GENERAL CLASSIFICATION OF 3D PRINTING

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Introduction

Additive manufacturing (AM) is one of the main world trends mentioned in the context of the new industrial revolution.The annual growth of this market, which is not actually formed and has no clear limits yet, varies from 20-30%. It is well known that there are several methods of 3D printing, but all of them are derivatives of the additive technology of the production. No matter what 3D printer is used, the workpiece construction is carried out by layer-based addition of raw materials. As a result we have details of a complex geometric form, made in short period of time [1].

Main problem and its solution

Over the past few years, 3D technology has become an innovative solution for creating three-dimensional projection. The use of 3D devices gives new opportunities in scientific researches, engineering, medicine, architecture, heavy, textile, food and jewelry industry. In order to choose a particular 3D printer for solving a specific technological problem, it is necessary to know all its types, its relation with different needs, material capabilities and a specific area of usage. To find the answer for many questions, you need to make up the general classification for all possible types of 3D printers which correspond to different needs and use different working principles, which also allow to assess the principles embodied in 3D printing technology, used materialsand finally which technology is better to solve a specific technological problem.

Main body

Let us make up the general classification of 3D printers in order to find out in detail all the types of 3D printing, 3D printers, and their principle of work. We can classify all existing printers for creating three-dimensional projectionby following types:

- by printing technology
- by the type of expense
- on to appointment

- on scopes of application
- on kinds of printers
- on the axis of movement of the extruder and platforms

Each group has many different subspecies that have their own peculiarities.

Let us consider all possible types of 3D printers according to the printing technology. The 3D printer principle is based on two printing technologies:jet and laser. These technologies are fundamentally different in the way ofthree-dimensional projection creation.

With the help of inkjet technology printing is achieved through the use of a special piece with an extruderin which the consumable material is heated and its dosage is served to the desktop. The production process takes place very accurately but it needs some time. Different thermoplastic materials are used as raw materials;the most common among them is ABS-polymer, produced in the form of granules or special threads.

Laser technology works by another principle. No matter what type and material is used in the process, the printing is based on the powder sintering, lamination or melting with the help of laser.The main advantage of such technology is the ability to use not only thermoplastic materials, but also metals or alloys as consumables.

Classification by the type of expense. The basis of this classification is the kind of consumable material that the 3D printer works with. Below we can see the printer characteristic of this group.

1. Printers using powder.This is a group of devices that uses special powder components to create three-dimensional models.The presence of adhesive is necessarily. The working principle of this device is very simple. First one piece attaches the adhesive substance, and then covers it with a powder material from the top and after that sinter.

2. Printers with use liquid photopolymer.This kind of printer works with special liquid materialsthat freeze under the ultraviolet (UV) influence. When the first layer is done and highlighted in the required places,the hardening takes place and after that the next layer is attached and so on.The main drawback is the very slow printing speed and the high cost of consumables and the device itself.

3. Printers using rod polymer.These devices have become wide popular because of their simple design, low cost and good print quality. The working

principle of this printer is to fill a polymer bar through the printheadwhich solidifies at room temperature [2].

4. Printers with use the granulated polymer. This device is based on the principles of FDM-printers, but polymer granules are used instead of the rod.

Regardless of the used technology for 3D printing and consumables, all 3D printers can be divided into major groups by the type of appointment: consumer, professional, personal and industrial.

Consumer group includes the type of printer, which is intended, mainly, for personal use. It is delivered as a constructor or in a collected form. The majority of such printers are derived from the open source project RepRap. They are designed for the regular user and equipped with a fairly simple and understandable interface.They printwith ABS and PLA plastics.

Professional printers are not compact; they rather look like large refrigerators.The appointment of professional systems can be very diverse, from prototyping to full-scale production, which makes them an excellent option for both large businesses and high-tech companies with a small staff of employees.Incidentally, Shapeways uses printers of this kind. The work space part here is alsonot so simple.

The personal printer type is for everyday use, but at the same time these printers can be used for business.These printers have a lot in common with the consumer ones, but they have higher print quality and accuracy that are characteristic to professional 3D systems.The appearance of these printers is more likely the reaction of large manufacturers to the growing domestic systems market. According to the low accuracy of the consumer system, diminished models of professional systems with similar indicators were proposed. Managing the printers of this type is not difficult, it is enough to load the image and press the "start" button.At the same time,the possibilities of various additional printing options are limited. The latter group includes industrial 3D printers, which are large in size, have complex design and almost unlimited capabilities.This is no longer just a printer for creating three-dimensional projection; it is an entire line for manufacturing of different details of any complexity.It is required to have specially trained staff to work with such devices. Such machines work with almost any kind of material (from thermoplastics to metals).

