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MŰSZAKI KATONAI KÖZLÖNY

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The Possibilities and Limitations of Applying 3D Printing Technology by the Engineer Troops of the Hungarian Defence Forces[6]

The purpose of the research presented in the article is to examine 3D printing, the best-known type of additive manufacturing technology today, and its potential applications within the technical units of the Hungarian Defence Forces. In the first part of the paper, we describe the 3D printing process and classification according to various aspects, as well as the manufacturing process from design to the finished product. We then outline the strategic goals and the advantages of this manufacturing technology, justifying its legitimacy as a modern manufacturing method in the execution of military tasks. In the main part of the paper, we present the personnel and material conditions, possibilities and limitations of applying 3D printing technology in military contexts. All of this contributes to the organisational development required for applying the manufacturing process, education exploring further application possibilities and minimising potential risks associated with the manufacturing technology.

Keywords: *additive manufacturing, 3D printing, 3D printing capability, logistics, supply chain*

Introduction

Due to the relatively peaceful years in Europe over the past decades, many countries, including Hungary, spent significantly less on defence expenditures than the 2% of GDP required

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by NATO guidelines. For example, in 2014, only three countries met this target.[7] As a result of the reduced defence budgets, the necessary military technological developments and modernisations in the Hungarian Defence Forces were delayed, directly causing a decrease in combat effectiveness. In what was perceived as a stable security environment and the absence of threats, this had no noticeable impact or major consequences.

In recent years, radical changes in the global security environment, various geopolitical tensions, and the continuously escalating armed conflicts, such as the Russo–Ukrainian war in our neighbouring country, have forced a reassessment of NATO's strategic goals and defence policy. Due to increasing security threats and risks, more and more countries have raised their defence spending, resulting in 11 NATO allied countries meeting the 2% GDP expenditure guideline by 2023, and 18 countries meeting it by early 2024.[8]

Consequently, NATO's budget has grown significantly year after year, enabling the Alliance to fulfil its three core tasks: deterrence and defence, crisis prevention and management, and cooperative security. In addition to contributing to the collective burden-sharing, the significantly increased domestic defence budget has provided an opportunity for previously delayed investments, refocusing the development of the Hungarian armed forces. As a result, modern helicopters, combat vehicles and tanks have been acquired and put into service. Alongside the acquisition of modern military equipment, the necessary organisational restructuring and the preparation of personnel for their use have also been carried out.

To ensure Hungary's sovereignty and territorial integrity, the Government, in line with NATO's strategic concept, has developed and adopted the National Military Strategy.[9] This strategy provides guidance for the medium and long term for the Hungarian Defence Forces, based on the experiences of current conflicts and anticipated future challenges. The strategy outlines, for example, the roles and applications of the armed forces and the directions for their development, aiming to transform the Hungarian Defence Forces into a modern, flexible and efficiently deployable military force. Through ongoing and future developments, a modern military will emerge, equipped with advanced technology, high mobility and rapid responsiveness, capable of meeting both current and future challenges while continually evolving and adapting.

To achieve these goals, such as the developing military organisation and technology, and establishing additional competencies, it is essential to utilise modern technology and innovations. These advancements contribute to the successful execution of tasks, enhance operational efficiency and improve survivability.

The directions for developing the domestic defence industry must be aligned with the goal of ensuring that the armed forces possess technological capabilities essential for future warfare, such as cyber defence, artificial intelligence, robotics, unmanned aerial vehicles and countermeasures against them, and advancements in materials and manufacturing technologies. The list clearly demonstrates that the defence industry actively adopts innovative solutions

[7] The Secretary General's Annual Report 2023.
[8] The Secretary General's Annual Report 2023.
[9] Government Resolution 1393/2021 (VI. 24.) on the National Military Strategy of Hungary.

and technologies that have proven competitive and efficient in the profit-oriented economic sector. Among these, 3D printing technology stands out, offering numerous advantages over traditional manufacturing processes. Our research on 3D printing, with most results already published, demonstrates that this technology[10] has a place in a defence system equipped with modern military technology and its own manufacturing capabilities.

Introduction to 3D printing technology

The production of a product tailored to the various needs of the customer is the result of a planned, optimised and cost-effective manufacturing process that systematically alters the shape and properties of the raw material. Today, this is still primarily achieved through traditional manufacturing methods, where excess material is usually removed according to the product design, typically using machining processes like milling, drilling and turning. In contrast, additive manufacturing, like the 3D printing process discussed in this paper, builds objects layer by layer by adding material based on a digital 3D model. Preparing the necessary files for printing can be done through:

- designing, using CAD software
- 3D scanning

3D printing is spreading at an increasing pace, from hobby users to profit-driven economic players. In addition to home use, it is appearing in businesses involved in manufacturing and it is becoming more common in the service industry, too. Almost every sector of the economy is beginning to discover and exploit the advantages of 3D printing. These advantages led us to begin researching this manufacturing technology a few years ago. Our research focused on its methods, materials and untapped potential for military applications.

