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MŰSZAKI
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KÖZLÖNY

**István Ember**[1]

# Possible Applications of Photopolymerisation Additive Manufacturing Processes in the Armed Forces[2]

*The spread of additive manufacturing is no longer a possibility today, as the technology is already present in almost every field. There are countless practical examples of military applications, even from active conflict zones. Manufacturing practice requires skilled professionals at both the technician and designer levels. However, military applications require more than just one or two technical solutions, as each one offers exploitable opportunities. Components manufactured from photopolymers are one such example, as they can be used to make special-quality products for combat soldiers, but manufacturing is only possible away from the fighting, deep within the defence perimeter.*

***Keywords:*** *3D printing, additive manufacturing, military industry, defence industry*

## Introduction

Military research is becoming increasingly important these days, with disruptive technologies playing an increasingly significant role, although many are not happy about this. Additive manufacturing did not start transforming markets recently, but it is still undergoing aggressive development today. New technical solutions and patents are constantly emerging, while composites and special metals such as titanium[3] or even hydrogels[4] have become almost common to use in additive processes. It can offer us amazing advantages in the defence sector. It can also address issues that pose challenges to both the civilian and military sectors,

1 Assistant Professor, Ludovika University of Public Service, MSOT Combat Support Department, e-mail: ember.istvan@uni-nke.hu
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3 Hlinka et al. 2023.
4 Vég 2023: 86.

such as climate change and other related environmental problems.[5] A significant portion of targeted military-related news revolves around the application of artificial intelligence,[6] which is particularly important, but we must not forget the active areas where 3D printing can provide real and proven support. These include producing operational and combat drones,[7] the manufacture of components for explosive devices (e.g. aerial bombs)[8] related to training and preparation (ranging from the technical units that locate and neutralise mines[9] to the training of future officers), educational materials[10] and spare parts necessary for the maintenance of various technical equipment.

Although the technology has already proven its technical feasibility, this alone is insufficient for effective military application. Skilled engineers are needed who are capable of using special software to create generative designs[11] in order to optimise tools. The goal may be durability, but it may also be to simplify manufacturing processes and make them more efficient. Technology and a skilled design team are key to creating the right digital warehouse, which is the basis for self-sufficiency, but also to creating the right 3D printer park.

In this study, I set out to summarise the background of two photopolymer resin-based additive technologies and their military applications.

The aim of this study is to provide a structured overview of two widely used photopolymer-based additive manufacturing technologies – SLA and DLP – and to analyse their potential applicability, advantages, and limitations in military and defence industry contexts, with particular emphasis on logistics support, rapid prototyping and operational sustainability.

## SLA technology

Stereolithography apparatus (hereinafter: SLA) is an additive manufacturing technology that uses liquid photopolymer resin that solidifies layer by layer. Solidification is performed by ultraviolet (hereinafter: UV) light, thereby forming three-dimensional objects in the build space. SLA is a widely used, relatively inexpensive version of photopolymerisation additive manufacturing, which primarily enables the production of high-resolution parts and objects with smooth surfaces.[12]

The spatial hardening of photopolymer raw materials using UV rays and its description dates back to the early 1980s. Hideo Kodama described the method by which spatial models can be created from photopolymer layers that harden under UV light. However, the patent for the technology was not registered because it did not receive support, but regardless of

[5] Padányi 2024; Dénes et al. 2024.
[6] Négyesi–Fazekas 2022; Fazekas 2023.
[7] Daruka 2014a.
[8] Daruka 2014b.
[9] Horváth–Szatai 2020a; Horváth–Szatai 2020b.
[10] Daruka et al. 2024; Vég 2024.
[11] Hegedűs et al. 2024; Markovits et al. 2023.
[12] Pagac et al. 2021; Gál–Németh 2019.

this, he can be considered the inventor of the process. The first patent for the photopolymerisation process was registered in 1986 by Charles W. Hull, who created SLA technology as we know it today.[13]