Every year 3D printers become more and more popular. 3D printing is becoming an important part of our life;it is turning from narrow and expensive thing into an indispensable device for professionals of various business fields.The availability of 3D printing allows us to carry out serious experiments in engineering, clothing industry, architecture, construction, medicine, education, jewelry industry,design, printing industry, advertising and souvenir production [3].

There are such kinds of printers:

1. expressive printers poured, sprayed materials;

2. printers which are cemented, stick together materials;

3. printers which print granules.

1. Let us consider the first type of printers. This group includes:

a) FDM printers that squeeze the consumable material layer by layer through thedispenser nozzle (the Stratasys printers; food printer (use glaze, cheese, dough); medicine printers that print with "live ink" (when any set of living cells is placed in a special medical Gel, which is subsequently used in biomedicine)).

b) Polyjet printers. They work as follow: small doses of photopolymer are shot from thin nozzles, as in inkjet printing, and immediately polymerize on the surface under the UV influence. The important feature that distinguishes Polyjet from stereolithography is the ability to print with various materials. They are mainly used in industrial prototyping and medicine.

c) LENS (Laser engineered net shaping). The powder material is blown out of the nozzle and falls on a focused laser beam.Part of the powder passes past, and the part that gets into the focus of the laser instantly cements. The three-dimensional projection forms layer by layer. With the help of such technology the 3D-printing with metal (steel and titanium objects) is hold. Before this technology it was possible to print only with plastic objects, that is why nobody took 3D printing seriously. This technology has opened the doors for 3D printing in the "big" industry.Powders of various materials can be mixed and in the result different alloys are received. They can be used in different spheres, for example, the manufacture of titanium blades for turbines with internal cooling channels.

2. The second type of printers includes:

a) SL (Stereolithography)stereolithography, which looks like a small liquid-polymer bath,where the laser beam passes through, and at that place the polymer is polymerize under the influence of UV.When the first layer is done, the platform with

the detail drops down, andthe liquid polymer fills theemptiness, then the next layer is cemented and so on. Sometimes the platform with the detail rises upwards; in that case the laser is located below.

b) DLP printersare almost the same as stereolithography, but the budget projector is used instead of a laser. These printers have good print quality even if they are not expensive. They are used in dentistry, for jewelry printing and so on.

c) LS (laser sintering). These printers look like SL,but instead of a liquid photopolymer, a powder is used that is cemented by a laser.

d) 3DP (three-dimensional printing).The technology was invented in 1980. The glue in powder form is attached to the material, that binds the granules,and then a layer of powder is applied over the glue layer, and so on.In the result we have the material called sandstone (similar to the gypsum) [3].

3. Printers which print granules.This type of printer is under development now, so it the first time to write down it into the general classification of printers. As a result, the material isextruded from the heating element, as in FDM technology. And there are no more similarities between these printers and others. Therefore, it would be wrong to write down this kind of printers to the type described above. The technology of printing granules is as follows: instead of the finished bar, which is mainly used for printing, polymer granules are used,which fall into the appropriate hopper or loading area.After that,the raw material is sent by a rotating auger (drill) to the heating zone of the melt for further extrusion.In order to ensure the necessary material movement, theconditions for the solid material moving from the loading zone and the filling of the intertexture space in the screw are very important. Loading with the polymer material for the extrusion what is supplied to the bunker can be in the form of powder, granules and small plates.The polymer processing in the form of granules is the optimal power supply for the extruder. The polymer granules are less prone to "freezing" and the formation of plugs in the hopper than the powder, and they also plasticize and homogenize easier.

Granule printers are ideal for those who want to combine additive and subtractive production methods,when the item can be quickly printed on a 3D printer using granules.The extruders for the rods manufacture are widely used now, but these devices cost much and they have long-term process of making the bar, which is unacceptable in our competitive environment.

The experts, representing construction companies, processing enterprises and consumer's sphere, predict further growth of granular polymer demand. These expectations fully measure up the global trend. But the amount of waste will increase hand in hand with the growth of polymers use.