The classification of 3D printing processes not only facilitates navigation for average users within the ever-expanding range of options, but it is also essential for selecting the printer most suitable for our research and specific technical tasks. Based on the classification, 3D printing processes can be grouped according to their field of application (e.g. education, research, prototype production, etc.), the printing method (e.g. extrusion-based, powder bed, etc.) and the type of printing material used (e.g. plastics, metals, composites, etc.). Considering that the acceptance and use of 3D printing is growing, the technology is continuously and rapidly evolving. As a result, newer, more accurate and more efficient printing methods[11] and materials are becoming available to users. Consequently, 3D printing processes have become economically viable and successful in areas where production or the operation of supply chains used to be very costly.

In our research on the application of 3D printing processes within technical units, we considered the fact that the technology's use and development are still in the early stages. During this period, we are refining the manufacturing process details that best meet the

[10] Daruka et al. 2024a.
[11] Kara et al. 2023.

requirements and regulations of various fields of application, with the aim of partially or fully replacing the previously used solutions. Despite the advantages uncovered so far, the process still requires significant improvements in several areas. Reducing printer errors,[12] improving the mechanical properties of materials,[13] localising and applying existing manufacturing standards, and standardising quality control procedures for the finished products will further enhance user satisfaction.

The 3D manufacturing process is being increasingly adopted by various profit-oriented players in the economy, as it enhances production efficiency, reduces costs and increases revenues. Due to the significant advantages and opportunities of this technology, it is also being researched and utilised by the defence industry, including the military, in various areas such as military logistics to reduce supply chain risks, a topic we have addressed in detail in a previous publication.

Application of 3D printing technology in the Hungarian Defence Forces

Like private sector businesses, the Hungarian Defence Forces also employ modern and innovative solutions that provide certain advantages and added value to the organisation. These include modernisation based on technological advancements,[14] efficiency improvements brought about by high-end military technology, and achieving faster response capabilities. All of these contribute to fulfilling military strategic objectives, reducing risks and enhancing security, which together ensure the success of mission execution and the safety of personnel carrying out the tasks.

To achieve the set goals, it is essential to examine the adaptation of modern technologies and advancements into the military, as previously mentioned. To enhance supply security, the renewal of the domestic defence industry is necessary, and partial successes and results have already emerged within the armed forces. The outcomes of defence-related research and development can lead to breakthroughs in various areas of defence capabilities, such as the development of critical military equipment. The significant increase in the budget of the Hungarian Defence Forces creates the opportunity for this, contributing to the modernisation and strengthening of the military, which is both a national interest and supports the strengthening of NATO.

Driven by national interests, the domestic defence industry, including national defence, effectively employs innovative and modern procedures that contribute to the development of a contemporary organisation and military technology in line with current requirements, thereby enhancing security. Achieving a modern military, however, requires not only the development of existing capabilities. It also demands the creation and integration of new capabilities into the armed forces, ensuring that goals are met more efficiently and swiftly.

[12] Zentay et al. 2023a.
[13] Zentay et al. 2023b.
[14] Hegedűs–Gyarmati 2022.

The combat actions of the ongoing Russo–Ukrainian war, for more than two years in our neighbouring country, demonstrate how the military application of innovative and modern solutions fundamentally alters established rules and procedures of warfare. Among these, particular importance is given to modern weapons systems AI-powered robots, and the widespread deployment of drones and, most importantly, 3D printing, the focus of our research. The successful application of 3D printing in military technology has enabled the local productions of drones and weapon parts near the front lines. Specialised 3D printers optimised for military requirements are used for these tasks, which can even meet supply needs under field conditions. Large-scale 3D printers designed for construction purposes will be used to rebuild buildings destroyed, demolished, or damaged in the fighting. These examples underscore the legitimacy of applying modern technologies in the military and the necessity of developing military capabilities. Furthermore, these examples support our view that 3D printing, a revolutionary new manufacturing technology, should play a decisive, though not exclusive, role in the Hungarian Defence Forces, particularly in defence-related education, research and supply chains.

The possibilities of applying 3D printing technology by the engineering units of the Hungarian Defence Forces

According to the timeless thoughts of Colonel Ágost Jacobi:[15] "The engineer soldiers, we mean that large family that not only fought with weapons in hand, but with their knowledge, special equipment, training and ingenuity, were the most loyal and indispensable supporters of the combat forces." This often-cited and fitting statement not only defines the concept of engineer soldiers but also outlines the essential skills that have equipped this long-standing branch to assist and support combat operations for millennia. The spirit of Jacobi Ágost's thoughts, which have been relevant for nearly 100 years and are still forward-looking, lays the foundation for the justified expectation that technical soldiers must adapt to changing circumstances and requirements.

The concept of engineering support, as it is understood today, evolved over a long period and gained its current interpretation. Its concept, objectives and task system developed in parallel with the advancement of armed conflict, and its tasks multiplied according to the needs of the times. The basic elements of engineering support, as defined in both Hungarian and NATO engineering doctrines, include mobility support, counter-mobility, enhancing survivability and general engineering support.