The materials used in SLA are photopolymers, in which photo-initiators create free radicals under the influence of UV light, which catalyse the monomers and initiate cross-linking, thereby creating a solid polymer from liquid resin. This photopolymerisation is an irreversible chemical reaction. Light can only penetrate a few millimetres into the resin, which is particularly advantageous in SLA technology because very thin layers are built up on top of each other.[14]

An SLA printer (Figure 1) always has a tank (also known as a build chamber) containing a liquid photopolymer. A build platform is immersed in this material and UV light illuminates the points where the resin is to be solidified according to the given cross-sectional layer. After the layer has hardened, the platform moves by a preset amount, which is also the layer thickness. The process is repeated layer by layer until the entire object is complete. The hardened resin cannot be converted back into liquid; the solidification is an irreversible thermochemical process.[15]

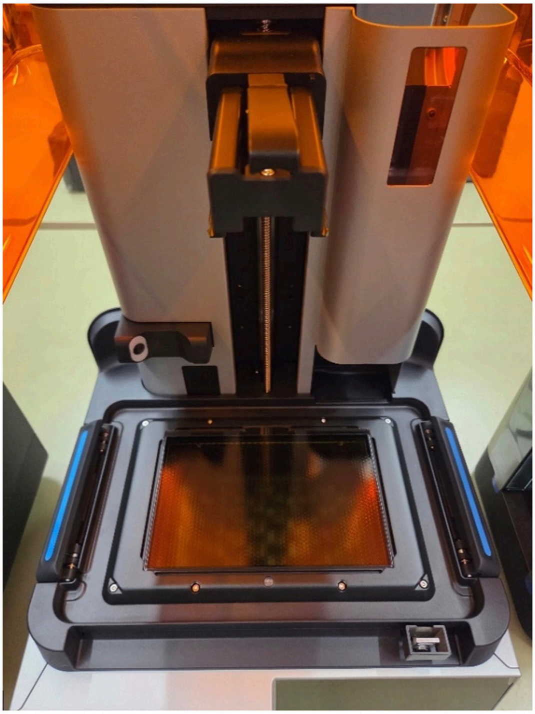

*Figure 1: Formlabs Form 4 3D printer interior space*
*Source: edited by the author*

[13] Pagac et al. 2021.
[14] Mukhtarkhanov et al. 2020.
[15] Pagac et al. 2021.

SLA technology allows the use of multiple types of photopolymer resins (only one at a time for a single object), which provide different mechanical and physical properties to the finished product. Basic resins are mainly suitable for rapid prototyping, while more durable, technical resins can be stronger and have increased heat resistance. In addition, there are biocompatible materials suitable for medical use, and even transparent or castable versions are available.[16]

There are several alternatives to the SLA process in the field of photopolymerisation additive manufacturing. Digital light processing (hereinafter: DLP) can be considered the classic solution, while continuous digital light processing (hereinafter: CDLP) and continuous liquid interface production (hereinafter: CLIP) are more advanced methods that require oxygen and light-emitting diodes (hereinafter: LED) for production. These variants therefore differ mainly in terms of the light source, its control and the production speed.[17]

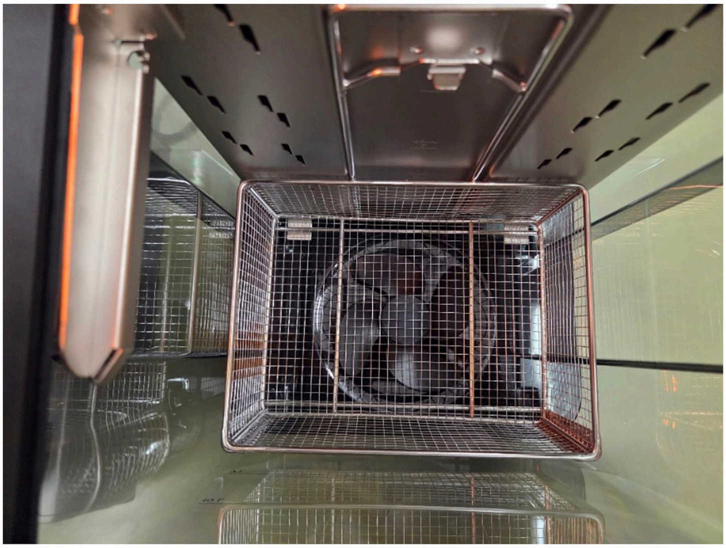

*Figure 2: The interior of the Formlabs Form 4 3D printer washing station*
*Source: edited by the author*