One of the main advantages of this printer is the ability to reprint any parts with the help of waste pellets,which were obtained at the previous printing.Therefore, it is possible to cheapen the filament at all, using secondary raw materials.It is almost impossible to obtain a bar equal to the diameter from the secondary raw material because the properties of the melt will be heterogeneous in mass; that is why the pressure in the industrial extruder and plasticity of the melt and its shrinkage are irregular. Accordingly,such wire will behave absolutely unpredictable while printing. In the first stage of the initial polymer processing and first service of the polymer chain, there are the irreversible changescaused by chemical influences of thermal, heat, and photo oxidation destruction, which leads to the appearance of active groups.These groups, while processing, are capable of triggering oxidation reactions.Accordingly, the smaller number of alterations leads to the better material; and as a result, it will affect the quality of the future detail.But also in cases of polymer recycling, it is possible to create a new material with new properties due to the addition of variousimpurities, dyes, plasticizers in order to improve elasticity, plastic deformation, frost resistance, impact strength and to reduce viscosity to improve their further processing and exploitation.

Then there is a classification of printers by the axis of movement of the extruder and platforms. In general, 3D printers work as follows: the detail is formed gradually, layer-by-layer, by the addition of plastic material.The 3D printer has a frame and three axes: X (left and right), Y (forward and reverse) and Z (up and down).The extruder, through which molten plastic is served, is located on the X axis.

The bottom part of the extruder is called the nozzle. There are three linear coordinates for printing with 3D printer; to control them the Arduino card is usually used [4].

As the 3D printer prints three-dimensional objects,its heating element must move during the working processon three axes: X - forward and reverse, Y - right and left, and Z - up and down.In some printers the extruder during the printing remains static and operative platform moves along the X, Y, and Z axes.

The I subgroup includes 3D such printers, in which the shutter moves up – down and forward – reverse, and the operative platform moves only to the left and right. This group often includes Rep-Rap printers; its distinguishing feature is the open platform and the triangular skeleton of the side walls.The improved design of these printerssimplifies the process of printer assembling, but there are vibrations when printing, which sometimes reduce the quality of finished products. One of the most popular representatives of the first group is the"grandpa" of all 3D printers - the Darwin project,from which the devices Prusa Mendel and Mendel split up.When designing Prusa Mendel, the constructor slightlysimplified the design and added an additional engine to the Z axis.

The Mendel-90 device, with wooden panels located right angles, was in demand during the post-Soviet time. Plywood can be easily replaced with plexiglass or other suitable material. This design positively affects the print accuracy and reduces the vibrations number.

The II subgroup includes 3D printers where the extruder moves reverse and forward, right-left while theoperative platform only up and down. The most popular 3D printers of this group are Ultimaker, RapMen and MakerBot Cupcake.The Ultimaker 3D printer, developed by German engineers, has quicklybecome very popular around the world.The printer is "dressed" in a wooden case, it is difficult to assemble, but it differs in good speed and printing quality. RapMen 3D printer refers to Rep Rep printers. The device can be recognized by the simplified square design and cross-shaped structures on the side panels.The most popular representative of the second group, without a doubt, is the MakerBot 3D printer.

The III subgroup includes 3D printers, in which the extruder moves forward-reverse while working, and the operative platform moves right – left and up – down. Unfortunately, 3D printers of this subgroup are not widely available due to the complexity of their assembly and configuration.The only successful representative of this group is the 3D printer UP from the company PP3DP.The 3D printer UP does not require any assembly and setup before using,it is enough to get it out of the box, connect to the network and a personal computer, and you can immediately start printing.The only significant drawback this printer is its high price.

The printers of the last IV subgroup, due to the unusual design, are similar to the tower.Such printers have a platform that moves along the X, Y, and Z axes.3D

printers of this group are called "delta printers" due to the circle-located manipulators that make the head-detailmove.

One of the factors that reduce interest in 3D-printers of the fourth subgroup is the small print area, which is limited to three semicircles. But nevertheless, delta printers have undeniable advantages, such as speed, positioning accuracy, low power consumption and high printing area vertically [4].

