METAL ADDITIVE MANUFACTURING OF END-USE COMPONENTS AND PARTS: A PRACTICAL OVERVIEW

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Abstract

This research offers an up-to-date practical overview of the state and capabilities of creating typical applications from metal by AM 3D printing technology. The latest achievements and innovations of each technological metal AM option are under investigation and worth attention to analysing the real production capability. The present technical review, confirms the proper capabilities of AM in accelerating the development of 3D printing of end-use components and parts ready-to-market metal products supporting the overall industrial investment strategy, also the rest of professional demands, and sectors.

Introduction

AM 3D printing in the case of metals needs state-of-the-art solutions, and sophisticated and intelligent machines, capable of producing high-precision components at a low overall cost. The most significant factors that affect 3D metal printing, are software and hardware potentials, energy used, corresponding material and its optimization, post-processing technology, real-time process monitoring, and the like.

Classification of metal AM technologies

Classification of metal AM technologies by type of energy, post-processing required, and type of process metal printing and related material shown is in Fig.1 (a), (b), (c), and (d) [1].

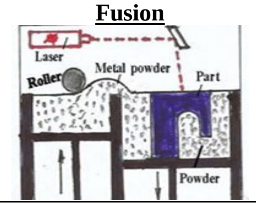
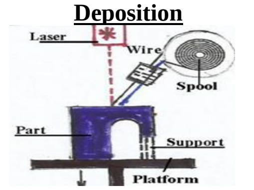
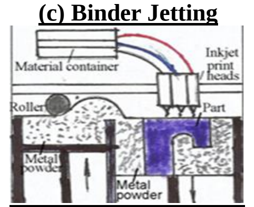
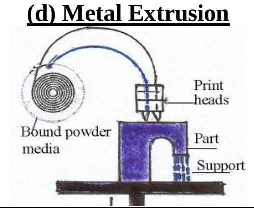
(a) Metal Powder Bed Fusion 	**Processes:** -Selective Laser Melting /Sintering (SLM)/(SLS) - Direct Metal Laser Sintering (DMLS), -Electron Beam Melting (EBM), etc.
	Corresponding Materials: Metal powder: stainless steel, nickel, titanium, ceramic powder, polyamide, etc.
	Post-processing: -Ventilation, CNC, EDM, HIP, surface finishing, heat treatment, etc.
b) Direct Energy Deposition 	**Processes:**- Powder Direct Energy Deposition- (DED)- Wire Direct Energy Deposition, etc.
	Corresponding Materials:- Bound metal printing,-Molten metal powder, etc.
	Post-processing: -Ventilation,- CNC, -surface finishing, -heat treatment, etc.
(c) Binder Jetting 	**Processes:** - Material Jetting. - Binder Jetting.- Powder Bed Fusion, etc.
	Corresponding Materials: -Metal powder,- ceramic powder, polymer powder, photopolymer, wax, etc.
	Post-processing: -Batch sintering solution, -surface finishing, -heat treatment, etc.
(d) Metal Extrusion 	**Processes:** -Metal Fused Filament (FFF/ /FDM), Atomic Diffusion AM (ADAM), etc.
	Corresponding Materials: -Bound metal printing, thermoplastics, ceramic slurries, metal pastes, composites, etc.
	Post-processing: Watch and sinter, some parts heat treatment, CNC, surface finishing, etc

Fig. 1. Classification of metal AM technologies by type of energy, post-processing required, type of process metal printing and related material.

(a) Metal Powder Bed Fusion

Powder Bed Fusion is a very successful type of 3D printing from which standard technologies have evolved, shown in Fig.1 (a). The basic feature of all these machines is that they use a high-power laser power source.

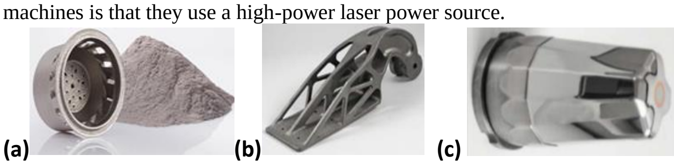


Fig.2.(a) Metal powder whit one end-use metal part (Source: EOS GmbH), (b) Lightweight turbine cover door hinge (source: EADS/EOS GmbH) (c) Tooling insert for child cup (source: Polymold/ EOS GmbH) [2]

This enables the selective dissolution of loose metal powder to form a precise and complex geometric figure. Using of the Metal Powder Bed Fusion process DMLS is shown in Fig. 2 (a) One end-use characteristic metal part (Source: EOS GmbH), (b) Lightweight turbine cover door hinge for Airbus A380, Material: EOS Titanium Ti64 (source: EADS/EOS GmbH). (c) One tooling insert for child cup, Material: EOS Maraging Steel MS1 (source: Polymold).

b) Direct Energy Deposition

Fig. 3 (a) shows the implementation of Direct Energy Deposition DED technology to repair the worn shaft seal, thereby extending the life of this vital component, and (b) and (c) show two cases of using DED technology for parts of complex geometries [3].