One of the most common applications can be found in the field of industrial prototyping. In this field, high resolution, detailed design and smooth surfaces are often essential. For example, concept models of aircraft and cars, objects tested for fit and dimensional accuracy, and visual presentation tools for developed devices can also be created using this method during iterations leading to the final product. The technology is particularly valuable and widespread in the medical and dental fields, where it can be used to create precise anatomical models, design templates for surgical procedures, and custom tools and prostheses. The use of biocompatible resins allows the creation of

[16] Engineering Product Design 2024.
[17] Pagac et al. 2021.

devices that can come into direct contact with body tissues, thereby aiding healing and improving patients' quality of life.[18]

The main advantages of SLA are therefore its outstanding resolution, smooth surface, detailed finish, and ability to reproduce complex geometric details. At the same time, the technology has its limitations, because although photopolymer resins with increasingly diverse material properties are available, the mechanical characteristics of the materials are still significantly limited and require post-processing.[19] This usually involves two steps to achieve the final quality of the object's surface. First, the remaining raw material must be removed from the surface, usually in an isopropyl alcohol bath (Figure 2), followed by final solidification of the surface using UV light (Figure 3).

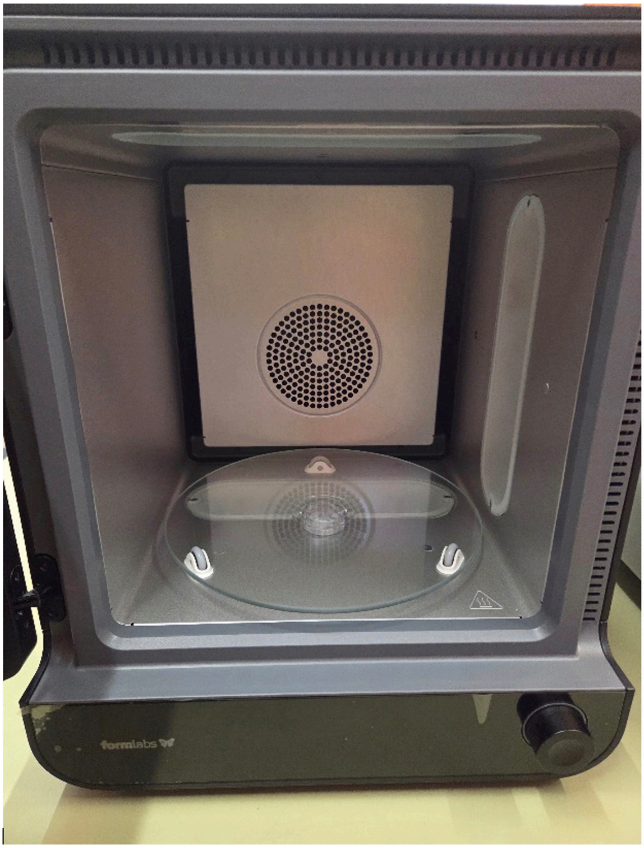


*Figure 3: The interior of Formlabs Form 4 3D printer UV post-processing unit*
*Source: edited by the author*

[18] Engineering Product Design 2024.
[19] Rapid Factory s. a.

## DLP technology

DLP 3D printing belongs to the family of photopolymerisation additive manufacturing processes; it uses UV light to cure photoreactive resin layer by layer, creating three-dimensional objects with high precision and smooth surfaces. The DLP process is based on simultaneous illumination of the entire cross-section of the layer, which provides significantly faster build speeds compared to traditional point-based light technologies.[20]

