Learner Centric Advanced Manufacturing Platform

3D METAL PRINTING

WPN° 3 Observatory

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GLOSSARY AND/OR ACRONYMS

AI - Artificial Intelligence

AM - Advanced Manufacturing

Cedefop - European Centre for the Development of Vocational Training

CoVE - Centres of Vocational Excellence

EAfA - European Alliance for Apprenticeships

EC - European Commission

ECVET - European Credit System for Vocational Education and Training

EntreComp - The Entrepreneurship Competence Framework

EQAVET - European Quality Assurance in Vocational Education and Training

EQF - European Qualifications Framework

ESCO - European Skills, Competences and Occupations

ETF - European Training Foundation

EU - European Union

HE - Higher Education

HVET - Higher Vocational Education and Training

I4.0 - Industry 4.0

KET - Key Enabling Technology

OECD - Organisation for Economic Cooperation and Development

SME - Small and Medium Enterprises

SWOT - Strengths, Weaknesses, Opportunities, Threats

TVET - Technical and Vocational Education and Training

VET - Vocational Education and Training

WBL - Work Based Learning

CONTENT TABLE

EXECUTIVE SUMMARY

Advanced Manufacturing (AM) and Higher Vocational Education and Training (HVET) need to update training, implement new technologies, and get quick access to data.

The causes behind these needs are technological factors (Industry 4.0), factors conditioned by education systems and education methodologies, social factors and environmental factors (the European Green Deal with its emphasis on the greening industry).

Under the CoVE initiative, the LCAMP project aims to support regional skill ecosystems and various stakeholders in providing new skills and implementing new or updated technologies in VET centres. LCAMP will tackle this by incorporating a permanent European Platform of Vocational Excellence for Advanced Manufacturing.

By collaborating across borders, LCAMP's goal is to support and empower regional Advanced Manufacturing CoVEs to become more resilient, innovative, and better equipped to train, upskill, and reskill young and adult students, to successfully face the digital and green transitions. We will help European regions and countries grow and be more competitive through their VET systems.

Therefore, the LCAMP OBSERVATORY is one of the services in the LCAMP platform. The observatory is led by the French cluster Mecanic Vallée and the French VET provider Campus des Métiers et des Qualifications d'Excellence Industrie du Futur.

This present document details the first results of the LCAMP Observatory, through the methodology that the LCAMP consortium used to set up and run the Observatory. We had set up a process cycle for the observation consisting of 5 stages:

Stage 1: Diagnosis and priority

Stage 2: Search and information gathering

Stage 3: Information Analysis

Stage 4: Creating value. Elaboration of LCAMP reports

Stage 5: Dissemination and communication.

1. INTRODUCTION

The LCAMP observatory is one of the services of the LCAMP platform.
The LCAMP Observatory must be a reliable and easily accessible source of information and data for trainers, VET teachers, and professionals, updated on Digital / Advanced Manufacturing / Smart Industry, delivered through a multimedia and interactive platform -LCAMP platform-, that can be customized according to individual interests (Work in progress in WP8).
This observatory must feed other Work packages (WP), for instance, WP 5 on Learner Centric Training, or Open innovation Community in the WP4.
In a first document about methodology, are set up a process cycle for the observation consisting in 5 stages:

- Stage 1: Diagnosis and priority
- Stage 2: Search and information gathering
- Stage 3: Information Analysis
- Stage 4: Create value. Elaboration of LCAMP reports
- Stage 5: Disseminate-communicate.

Following this process cycle, are detailed the main aspects of the observation methodology:

- Identify reliable sources that we can find in Europe about Advanced Manufacturing.
- Classify and filter data gathered from different sources.
- Present several ways to collect data and to analyse them.
- Define the methods for the creation of annual reports.
- Validate process for those reports.

The observatory will publish periodical reports for VET and HVET target audiences about technology trends, labour market changes, skill needs, and occupations in Advanced Manufacturing. It is expected that SMEs, industry clusters and other associations will also find valuable information in the observatory.
The publication of a yearly report is planned.

- Report 1: June 2023,
- Report 2: June 2024,
- Report 3: June 2025.

This first annual report is gathering sub-reports written by around twenty different writers, from the main partners involved in the LCAMP project. 39 Topics were determined, and 22 TOPICS were analysed and worked on during this first period.

2. ADDITIVE MANUFACTURING: 3D METAL PRINTING

The purpose of this chapter is to present some of the development areas related to AM. These are topics that concern all or some of the stakeholders

- CoVEs and VETs: teachers, trainers and heads of VET schools;
- Learners: students, active workers, job seekers;
- Companies;
- Policy makers and other stakeholders

2.1 INTRODUCTION

First patented in 1995 by the Fraunhofer Institute in Germany as a laser fusion technique[1], 3D metal printing has continued to evolve to become an essential tool to manufacturing in many sectors such as the aerospace, automotive, industry sectors.

