ŽILINSKÁ UNIVERZITA V ŽILINE
Strojnícka fakulta

DOI: https://doi.org/10.26552/tech. C.2025.4.4

Additive manufacturing technology

Ivana Domaniková, Ing.
Department of Transport and Handling Machines, Faculty of Mechanical Engineering,
University of Žilina,
Univerzitná 1, 010 26 Žilina.
E-mail: ivana.domanikova@fstroj.uniza.sk, Tel.: + 421 41 513 2659

Miroslav Blatnický, doc., Ing., PhD.
Department of Transport and Handling Machines, Faculty of Mechanical Engineering,
University of Žilina,
Univerzitná 1, 010 26 Žilina.
E-mail: miroslav.blatnicky@fstroj.uniza.sk, Tel.: + 421 41 513 2659

Ján Dižo, doc., Ing., PhD.
Department of Transport and Handling Machines, Faculty of Mechanical Engineering,
University of Žilina,
Univerzitná 1, 010 26 Žilina.
E-mail: jan.dizo@fstroj.uniza.sk, Tel.: + 421 41 513 2560

Patrik Slušňák, Ing.
Department of Transport and Handling Machines, Faculty of Mechanical Engineering,
University of Žilina,
Univerzitná 1, 010 26 Žilina.
E-mail: patrik.slusnak@fstroj.uniza.sk, Tel.: + 421 41 513 2659

Abstract: The article presents an informative overview on the challenges of additive manufacturing technologies. It highlights various methods and their practical applications. Additive manufacturing offers an innovative approach to producing a wide range of objects by depositing material layer by layer according to a digital model. The article describes the fundamental operating principles, commonly used materials, and key areas in which additive manufacturing is implemented. We will describe the benefits of using this manufacturing method, including product customization, reduced material waste, and shorter production times. Our aim is to acquaint the reader with the technology of additive manufacturing and the principles underlying its operation.

Keywords: additive manufacturing, manufacturing, 3*D* printing.

INTRODUCTION

Additive manufacturing, commonly referred to as 3*D* printing, is not a recent invention, however it continues to gain significance due to its numerous advantages [2].

It is used to create a wide range of objects based on a digital model, which is possible to produce a solid three-dimensional object [2].

We recognize several additive manufacturing techniques, for example *FDM* technology, FFF and others. *FFF* method is one of the most used additive manufacturing techniques in the world [2].

Additive manufacturing includes the processes, where thin printed layers of material are deposited with a bottom-up application [1].

This technological advancement has gained popularity and is often used by general public regarding its advantages and simplified manufacturing process. For example, it can reduce costs due to budget when designing a new product or producing new inventions and prototyping [1, 2].

1 HISTORICAL BACKGROUND

Additive manufacturing has progressed at a crucial pace since its invention dating back to roughly 50 years ago. During this time and now it has had significant impact on both commercial world and industrial sector [3].

Back in the 80´s, additive manufacturing techniques were considered suitable only for creation of prototypes. At that time, these methods were referred to as rapid prototyping. One of the first researchers contributing to this field was *Dr. Hideo Kodama*. The technology described by him was a *UV*-curable, layer-based fabrication, which later became important in the development of *Stereolithography* (*SLA*) [3]. In years 1987 and 1988, two of many additive manufacturing methods were developed,

such as *Laser Sintering* (*SLS*) and *Fused Deposition Modelling* (*FDM*), both of which are still used nowadays [4].

a) b)

Fig. 1. a) View of the *SLA* Additive manufacturing method and its founder, b) worlds first commercial released *SLA* machine (printer) [6]

In 2019 the quality, precision and material range of these methods had increased to the point that processes of this method are considered nowadays as a key development in many fields, such as mechanical engineering, electrical, medicine and other fields. This method has been since then spread among wide range of specialized fields and applications [4].

2 GENERAL PRINCIPLES OF ADDITIVE MANUFACTURING

The technique used for Additive manufacturing uses processes, where fine printed layers based on computer modelling are deposited following a bottom- up approach [1].