DLP technology was made possible by the digital micromirror device (hereinafter: DMD) developed by Texas Instruments in 1987, even though this development was originally used in digital projection systems. Ten years later, the projector technology was transferred to additive manufacturing, making it an alternative solution for photopolymer-based 3D printing.[21] The basis of operation is therefore a DMD consisting of more than a million units, which can be rotated to guide the light beams illuminating the resin into the correct position. The quality of the surface and internal structure of the manufactured objects is determined by the resolution of the device, which in this case is technically the distance of a few microns between the mirrors. What makes it special is that, due to the absence of high temperatures, pressure and forces during manufacturing, it may even be suitable for printing tissues and organs.[22]

In terms of raw materials, we can talk about the photopolymer resins described in the case of SLA, which harden under the influence of UV light. UV exposure causes cross-links to form in the raw material, turning the liquid phase into a solid object. The resins used in this case are typically acrylate- and methacrylate-based monomers and oligomers, which cross-link under the simultaneous exposure of light projected by the projector onto every point of the cross-section, forming a slice of the solid body.[23]

The outstanding accuracy and surface quality of the finished objects make the process particularly suitable for dental and medical modelling, such as surgical instruments, dental models and implants. The short production time and the ability to create unique objects significantly support its use in the healthcare sector.[24] The production of industrial prototypes described in the case of SLA has also become widespread through the use of the DLP process, but it also plays a significant role in the industry in the production of small series. Here, too, precision, smooth and even surfaces, and relatively fast production are fundamental requirements, and DLP is able to meet these requirements.

The main advantages of DLP technology include high resolution, a relatively wide range of raw materials, fast production due to simultaneous layer exposure, a smooth surface, and the ability to produce high-precision (small and medium-sized) parts. It does have its limitations, however, as it is only suitable for manufacturing high-strength or heat-resistant

[20] Swetha et al. 2024.
[21] Diga 2025.
[22] Zhang et al. 2020.
[23] Swetha et al. 2024.
[24] Chen–Wei 2025.

products within certain limits, and due to its resolution, the surface smoothness of large parts is reduced, requiring post-processing.[25]

## Comparison of technologies

Both SLA and DLP are additive manufacturing processes based on liquid photopolymer resin, but they differ significantly in their method of illumination. In SLA manufacturing, a UV laser draws points to be solidified in each layer on the surface of the resin liquid, while DLP uses a digital light projector to simultaneously project and solidify entire layers in the resin. This difference has a decisive impact on printing speed, accuracy and surface quality.[26]

One of the advantages of DLP is time efficiency, as the entire cross-sectional layer solidifies with simultaneous exposure. This means that larger objects or multiple objects can be produced much faster. Its speed is particularly advantageous when many identical parts need to be produced. In the case of SLA, the UV light moves from point to point, which means that it takes much longer to illuminate a layer, which is particularly noticeable in the increased production time for complex shapes with a large cross-section. Both technologies are capable of high-resolution production, but there are noticeable differences in surface quality and detail. The SLA laser has a small focal point, which can result in smoother surfaces and softer curves. This is particularly advantageous for objects without curved edges. Due to the pixel structure of the projected layers, certain curves may be slightly stepped in DLP, which can only be eliminated by a higher-resolution projector. Another indisputable advantage of SLA systems is their generally larger build volume. Despite the large volume, the level of detail is not reduced because the focus of the UV beam does not depend on the projected image. In contrast, with DLP, the number of pixels limits the quality of use of the build area. A larger projection area results in a larger pixel size, making a reduction in resolution inevitable.[27]

Both technologies use photopolymer resins, but these are not necessarily compatible with each other. In the DLP process, the intensity and spectrum of the projected light may differ from that used in the SLA process, which is why it is necessary to use specific raw materials. This also determines that the mechanical characteristics may differ for parts manufactured using different technologies.[28]

One of the key advantages of SLA technology is its excellent surface quality, meticulous detail and high precision, which is particularly important in healthcare applications. In most cases, SLA systems have a larger build volume, which can also be advantageous during prototyping. The strongest advantage of DLP is speed and efficient production. An entire layer can be exposed in a matter of seconds, supporting the production of larger quantities of parts. In addition, the projector is made up of fewer mechanical parts, which can be reflected in the price and maintenance requirements of the device.[29]

25 Janbain 2025.
26 Elo 2025.
27 McClements 2022.
28 Flynt 2019.
29 McClements 2022.

In general, we can say that SLA is the better choice when surface quality and precision are the most important requirements, for example in the case of complex prototypes or demonstration models. DLP is a much better choice when production speed and efficiency are the decisive factors. When manufacturing small parts or larger series, the outstanding cycle time of the equipment can be a definite advantage.[30]

From a military perspective, the choice between SLA and DLP technologies should be driven by mission-specific requirements. While SLA systems offer superior surface quality and larger build volumes suitable for complex prototype development, DLP systems provide higher productivity and faster turnaround times, which may be advantageous in scenarios requiring rapid replacement of standardised components.