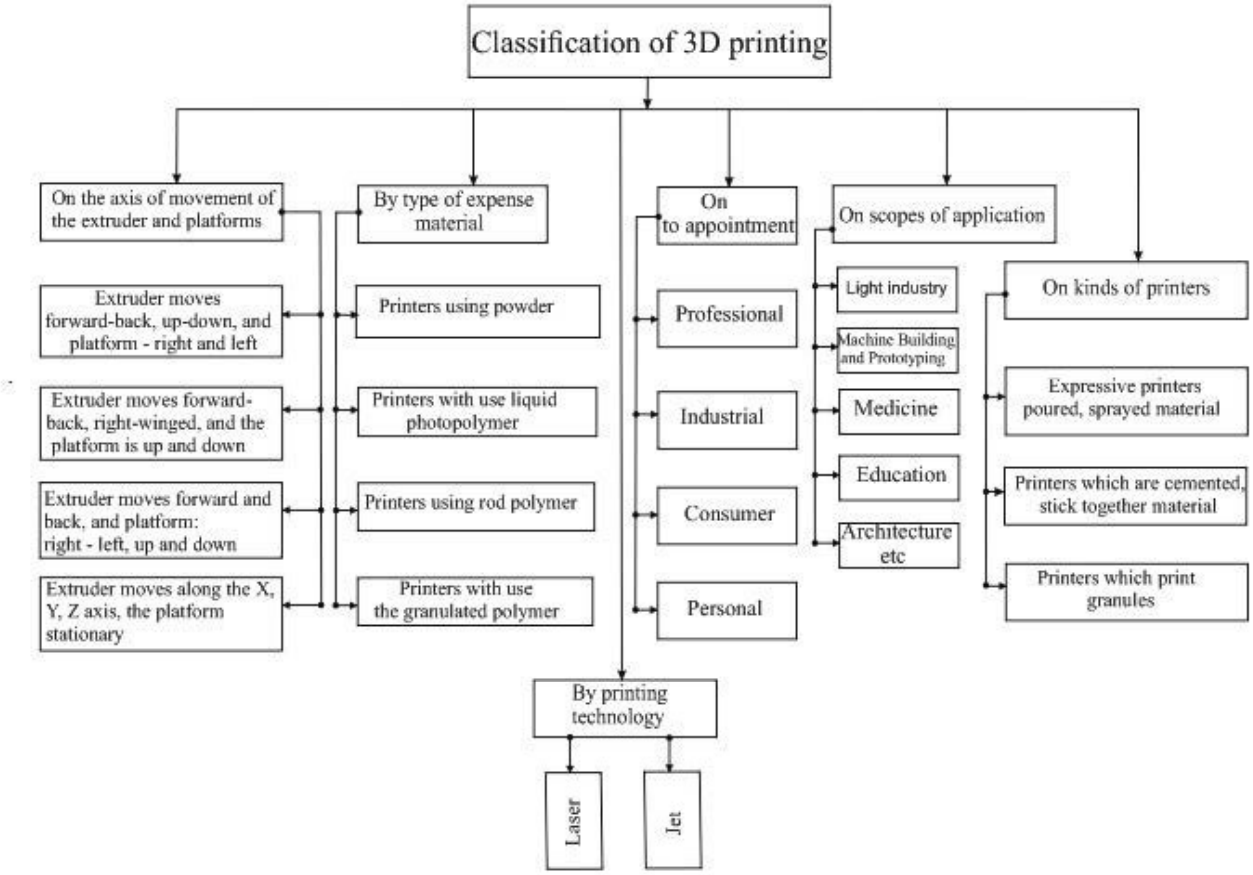
The result of work

Thanks to the general classification that was developed, we can see that there are many types of printers available for three-dimensional printing.This makes it possible to select the exact model that is required for specific tasks.Despite the almost limitless capabilities of industrial devices, the most common ones are 3D ink jet printers, using a polymer in the form of a rod and granules as the main raw material.This general classification of 3D printers is presented on the Picture 1.

Conclusions

The article analyzes and systematizes modern technologies of 3D printing and 3D-printers.Modern inventions and developments improve every day, so as a 3D technology.

All types of 3D printing technologies that are used in everyday life and in industry are considered. All species and subspecies are described. This article proposes the general classification of 3D printerswhich gives a complete idea and description of each type, its purpose, etc. Also, it is the first time to write downa new type of 3D printing, namely 3D-printing with polymeric granules, to the general classification; this type, in the rapidly developing industry, will become competitive along with other types of 3D printing and types of consumables.



Picture 1 – General classification of 3D printers

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