9].



**Figure 6.** Connection between base frame and extension unit. 1 – base frame, 2 – linear guide overlap (at least for two bolted connections), 3 – bolted connection between frames, 4 – linear guide, 5 – extension unit frame.

By adding one extension unit will result in a workspace with dimensions of 2 x 4 meters. The cable (and also energy chain) length for the X axis is sufficient for use in the basic configuration (2 x 2 meters) even in the extended (2 x 4 meters). If necessary, the area can be further expanded by adding additional unified blocks. In this case, it is necessary to change the length of the cables and also the toothed belt (as mentioned before). Such a solution makes it possible to extend the workspace almost unlimited.

#### 4. Conclusion

The goal of this project was a design of a 3D printer whose dimensions could be changed as needed. The printer is focused on fast printing of large-sized objects without requirement for high accuracy. The printing technology was determined at the beginning and the entire engineering process was then based on it. The proposed solution uses a unified extension unit, which is also the basic framework of the whole device. Using this unit, the basic workspace size 2 x 2 m can be extended in the direction of one axis to almost unlimited length (2 x 4 m, 2 x 6 m ...). The use of a unified extension unit requires absolutely no change in construction. In the case of 2 x 4 extension, it is needed to use a longer toothed belt, in case of bigger extension, the longer cable lengths are needed for the X axis. Extending the workspace in Y and Z direction requires huge constructional changes and is not possible at this time.

#### Acknowledgments

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