## Possibilities for military and defence industry applications

Unlike civilian or purely industrial applications, military use of additive manufacturing technologies is strongly influenced by operational constraints such as mobility, environmental conditions, supply chain vulnerability and security requirements. Therefore, the applicability of photopolymer-based technologies must be evaluated not only on the basis of material properties and production accuracy, but also with regard to their logistical footprint, maintenance needs, and integration into existing military support systems.

Additive manufacturing has become a key element of defence technologies (although not all countries' armed forces are developing at the same pace in this area), as it can significantly reduce the time required for research and development and increase design freedom. In addition, it can reduce the procurement and supply burdens associated with logistics tasks. This manufacturing technology, including the processes detailed above, enables the production of optimised, customised parts without the burdens of traditional manufacturing processes. Of course, there are limitations, but by leveraging its advantages, the military can rely on an important form of self-sufficiency.[31] SLA and DLP technologies using photopolymers – as fundamental and universal tools for additive manufacturing – can serve as an excellent basis for rapid prototyping and the production of objects with unique geometries.[32]

In the field of military logistics, the flexibility of supply chains and the possibility of on-site[33] spare parts replacement are of paramount importance. SLA and DLP-based 3D printers are suitable for local manufacturing, which can significantly reduce the complexity of procurement and replenishment. Other technologies can also provide this in general, but with different advantages and disadvantages.[34]

It should be noted that although SLA and DLP technologies enable decentralised production, they are not optimised for frontline or combat-zone manufacturing. Their effective use

30 Elo 2025.
31 Atalie et al. 2024: 502–506.
32 Ficzere 2022: 73–74.
33 In this context, "on-site" refers to secured rear-area facilities such as permanent bases or protected logistics hubs, rather than frontline or combat-zone environments.
34 Raise3D 2025.

is rather limited to secured rear areas, bases, or containerised workshops operating under controlled environmental conditions.

As mentioned above, several types of resin can be used as raw materials. Some of these have particularly interesting and innovative properties for military use and are available on the market as high-strength and heat-resistant raw materials. This is particularly important in the defence industry and military applications, as objects and tools with outstanding material properties are sometimes necessary for combat. It also enables the manufacture of components that previously could only be made from metals. Although these materials do not yet match the mechanical performance of metals, special compounds are already suitable for higher strength and industrial applications, which also affects military support and logistics.

## Summary

The strategic relevance of photopolymer-based additive manufacturing lies primarily in its contribution to logistics resilience and reduced dependency on extended supply chains. When combined with a well-maintained digital inventory and trained personnel, these technologies can enhance operational flexibility and support sustained military operations.

Both SLA and DLP technologies enable high-quality photopolymer 3D printing, although this obviously depends heavily on the capabilities and quality of the device in question. The technologies work differently, so compromises may be necessary when choosing between them. SLA uses point illumination to provide a smoother, more detailed surface and a relatively larger production space, while DLP projects light onto an entire layer, offering faster production but poorer surface quality for larger objects.

Based on the above, both technologies may be necessary for defence industry and military applications. These devices do not enable frontline or combat-zone component manufacturing, as they are not optimised for such conditions; however, they may be effectively employed at secured rear-area bases or containerised logistics facilities operating under controlled environmental conditions. Such devices can reduce logistical burdens and supply chain dependencies to an astonishing degree, which can be a strategic advantage during an active conflict if their operation and maintenance are well organised and the organisation has a digital warehouse of sufficient quality. The latter is essential for a nation to be fully prepared to carry out its military operations today.

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