Like 3D plastic printing, 3D metal printing offers various advantages. It allows to quicken the process between the idea and the manufacturing of the part. It also allows to make parts with less material than with machining. It can be used to repair parts by remaking subparts, which allows parts to last longer as a whole and reduces waste. Finally, since printing parts means producing parts locally instead of importing them. These various advantages mean a lesser cost in transportation, materials, and parts. However, a drawback is the lack of reproducibility of parts.

According to a Wohlers report from 2018 on the 3D printing material market, metal represented 16,2% in 2017.[2] This report also estimated that the metal 3D market was worth $720 million and that the sales of 3D printers using metal increased by 80%.[3]

[1] 'Impression 3D métal : Le guide de l'impression métal', Hubs, accessed 14 April 2023, https://www.hubs.com/fr/guides/impression-3d-metal/.

[2] 'Wohlers Report 2018 Shows Dramatic Rise in Metal Additive Manufacturing and Overall Industry Growth of 21%', *Wohlers Associates* (blog), 27 March 2018, https://wohlersassociates.com/press-releases/wohlers-report-2018- shows-dramatic-rise/.

[3] Impression 3D métal'.

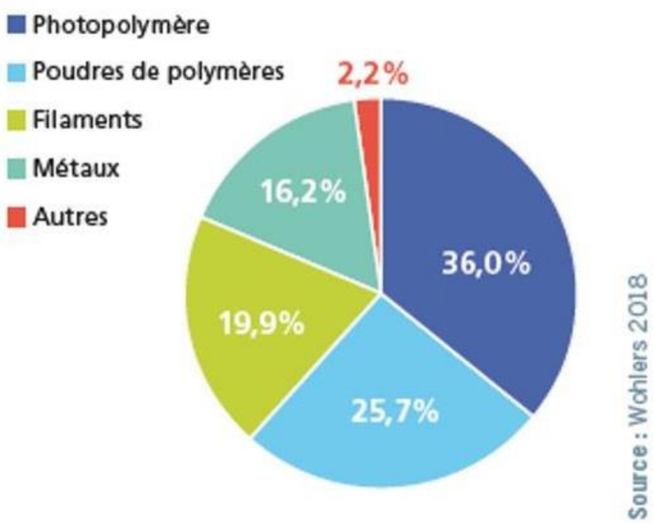

Figure 1 : Market in 2017

Since then, many different printing technologies have been developed. As more and more companies developed 3D metal printing techniques, the future of the sector appeared bright. During the 2010s market research expected the sector to boom however 10 years later the sector has not grown nor changed as much as expected. Despite a great number of innovations over the years, the DMLS technique is still the most common used technology in companies.

It appears that this sector is slowed down in its growth by the price-range of 3D metal printers and their implementation in a company unsure of its efficiency.

2.2 OBJECTIVES / RESEARCH QUESTION / PROBLEM STATEMENT

2.2.1 OBJECTIVES

The objectives of this work are to understand how the 3D metal printing sector is growing, what are its trends, and what changes can be expected in that sector.

2.2.2 RESEARCH QUESTION

How come the 3D metal printing sector hasn't taken off like predicted? What are the obstacles that are slowing the growth of the 3D?

2.2.3 SOURCES

Table 1 : Main sources

Title	Description	Geographical scope	Sectorial scope	URL
3Dnatives	Industry publication specialized in 3D printing	French and International	3D printing	https://www.3dnatives.com/ https://www.3dnatives.com/en/
Aniwaa	Website that advises professionals on additive manufacturing equipment	French	Additive manufacturing	https://www.aniwaa.fr/
L'Usine Nouvelle	Industry publication providing manufacturing news	French, International	Multisector	https://www.usinenouvelle.com/
The Manufacturer	Industry publication providing manufacturing news	European, International	Multisector	https://www.themanufacturer.com/
Manufacturing	Industry publication providing manufacturing news	European, International	Multisector	https://manufacturingdigital.com/
IDTex	Independent market research provider	European, International	Multisector	https://www.idtechex.com/

2.2.4 PROBLEM STATEMENT

Despite the boom of the 3D plastic printing sector and continuous innovations that make 3D metal printers better and better, companies don't appear to adopt 3D metal printing as a new production process.

2.3 FINDINGS

The 3D metal printing sector is constantly putting forward new printing techniques that allows companies to print parts more easily.

2.3.1 DIFFERENT PRINTING PROCESSES

Companies also use varying 3D printing techniques to take advantages of different aspects in 3D printing.[4]

The two most common types of techniques are Powder Bed Fusion and Directed Energy Deposition[5]. These two are types of techniques that include many different techniques and labels with each their own advantages, drawbacks, price-range, and uses.

