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The concept of the material supply system in 3D printer using a wear FDM material

Koncepcja systemu podawania materiału w drukarkach 3D wykorzystującego zużyty materiał w technologii FDM

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Presented is a conceptual model of an extruder that prints from waste after the printing process as well as from unsuccessful models. Particular attention was paid to the construction of the print head with an extruder adapted to previously fragmented plastic parts. The purpose of this solution is to reduce waste from the printing process.
KEYWORDS: 3D printer, FDM, extruder, recycling

3D printing is classified as additive manufacturing methods, consisting in the production of three-dimensional physical objects based on a computer model. The first spatial printing techniques were developed in the 1980s. However, it was only at the beginning of the 21st century that this field was properly developed [1] due to the patenting of various technologies.

FDM technique

Spatial printing techniques differ from each other, among others: the accuracy of the actual model, types of materials served, printing speed and purpose (different technologies have separate applications). The most popular 3D printing technique is fused deposition modeling (FDM).

This technology is identical to fused filament fabrication (FFF), layer plastic deposition (LPD) and melted and extruded modeling (MEM). The material used to build the model is heated in the head to the melting temperature and then extruded through the nozzle [5]. The head with the extrusion nozzles controls the flow of material and moves in the working area of the device. The material is delivered to the extruder in the form of a wire. The principle of operation of printing devices using this method is shown in fig. 1.

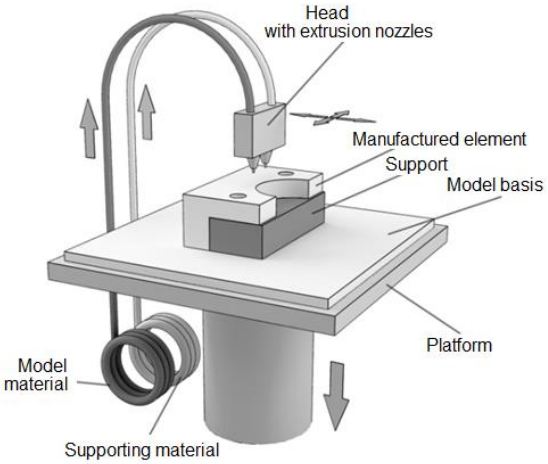

Fig. 1. FDM technology [2]

In the FDM method, as in the case of other techniques, the model is created by applying a thermoplastic layer by layer. The molten material is bonded to the previously laid layers during cooling. The application of subsequent layers lasts until the full height of the detail is reached. Support structures are usually built using the same extruder.

The main advantages of the FDM technique include:

- high dimensional accuracy of ±0.02 to ±0.3 mm depending on the orientation in the working chamber,
- low cost of purchase and operation of printing devices,
- possibility of using soluble support materials,
- large database of materials intended for printing,
- ability to work in an office environment,
- easy post processing of printed details.

Types of extruders

Currently, in printers working in FDM technology, the material is fed into a wire extruder. There are two types of extruder solutions:

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- direct extruder,
- "Bowden" type extruder.

The direct drive extruder (fig 2) is mounted directly in front of the print head itself. The drive is provided by a stepper motor, often coupled to the gear. This solution is characterized by simplicity of operation and reliability. The disadvantage of this method of material handling is the heavy weight of the carriage, which causes its movements to cause high inertia forces acting on the printer's support structure.

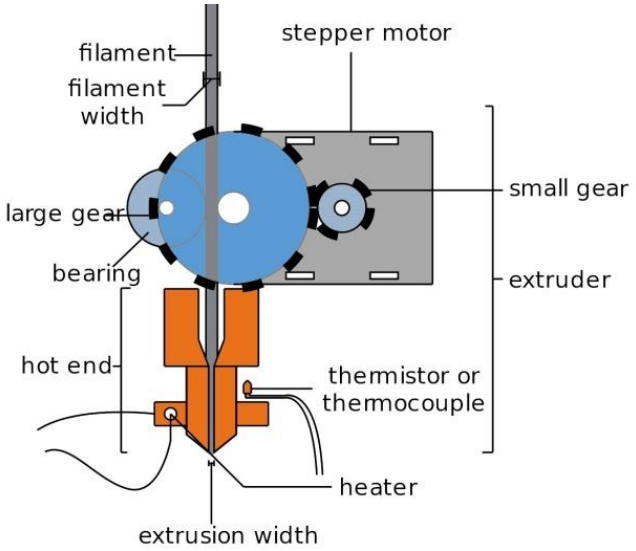

Fig. 2. Diagram and construction of a direct drive extruder [3]