This approach is based on an outcome of 3*D CAD* data file. The following process described in the upper section consist mainly of 2 steps, which are repeated until the part is manufactured:

1. Formation of an individual layer, where the geometry and thickness are prescribed by the digital cross-section of the model.
2. Integration of each subsequent layer with the preceding one, resulting in a continuously accumulated structure [10].

This process is showing that with increasing the layer thickness of the part, the stair step effect is shown. This effect is typical for additive manufacturing [10].

Standard thickness of a layer is around 0.1 mm and can be reduced to approximately 0.016 mm, regarding the process used. Reducing the thickness means increasing the exactness of the parts and number of layers, which are required, also the manufacturing time, and the data volume [10].

Layer thickness of the product depends on used material forming the stair step effect. Hard materials such as metals and ceramics usually require more extensive finishing process than softer materials, like plastics [10].

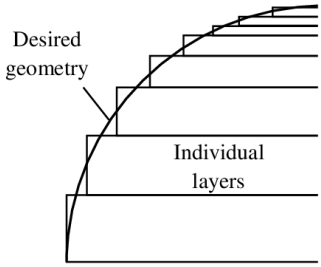

Fig. 2. The comparison between designed object and the outcome of the printed product using stair- step approach in Additive manufacturing [14]

3 MOST COMMON ADDITIVE MANUFACTURING TECHNOLOGIES

There are many technologies in additive manufacturing. For the purpose of this article, we outline only the following technologies, which are the most commonly used upon this field, namely *FDM*, *FFF*, *SLA*, *DLP*, *SLS*, Material jetting, Binder jetting and *DMLS*, *SLM*, *EBM*. The methods are described in the paragraphs below.

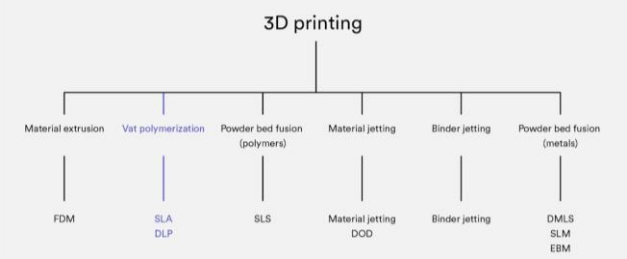

Fig. 3. Types of additive manufacturing - simplified scheme [7]

Material extrusion - *Fused Deposition Modelling* (*FDM*) or *Fused Filament Fabrication* (*FFF*) printing is a technology based on melting the material, often using plastic string, which is named filament. It is stored in the storage of an 3*D* printer on a spool, from where the printer unwinds needed material continuously until the end of printing process. The material is then melted by a heating extruder and layers the outcome product via bottom-up approach as described in the previous chapter [2].

Polymerization - *Stereolithography* (*SLA*) and *Digital light processing* (*DLP*) rely on photopolymerization of liquid resin, such as acrylate, epoxy and vinyl ether type, which are initiated through exposure to ultraviolet radiation. [10]

Powdered bed fusion (*polymers*) – *Selective laser sintering* (*SLS*) is a method, which uses laser beam to melt or selectively sinter a polymer powder into an object. [10]

Material jetting - first technique is a continual ink-jet printing, namely *Continuous Inkjet Printing* (*CIP*), where a stream of droplets is extruded through a nozzle continuously, where the Rayleigh principle of

instability is used to separate the jetted stream into droplets. Second technique in material jetting is *Drop on demand* (*DOD*). It is a technique in which the droplets are regulated and dispensed only when it is needed through heat-related or digital piezo-electric signal [11].