We examined and analysed these task areas to identify specific tasks where 3D printing technology could contribute to more successful and efficient execution. When selecting the appropriate areas for the adaptation of 3D printing technology, we were aided by a SWOT analysis of the manufacturing process, conducted by our research group. The results and findings of this analysis will be published soon.

[15] Balla–Padányi 2019.

3D printing in the military offers numerous potential applications that can simplify military operations and logistics, making them safer and more efficient. After examining and analysing the technical tasks performed by the engineering units supporting military operations based on their mission, we identified areas where 3D printing could contribute. These include specialised tasks aimed at efficiency in task execution:

- Manufacturing classroom and educational tools: Producing educational aids, such as bridge models or training replicas of explosive devices, essential for the training, education and further skill development of the personnel. Printing educational models and tools that aid students' understanding and make learning more interactive.
- Research tools: Printing specialised laboratory equipment tailored to specific research needs.
- Manufacturing unique or specialised tools: Producing tools, unique or specialised equipment used in the execution of technical tasks.
- Custom tools and equipment: Soldiers can on-site print custom tools and equipment required for special tasks, allowing quick adaptation to changing conditions.
- On-site construction or repair: The technology enables the printing of construction elements or entire structures, such as houses, using concrete, which can reduce construction time and costs.
- Manufacturing prototypes and sample pieces: During the design and development, 3D printing enables rapid on-site production of prototypes and parts from various materials, facilitates faster testing and further development.
- Producing parts and spare parts: This process shortens delivery times reducing supply chain risks. It enables rapid on-site production of parts for military vehicles, bomb disposal robots and other technical equipment, even on the battlefield.
- Production charge housings for demolition and bomb disposal tasks: Using low-density materials, various designs of charge housings can be produced,[16] which can be used for demolishing structural elements or neutralising explosive devices. The application of artificial intelligence in this field, combined with existing research,[17] can further enhance the safety and efficiency of bomb disposal tasks.
- On-site manufacturing, even in the field of operations: Printers optimised for military manufacturing tasks enable mobile production of parts, even on the battlefield.
- Printing tactical maps: To better understand geographic conditions or urban structures, 3D printing can quickly create maps[18] and other informational tools.
- Creating a digital database:[19] Establishing a database and continuously expanding it with printable digital 3D models ensures that authorised users can download and print the necessary components, saving time.
- Simplifying transportation logistics and the supply chain: The manufacturing technology offers units the ability to produce the necessary tools or parts on-site, shortening the supply chain and reducing transportation time, costs and risks.

[16] Ember–Ádám 2022.
[17] Ádám 2023.
[18] Kállai 2023.
[19] Daruka et al. 2024b.

- Construction and infrastructure solutions: Large-scale 3D printers optimised for construction tasks provide the opportunity to build various functional structures (e.g. residential buildings, schools, defence structures, etc.), whether permanent or temporary.

The expected results of further development in 3D printing technology are likely to create opportunities for its effective use in additional technical tasks.

Conclusions

In response to recently emerging security risks and tensions escalating into war, a natural protective response has developed among the populations of peace-loving countries. As a consequence, responsible national governments have increased their defence budgets to the necessary extent in line with expected threats, initiating or accelerating the modernisation of their armed forces and further enhancing their defence capabilities. Undoubtedly, the Russo–Ukrainian war was the primary reason why the Hungarian Government promptly raised the defence budget above the expected 2%, contrary to previous plans. This significant additional funding is expected to enable the military's modernisation and upgrading objectives to be achieved in a shorter period.

Enhancing defence capabilities nationally and within alliances demands a modern defence industry that adopts innovative procedures to develop advanced military technology and organisational systems aligned with current needs. Achieving a modern armed force capable of responding swiftly to challenges requires not only the development of existing capabilities but also the creation and integration of new ones that more effectively ensure the attainment of objectives.

The results of our research in this field confirm that the establishment of 3D printing capabilities within the Hungarian Defence Forces is one of the key areas that can contribute to the development of a modern military force with independent manufacturing capacities, in line with current demands. As an additive manufacturing technology, 3D printing has, within just a few years, overshadowed traditional manufacturing processes in many fields due to its numerous advantages. Advantages such as rapid prototyping, material savings, design flexibility and the ability to create complex structures all contribute to achieving greater success and efficiency through its application. Its role is expected to become more prominent in the future, as the capability for on-site manufacturing,[20] even in the field of operations, reduces supply chain risks, which is crucial during combat operations.

However, additive manufacturing technology can not only be utilised for general product manufacturing tasks in military logistics, but it can also be effectively applied in various specialised tasks. In the research presented in this article, we accordingly examined the possibilities of using 3D manufacturing processes within engineering units. We explored both the known and untapped advantages to identify the specific technical tasks where 3D printing could serve as a viable alternative to traditional manufacturing methods or procurement. Finally,

[20] Végvári 2023.

we outlined the personnel and material requirements necessary for implementing 3D printing capabilities in engineering units and for the more efficient execution of specific technical tasks.

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