Compared to an extruder mounted directly in a "Bowden" type extruder (fig. 3), the extruder and printhead are separated from each other by a Teflon tube. This is to reduce weight and reduce the dimensions of the ambulance.

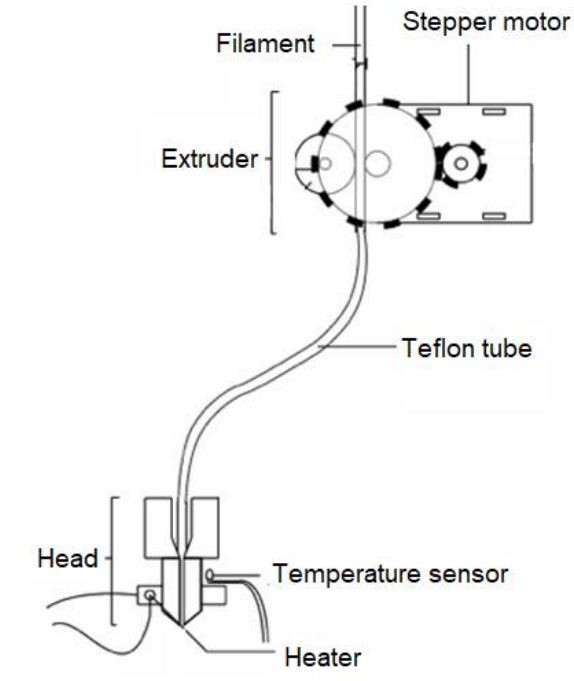

Fig. 3. Filament feeding in a "Bowden" type extruder [4]

The extruder with the stepper motor is usually mounted to the 3D printer housing. The filament fed by the extruder moves in a Teflon tube that acts as a guide. There is free space between the filament inside the tube and its walls, which contributes to the buckling of the material. The degree of material buckling can be important for the uniform rate of material feed to the zone in which it is penetrated [4]. For this reason, the "Bowden" type solution is not intended for printing on plastics characterized by high elasticity and brittleness (like some composites).

Concept of building an extruder

Solutions for feeding material in 3D printing to the head require a specific form of material – the so-called filament. Its basic parameters include the diameter, which should be constant over the entire length of the filament.

When making prints in FDM technology, a significant amount of waste is generated. This is mainly due to the need to use the so-called supporting elements. In the event of problems related to the operation of the printhead or filament extruder, it may block, causing additional waste. It is estimated that the weight of waste can reach approx. 20% of the mass of the printout.

After analyzing the applied solutions of feeding the material to the head, a concept for feeding the printing material in the form of a granulate was developed. It is a form that allows the use of waste from printouts. The use of granulate would also eliminate problems related to deviations of filament diameter from the nominal dimension. Plastic granules used in 3D printing are available on the market. Concept of the system of feeding the printing material to the head is shown in fig. 4.