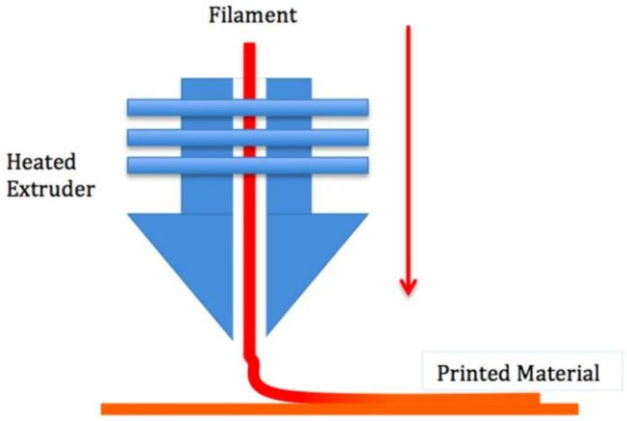

Fig. 4. Principle of function *FDM* [5]

Binder Jetting - this additive manufacturing technology is characterized by high efficiency in production and material utilization, also excellent compatibility with multiple materials. *BJ* process consists of depositing liquid binder droplets onto a powder bed via printheads, which is followed by spreading the powder layer by layer and selectively binding it. When the part is formed, the binder is thermally removed, and densification is accomplished via sintering or infiltration. This method is not reliable on laser, electron beams or optical systems, which make it a cost-effective method [12].

Powdered bed fusion (*metals*) is a group of *AM*, where the energy source uses a selective bind or melted powder to build an object. This technology consists mostly of 3 methods. *Direct metal laser sintering* (*DMLS*) is a metal *AM* method based on powder-bed fusion, where a laser beam selectively processes thin layers of metal powder. *Selective laser melting* (*SLM*) is a process, which is used, when there is need for complexly shaped, hollowed slender objects with thin walls. This process is using a power-dense laser to melt the metal powder in a powder bed, to create a solid object. *Electron beam melting* (*EBM*) is an *AM* technique used for metals, using a high-energy electron beam, to melt the metal powder (rather than a laser) in a controlled vacuum chamber [13].

5 MATERIALS IN ADDITIVE MANUFACTURING

From the invention of this technology, the most common used materials among this manufacturing method are mostly *acrylic*, *plastic*, *polymers* and *resin* [1].

With the development of material science AM has been used for fabricating parts from composites of polymer, polymer powders, granules, ceramics and metals. [1]

The most used material among methods in Additive manufacturing is polymer, used for in SLA, powdered bed fusion processes such as SLS, extrusion processes in FDM, material jetting processes in poly jet printing and sheet lamination in laminating object manufacturing. Polymer or polymer composites are beneficial when manufacturing lightweight and complex geometries with geometrical tolerances that are narrow or observed closely for size. Polymer prints in optimized processes benefit in improved accuracy, surface texture and strength in the result printed object. [1]

They are also resistant against UV light and suitable for high temperature applications, and we also benefit from their low price compared to other methods in additive manufacturing. [1]

Fig. 5. Various shapes printed parts from Polymer [8]

Usage of metal powders in *AM* is increasing, but comparing it to polymer materials, the metal is slowly built and higher in cost. Also, the disadvantage of the metal in this method is, that is has not been so developed compared to polymers. There is a limited number of metals that are printed and depending on the machines used, the limiting factor is also that the sizes of metal parts and porosity are a limiting factor that affect strength of printed objects [1].

Fig. 6. Printed metal parts [9]

CONCLUSION

Additive manufacturing represents a continuously evolving group of production strategies that rely on the controlled accumulation of material to generate three-dimensional structures directly from digital data. This paper has outlined the historical trajectory that led to the establishment of modern *AM* systems, clarified the operational principles that govern layer-wise fabrication, and compared the primary technological categories currently in use. The discussion also addressed the material domains that these technologies support and the implications of material selection for the performance and integrity of fabricated components. Overall, the article summarized the most commonly used techniques which are used in additive manufacturing, such as *FDM*, *FFF*, *SLA*, *SLS*, *DLP*, *CIP*, *DOD*, binder and material jetting and highlighted the materials connected to those methods, providing a comprehensive overview of the field.

