

ANALYSIS OF THE APPLICATION OF 3D PRINTERS IN INDUSTRIAL AND EDUCATIONAL ENVIRONMENTS

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Abstract: The use of additive manufacturing is a crucial aspect of the broader initiative to merge digital technology and Internet of Things with conventional techniques. The paper presents the state and the application of 3D printers in industrial and educational environments. The current state is analyzed, as well as the Cartesian coordinates and delta configuration printer, and the characteristics of 3D printers of polar and SCARA configuration. After presenting the application of 3D printers in educational and industrial environments, the point of view is that a 3D printer for metal represents the necessary equipment for raising the level of studies and preparing students for serious challenges in solving various industrial problems.

Key words: additive manufacturing, 3D printing, Delta system, materials for 3D printing

1. INTRODUCTION

A 3D printing is the process of creating three-dimensional objects by adding layers of material on top of each other, often under the control of a computer system. There are several types and classifications of 3D printing, the most common of which are: by the method of construction, by the materials used, by application, and by technology [1].

This devices use layered material technology to create three-dimensional objects. There are different types of 3D printers, but the basic idea is the same – layering materials on top of each other until the desired shape is formed.

Industrial 3D printers are typically large, expensive, and used to produce parts in industrial settings, such as the automotive, aerospace, and medical industries. Home/ Hobby 3D printers are smaller, more affordable, and are often used in household or workshop settings to create various objects, prototypes, or works of art. Professional 3D Printers fall somewhere between industrial and home printers, offering greater precision and capabilities than home printers, but at more affordable prices than industrial models [2].

The 3D printing encompasses a wide range of materials, allowing the creation of objects with different properties, appearance, and functionalities. The choice of material depends on factors such as the printing technology used, the intended application of the printed object, and the desired properties such as strength, flexibility, and appearance. Some of the often used materials for 3D printing are Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), and Polyethylene Terephthalate Glycol (PETG). PETG is a durable, impact-resistant thermoplastic that combines the ease of printing of PLA with the strength of ABS. It is commonly used for mechanical parts and food-safe applications. Standard resins are commonly used in Stereolithography (SLA) and Digital Light Processing (DLP) printers, and they offer high resolution and smooth surfaces, making them suitable for detailed prototypes and jewelry [3].

Engineering resins, such as tough, flexible resins and high-temperature resins, are designed for functional prototyping and end-use applications that require specific mechanical properties. Specialized resins such as dental resins are formulated for dental applications, such as crowns and bridges, surgical guides and orthodontic models.

Stainless steel is commonly used in metal 3D printing processes such as direct metal laser sintering (DMLS) and electron beam melting (EBM). It offers high strength, corrosion resistance, and is suitable for a wide range of applications including aerospace, automotive, and medical use [4].

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Titanium is known for its high strength-to-weight ratio, biocompatibility, and corrosion resistance. It is widely used in aerospace, medical implants, and automotive industries. Aluminum is lightweight, strong, and has good thermal and electrical conductivity. It is used in a variety of industries, including aerospace, automotive, and consumer goods.

Zirconium ceramics offer high mechanical strength, wear resistance, and biocompatibility. They are commonly used in dental applications such as crowns and bridges. Alumina ceramics are known for their high hardness, chemical resistance, and electrical insulation properties. They are used in applications such as electronics, aerospace, and medical devices.

Carbon Fiber Reinforced Polymers (CFRP) filaments combine carbon fibers with thermoplastics such as PLA or ABS to produce lightweight, strong, and rigid parts. They are used in aerospace, automotive, and sporting goods, [4]-[5]. Glass Fiber Reinforced Polymers (GFRP) is similar to CFRP, GFRP filaments combine glass fibers with thermoplastics to produce parts with improved stiffness and impact resistance [4].

2. FUSED DEPOSITION MODELLING TECHNIQUE

There are several different techniques for creating objects frequently used in 3D printing: Fused deposition modeling (FDM), Stereolithography (SLA), Selective Laser Sintering (SLS) and Digital Light processing (DLP).