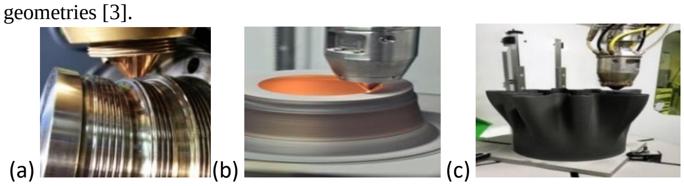


Fig. 3. (a) Repair of worn shaft seal (Source: BeAM), (b) End-use part (Source: BeAM), (c) End-use component of complex geometries (Source: BeAM) [3].

(c) Binder Jetting

Representative case studies of finished metal use components manufactured by ExOne Company with Binder Jetting 3D printing shown are in Fig. 4. (a) Metal filter components for strainers and metallic filter applications, (b) Case study one optimized of the part and (c) One new binder jetting printed casting mold [4].

Fig. 4. (a) Metal filter components for strainers and metallic filter application (source: ExOne), (b) Case study one optimized of the part (source: ExOne), and (c) Binder jetting printed casting mold (source: ExOne) [4].

(d) Metal Extrusion

Metal FFF is an advanced new process in additive manufacturing based on plastic FDM, where the heated metal filament deposited is through the nozzles layer by layer. Fig. 5 (a) Shows an FFF 3D printer from 3DEO capable of producing high-quality metal components of small to medium size max up to 250mm. Two case studies of metal 3D printing with design freedom and manufacturing flexibility manufactured in this Company are shown in Fig. 5 (b) and (c) [5].

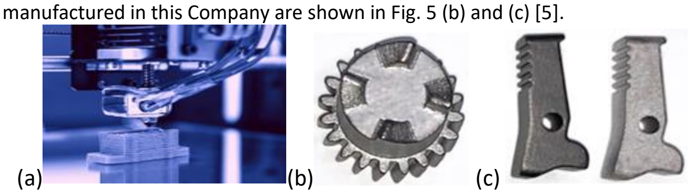


Fig. 5. (a) Metal FFF 3D printer from 3DEO (source: 3DEO), (b) One metal end-use component and (c) One optimized rack-wheel part (source: 3DEO).

Conclusions

Presented metal AM printing technologies provide outstanding optimized application capabilities in almost all industrial fields, and diverse sectors as well as in medical applications, from the design, testing, and rapid prototype phases to a wide range of commercial functional end-use components and parts printing.

Post-processing of Metal FFF parts is required for both wash and sintering, while heat treatment and surface finishing treatments depend on the complexity of the parts, although they significantly increase the cost of metal 3D printing, they are not limited, because the benefits of metal 3D printing are great. The investigation showed that metal AM systems in the production of metal components achieve predominantly more favourable design flexibility, shorter fabrication time, high precision of complex shapes, and a significantly lower cost of production compared to traditional machining processes.

References

[1] Sljivic, Milan, et al. Metal Additive Manufacturing of End-Use Components and Parts: A Practical Overview. Structural Integrity … 2022, 25: 149.– Springer.
[2] EOS GmbH Presents: EOS Parameter Sets for Direct Metal Laser Sintering (DMLS)... https://www.eos.info/press/eos-presents, last accessed 2020/03/26.
[3] BeAM Machines: Directed Energy Deposition, https://www.beam-machines.com/applications-process- 3d printing, last accessed 2020/03/26.
[4] ExOne Company: The Most Researched Binder Jetting Systems in 3D Printing: ExOne, https://www.exone.com/en last accessed 2020/03/29.
[5] 3DEO Company: Metal 3D Printing Processes - Metal Extrusion FFF/FDM, https://news.3deo.co/author/3deo

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