Additive Manufacturing – Application and Use in Defence Technology

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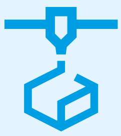
Additive manufacturing (AM), commonly referred to as 3D printing, is a process that creates items by layering material based on a digital 3D model or design. With its layer-by-layer build-up, AM contrasts with conventional manufacturing processes that use formative or subtractive methods to produce a part. **China**, **United States** and **Germany** are currently the three states with the highest funding rates into research and development of AM. The current market volume is **€10.5 billion**, with especially the aerospace, medical and tooling industry projected to be leading further AM integration. **German firms have been pioneering many AM processes**, dominating for example in the metal powder bed fusion market: 1. EOS (Krailing, GER), 2. SLM Solutions (Lübeck, GER, acquired by NIKON), 3. 3D Systems (Rock Hill, US)

Benefits and characteristics

- **Design freedom: diverse geometries and material compositions**
- **Lightweight design and one-component parts**
- **High degree of customisation**
- **On-demand manufacturing and rapid prototyping**
- **Decreased material consumption**
- **No tooling or mould needed to create volume**

Security concerns

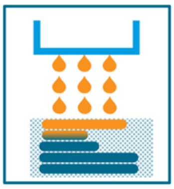


- Proliferation of materials and processes that allow the production of weapons of mass destruction (e.g. nuclear fuel cycle)
- Accessibility of "self-made" launch capabilities (e.g. missile technology) to malicious actors
- Novel and unpredictable challenges (e.g. 3D printed firearms)

According to DIN EN ISO/ASTM 52900:2018-06, AM covers seven main production categories (see images below) and many subordinate processes. Diverse materials can be processed, such as metals, ceramics, polymers or even cells. Systems can be roughly categorised as either liquid-, solid- or powder-based. Most commonly known processes are **material extrusion** and **powder bed fusion**.

Vat photopolymerisation

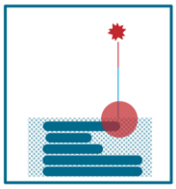
Material jetting



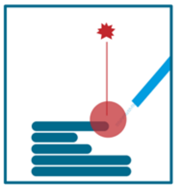
Binder jetting (3D printing)

Material extrusion

Sheet lamination



Powder bed fusion



Directed energy deposition

The principle behind **material extrusion** (MEX, Fused Filament Fabrication/Fused Deposition Modelling) is the creation of items through layering of heated/semiliquid material deposited onto a build platform. Depending on the envisioned use case or surface quality, it quickly becomes more complicated, e.g. when printing metals. MEX can be used for a wide range of applications: from the desktop printer at home to diverse industrial applications.

Powder bed fusion (PBF, Selective Laser Sintern/Selective Laser Melting) is currently the AM process with the biggest market share. Volume is created through the targeted melting or sintering of powder by a heat source. This powder is spread over a build platform and a new layer is applied on top after each melting process. A huge variety of materials can be processed and is next to the broad design freedom of structures PBF's big advantage.

Current limitations

- **Limited experience and knowledge of material characteristics (e.g. fatigue behaviour)**
- **High costs for industrial printer and maintenance**
- **Lack of training, material, testing and quality standardisation**
- **Item size confined by printer size**
- **Additional labour-intensive post processing often needed**

Military Applications of AM

As an **envisioned military capability**, AM for military purposes has been tested and tried by different national armed forces. Small items have been printed both during NATO exercises and in the war in Ukraine. As such, its envisioned purpose in the military realm – and for humanitarian missions – can be roughly categorised in two areas.

Logistical support

- *parts of consequence*: spare parts, temporary replacement parts (battle damage repair), old and legacy parts, tooling, low quantities
- customised parts for medical use cases
- rapid in-time and on-demand manufacturing
  - ➡ responsiveness, resilience and readiness, and increased autonomy in the theatre

New and lightweight design

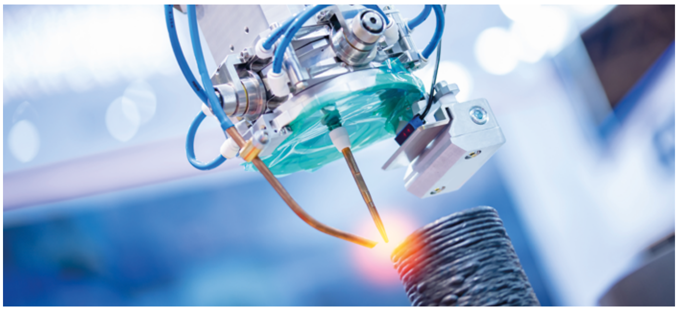
- weight reduction of armour, ammunition and other systems
- aeronautical industry: increasing thrust-to-weight ratio
- new possibilities such as printing propellants or explosives and new space systems
- advancing sustainability efforts

Case study:

AM has been used in Ukraine for the production of small parts in container factories and increasingly for printing parts for FPV drones. Parts such as fins to stabilise bomb droplets or even structural parts for lightweight (kamikaze) drones are printed by military units themselves and private cooperatives using MEX desktop printers.

Hardware limitations in missions

- sensitivity to external influences, e.g. temperature, humidity, vibration
- flexibility of use on-site depends on calibration and complexity of the system
- mobile plug-and-play solutions, such as systems utilising MEX or directed energy deposition (.i.e. container factory using wire arc AM), limited to non-critical parts
- limited quality control capabilities *in situ* and post-production on site



Wire arc additive manufacturing (Photo: Parilov/Shutterstock)

Problems

Legal: Contract liability, IP rights	Product variance and long certification times	Training and standardisation lagging

If self-printed parts are built into systems without the approval of the original equipment manufacturer (OEM), this could result in contractual penalties/loss of warranty. This illustrates the dependency of the armed forces on the willingness of the OEM to accept self-made parts and/or share original designs to allow for the production on-site.

Future outlook

- Increasing training and education of soldiers
- Military's collaboration with OEM to identify and develop use cases for AM
- Expanding scope of printable parts and available digital designs
- Progressing standardisation and certification
- Improvements of (in-situ) quality control and evaluation
- Legal security about IP rights in conflict situation

Appendix

Imprint

CNTR is a research alliance between the Peace Research Institute Frankfurt (PRIF), Justus Liebig University Giessen and the Technical University of Darmstadt. www.cntrarmscontrol.org · V.i.S.d.P.: Elisabeth Waczek (PRIF), Baseler Straße 27–31, Frankfurt a.M., Germany, Phone (069) 959104-0, info@prif.org, www.prif.org · Design: media | machine GmbH · Layout: CNTR

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aufgrund eines Beschlusses des Deutschen Bundestages