One of the most popular 3D printing techniques is Fused deposition modeling (FDM). It works by gradually depositing heated thermoplastic material (such as PLA or ABS) layer by layer through a nozzle. Each layer hardens until the desired object is formed [6].

Polylactic Acid is one of the most common materials used in FDM 3D printers. It can be derived from renewable resources such as cornstarch or sugarcane, making it environmentally friendly. PLA is biodegradable and comes in a variety of colors.

Acrylonitrile Butadiene Styrene is another popular thermoplastic used in FDM printing. It is known for its strength, durability, and resistance to high temperatures. ABS is typically used for functional prototypes and end-use parts.

Key components of an FDM system include [6]:

- Work platform
- Work plate that supports the workpiece
- Extruder head
- Replaceable nozzles
- Spools of material for making the work piece and supports.

The process of making work pieces is based on the following key steps:

- Thermoplastic filament is unwound from the spool and fed into the head of the FDM extruder
- In an electrically heated chamber with controlled temperature, the filament is partially melted
- The semi-molten material is extruded and deposited in a thin layer on the work surface
- After the current layer is completed, the work platform is incrementally lowered by the thickness of one layer and the process of depositing material continues layer by layer until the work piece is completed.

3. TYPES OF 3D PRINTERS IN EDUCATIONAL VERSUS INDUSTRIAL ENVIRONMENTS

The 3D printers in educational environments are based on FDM (Fused Deposition Material) technology. They use STL files modelled in any program for 3D modelling (SolidWorks, Pro-Engineer, Catia, Inventor, etc.), and 3D-derived files by scanning and work with PLA and ABS wire 3 mm thick. The outlet nozzle that melts the wire is 0.5 mm diameter. For PLA wire, the nozzle is heated to about 190°C, while for ABS it is heated to about 240°C. Glass panel (240 mm x 300 mm) is

heated to 65-70°C. Certain parts of the 3D printer can be made on the 3D printer itself, so that self-construction is practically possible. Axis control is performed via stepper motors and threaded spindles. The board that controls the 3D printer is the Arduino Mega 2560 (Mega ADK). Desktop 3D printers based on the Cartesian coordinate system are recognizable by their rectangular base and are controllable by spatial axes that are linear and mutually perpendicular. Thanks to the simple geometry of movement, this type of printer has a simple construction and control software, which makes it very popular on the market [6]-[7].

This 3D printer e.g. in [8] structurally belongs to the Delta system and uses 3 levers to control the movement of the 3D printer extruder head, which always maintains parallelism with the worktable because the movement of the levers is coupled. During operation, this printer incrementally raises the extruder head in the Z-axis direction thanks to a stepper motor for driving a vertical threaded spindle, in order to enable the production of each subsequent layer, whereby the extruder head performs movements in the X-Y plane, [9]. This movement in the plane is enabled by the action of a linear robot in which the axes are placed orthogonally, and the drive is realized in the form of two linear drives with two electric motors, [8]-[9].

When compared to rectangular systems, it is noted that the delta system operates at a higher speed and allows the production of models of greater height. Printers of this design can use a large printing surface, and the disadvantages are manifested in the complex trigonometric calculation of the extruder head trajectory, which greatly affects the development of control software. Also the drawback in case of delta configuration is that only half of the height or the volume of the printer is usable for 3D printing, [7]-[10].

The 3D printer at the Novi Beograd Section, in the Academy of Applied Studies Polytechnic is shown in Figure 1. [9].