Acknowledgements

This research was created within the following projects: VEGA 1/0037/25, KEGA 031ŽU-4/2023. The authors thank for the support.

REFERENCES

[1] EQUBAL, A. M. - EQUBAL, A. - KHAN, Z. A. - BADRUDDIN, I. A. (2024): *Machine learning in additive manufacturing: A comprehensive insight.* [online]. 2024 [Cited 21.11.2025]. Available at: https://www.sciencedirect.com/science/article/pii/S2588840424000933

[2] DOMANIKOVÁ, I. (2022): *Stavba funkčného modelu pásového dopravníka ako výučbového modelu pre študijný program Vozidlá a motory* [Bakalárska práca] (In Slovak)

[3] SUBHI, J. A. et al. (2018): *3D printing applications in cardiovascular medicine*. Academic Press, ISBN 978-0-12-803917-5 [cited from https://www.sciencedirect.com/book/edited-volume/9780128039175/3d-printing-applications-in-cardiovascular-medicine]

[4] 3D PRINTING, 2023. History of 3D printing [online]. 2023 [cited 21.11.2025]. Available at: https://en.wikipedia.org/wiki/3D_printing

[5] ČO JE FDM TLAČ? (In Slovak) 2022 [Cit. 24.11.2025]. Available at: http://sk.insta3dm.com/info/what-is-fdm-3d-printing-simply-explained-72004797.html

[6] THE HISTORY OF 3D PRINTING: 3D PRINTING TECHNOLOGIES FROM THE 80S TO TODAY. [Cit. 24.11.2025] Available at: https://www.sculpteo.com/en/3d-learning-hub/basics-of-3d-printing/the-history-of-3d-printing/

[7] WHAT IS SLA PRINTING? THE ORIGINAL RESIN 3D PRINT METHOD. [Cit. 24.11.2025] Available at: https://www.hubs.com/knowledge-base/what-is-sla-3d-printing/

[8] POLYMER 3D PRINTING IS BEING DRIVEN BY MATERIAL AND TECHNOLOGICAL INNOVATIONS. 2023 [Cit. 24.11.2025] Available at: https://www.3dnatives.com/en/polymer-3d-printing-material-technological-innovations-140220236/#!

[9] HOW IS METAL 3D PRINTING TRANSFORMING SPACE TRAVEL? 2022 [cit. 24.11.2025]. Available at: https://www.space.com/metal-3d-printing

[10] GEBHART, A. - KESSLER, J. - THURN, L. (2019): *3D PRINTING (SECOND EDITION) – Understanding Additive Manufacturing.* Munich, Carls Hanser Verlag / Hanser Publications. Page 33 - 40, ISBN 978-1-56990-702-3

[11] ELKASEER, A. - CHEN, J. K. - JAHNSEN, C. J. - REFLE, O. - HAGENMEYER, V. - SCHOLZ, G. S. (2022): Material jetting for advanced applications: A state-of-the-art review, gaps and future directions. [Cit. 26.11.2025]. Available at: https://www.sciencedirect.com/science/article/pii/S2214860422006595

[12] KAI, Y. - ZHANG, Y. - CAI, J. - ZHANG, B. - QU, X. (2025): Research progress on densification behavior of component fabricated by Binder Jetting additive manufacturing. 2025 [Cit. 26.11.2025]. Available at: https://www.sciencedirect.com/science/article/pii/S3050913025000737

[13] School of Materials Science and Engineering, North University of China, Taiyuan, China: 3D Printing of Metal – Printed edition of the Special Issue Published in Metals. Bazel, MDPI. Page 2 - 7. ISBN 978-3-0365-6864-5

[14] BROOKS, H. - RENNIE, A. - ABRAM, T. (2025): Variable Fused Deposition Modelling – analysis of benefits, concept design and tool path generation. 2011 [Cit. 27.11.2025]. Available at: https://www.researchgate.net/figure/Staircase-effect-in-layer-manufacturing-using-variable-layer-thickness_fig5_256504147