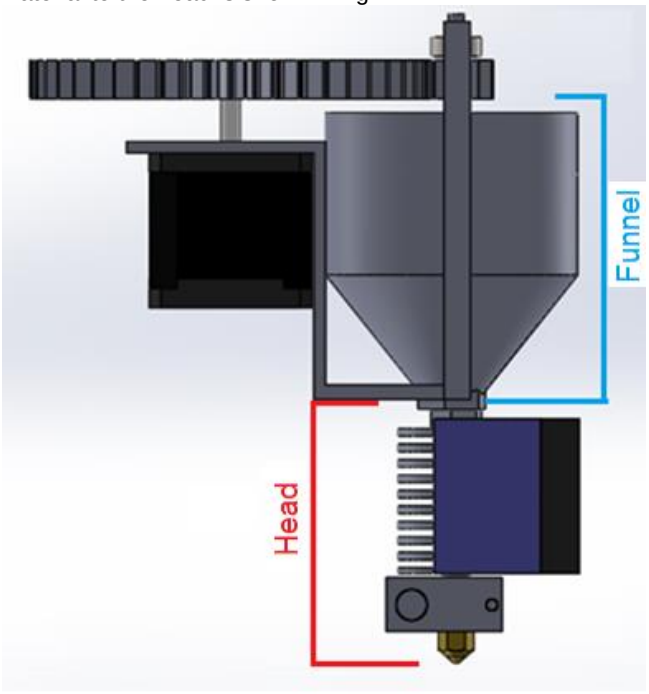

Fig. 4. Concept of the system of feeding the printing material in the form of granules

a) *b*)

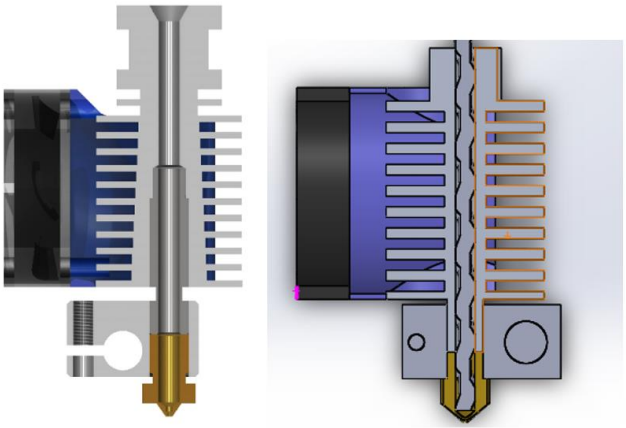

Fig. 5. Cross-section of the print head: E3D v6 (*a*); head construction concept (*b*)

Developed system of feeding the printing material requires the use of a structure consisting of three elements: a tray, a granule feeder and a print head.

Due to the need to maintain a compact construction, the material feeding system is a separate 3D printer construction module.

The tray, the bottom of which is in the form of a cone, provides the possibility of continuous feeding of material to the nozzle. In order to make the feeding speed of the granulate independent of the amount in the hopper, the granulate feeder in the form of a specially shaped rod was used. It ensures the free space between it and the side walls of the print head. Granules are moving in these spaces. The rotation of the feed bar causes the granules to move downwards. The drive is provided by a stepper motor and a gear transmission.

The granular material is transported to the melting chamber, which is an element of the print head. The head construction diagram is shown in Fig. 5 and compared to one of the heads used in 3D printers.

According to the developed concept, the printhead has the same structure as commonly used heads. It is assumed that the nozzle leading the material to the melting chamber will have a constant diameter. The rod placed in the nozzle performs a rotary movement. Thanks to its shape, the granulate's printing material will move along the rod. After reaching the melting chamber, it will be squeezed from the head through the nozzle.

The main features of the proposed system for feeding the printing material:

- delivery to the printhead of material in a loose form (plastic granulate),
- control of the rate of feeding of printing material to the head by selecting the rotation of the feeder bar,
- possibility of using material coming from waste,
- greater control over the speed of material feed and its changes when printing the model,
- the need to develop a system of reservoir backfilling with granules.

Conclusions

3D printers using the FDM method (commercial and RepRap type designs) allow printing with plastic in the form of wire. Due to the fact that printers are mainly used to create and build prototypes, many printed parts after short-term use are unnecessary. When printing most models, it is also necessary to use the so-called support elements that are removed after printing and constitute production waste. The solution of the FDM print media delivery system discussed in the article in the form of granules may allow the use of the material lost in this way.

Due to the lack of published research results on the impact of re-melted plastic on print quality, the development of the granule feeding system concept will be the beginning of research at the Faculty of Technical Sciences of the University of Warmia and Mazury in Olsztyn, aimed at designing the entire 3D printer module, which will be maybe it can be used in various models of printers available on the market.

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