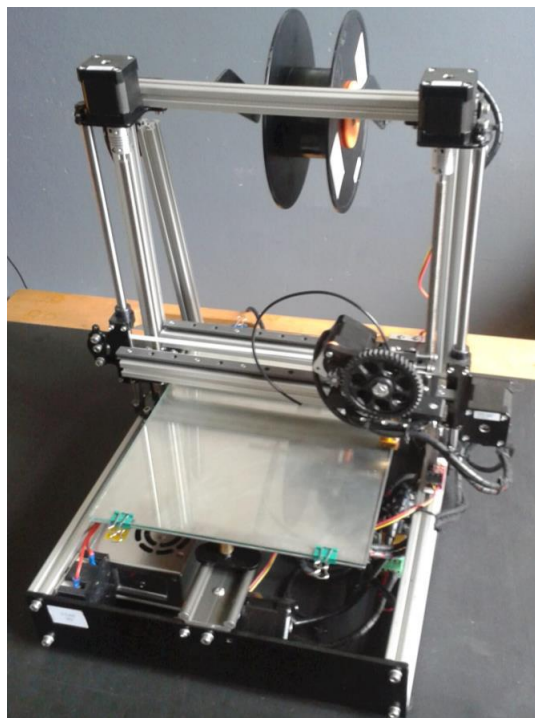


Figure 1 – The 3D printer at the Novi Beograd Section, in the Academy of Applied Studies Polytechnic [9]

Unlike the delta construction, the SCARA type of printer has two mechanical arms that bend at the joints, allowing the extruder head to perform the necessary movements above the work plate. Good articulation of movements is enabled by mechanical arms that have two joints and a joint for performing industrial assembly tasks [10].

Unlike three-axis systems, devices based on the polar system use two axes to control the movement of the work platform in conjunction with the extruder head, two electric motors and smooth deposition of filament within the required cross-section. However, despite these advantages, there are also disadvantages that are reflected in more complex mathematical calculations, complex geometry of the work platform rotation and difficult development of control software. In addition, the movable work platform complicates the practical implementation of heating the work plate, which is necessary for printing some materials such as ABS, PLA, [10].

Metal 3D printing is considered one of the most advanced additive manufacturing (AM) technologies, valued for its ability to produce highly durable and complex components with exceptional precision [11]. As one of the most versatile and widely adopted materials in the field of additive manufacturing, metals play a crucial role across various industries. The unique properties of metals - such as strength, heat resistance and durability - make these a preferred choice for applications that demand high-performance materials [12]-[14].

Metal 3D printing is utilized in several key areas in industry, including rapid prototyping, where it allows for the quick creation of functional prototypes that can undergo testing under real-world conditions. This reduces the time and cost associated with traditional prototyping methods. Beyond prototyping, metal additive manufacturing has expanded into mass production, enabling the efficient and scalable fabrication of metal parts with intricate designs that would be difficult or impossible to achieve using conventional manufacturing techniques [15].

Additionally, metal 3D printing has proven to be invaluable for the production of tooling, where precision and customization are paramount. The ability to manufacture custom tools or molds on demand significantly enhances production workflows. Moreover, metal AM is increasingly being used for part repair, particularly in industries like aerospace and automotive, where the repair of high-value components can extend the life of critical parts and reduce downtime [16]-[18].

Experience has shown that students who have undergone training on 3D metal printers at applied studies and universities very easily and quickly enter the industry and achieve remarkable results.

Additive manufacturing of energy storage devices and the application of 4D printing of stimulus-responsive materials represent a revolutionary breakthrough in the field of energy efficiency and sustainability. By using advanced technologies such as 3D and 4D printing, it is possible to design and manufacture energy storage devices that are not only more efficient, but also more flexible, adaptable and durable [16]-[18]. These technologies allow for the precise design and optimization of structures that can respond to changing energy needs and different operating conditions, which is crucial in a world that is increasingly reliant on renewable energy sources.

4. CONCLUSION

The paper presents an overview of the state and the application of 3D printers in the educational and industrial environments. Desktop 3D printers are widely used in education. They are based on the Cartesian coordinate system, controllable in X, Y, and Z axes that are linear and perpendicular to each other. The characteristics of Cartesian coordinates and delta structure printers are presented, followed by an analysis of the characteristics of SCARA printers and printers based on the polar system. In SCARA systems, mechanical arms that have two joints and a wrist provide good connectivity of movements and are widely used in industrial assembly work. Metal printers are very expensive, but considering their performance and great importance in the training of students in different industry study programs, they represent indispensable equipment for raising the level of studies enabling them to more quickly integrate into solving a variety of engineering problems.

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