2.3.2 POWDER BED FUSION

The first technique[6] developed in the 1990s is still the most common one. It works by sintering or melting a powder bed using a heat source such as a laser or electron beam. EOS' Direct Metal Laser Sintering is one of the most renowned technologies using that technique. Though this technique can either sinter or melt metals, melting is considered more convenient because sintering implies that metal particles are agglomerated together leaving holes. Because of these holes the mechanical resistance of the final part is weaker than if it had been melted.

If the heat source used is an electron beam, the technique is called Electron Beam Melting. The process is faster and there are less strains. However, it is not as precise as laser melting and the maximum size of parts is about two times smaller for EBM depending on the printer used.

There is currently research being led on ways to make 3D metal printing more sustainable. That is for instance the case of F3nice that worked on working with more sustainable metal powder.[7]

2.3.3 DIRECTED ENERGY DEPOSITION

The second one[8] melts the metal (provided in the form of powder or wire) using concentrated energy such as a laser, an electron beam, or a plasma arc. This technique requires machining in post-treatment. It can be used with every weldable metal, which isn't the case of the Powder Bed Fusion technique.

2.3.4 OTHER TECHNIQUES

A somewhat-similar technique worth mentioning is the binder jetting[9] technique. Instead of melting the powder the particles are bound together by a jetted binder. This technique is more cost effective than PBF processes but as the particles aren't melted together the product is slightly weaker[10].

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[4] 'Tout savoir sur l'impression 3D métal', 3Dnatives, accessed 23 March 2023, https://www.3dnatives.com/impression-3d-metal/.

[5] Tom Comminge, 'Fusion laser sur lit de poudre VS DED : quel procédé d'impression 3D métal choisir ?', 3Dnatives, 13 March 2023, https://www.3dnatives.com/metal-pbf-ded-14032023/.

[6] Mélanie W, 'Fusion laser sur lit de poudre, on vous explique tout !', 3Dnatives, 2 September 2019, https://www.3dnatives.com/frittage-laser-poudres-metalliques-on-vous-explique-tout/.

[7] Tom Comminge, '#Startup3D : F3nice développe des poudres d'impression 3D métal plus durables', 3Dnatives, 9 November 2022, https://www.3dnatives.com/f3nice-poudres-metalliques-091120223/.

[8] Mélanie W, 'L'impression 3D par dépôt de matière sous énergie concentrée, on vous explique tout !', 3Dnatives, 9 September 2019, https://www.3dnatives.com/depot-de-matiere-sous-energie-concentree-10092019/.

[9] Philippe G, 'Avec l'acquisition de Digital Metal, Markforged se lance dans le liage de poudre', 3Dnatives, 20 July 2022, https://www.3dnatives.com/digital-metal-markforged-21072022/.

[10] Tom Comminge, 'TOP 5 des vidéos de la semaine : Tout savoir sur le binder jetting', 3Dnatives, 25 February 2023,

There is also the Fused Deposition Modeling process, also called Fused Filament Fabrication[11]. Instead of using a powder, a composite filament of melted metal or polymer is used. It is more accessible as its price starts at 200€ and it is easier to use. However, the parts aren't as detailed as on parts made with other processes.[12]

Companies such as the Italian F3nice[13] or the American VEL03D[14] have also developed printers that require no or much less support to print parts. This allows the manufacturing of parts using less material.

2.3.5 SIZE OF 3D PRINTED PARTS

A major obstacle to 3D printing is the size of the final product. As the part can't be bigger than the printer, the parts' size is limited. But companies are working on making bigger printers to print bigger parts. As such in 2020 Titomic unveiled a new printed that they claimed to have developed the world's largest 3D metal printer[15], capable of even printing airplane wings.

As such bigger parts have been printed through 3D printing. For instance, Czinger has made an entire gearbox through 3D metal printing[16].

2.3.6 COMPONENTS

3D metal printing can be done using different metals. Each have different advantages and inconvenient which make them more suitable for some sectors compared to others.

Steel is considered to be versatile, to have a good corrosion resistance, an overall strong resistance, a strong hardness, but a loss of resistance when submitted to high temperatures. Because of these characteristics and particularly its resistance, steel is more used in the aerospace, automotive, manufacturing, and medical sectors.

Aluminium is another common resource for 3D metal printing. It has excellent mechanical properties and it can produce complex parts. However, it has a high cost. As such it is mostly used in the aeronautics, space, automotive, and medical sectors.

Cobalt-chrome is an alloy used in 3D metal printing for its high resistance to wear, biocompatibility, and heat resistance. But, like aluminium, this alloy is also expensive. It is mostly used in surgical implants, engine parts, wind turbines, and the aeronautics sector.

Finally, nickel is used for its high temperature corrosion resistance, its mechanical properties equivalent to forgings, its good ductility at low temperature, and the fact that it is a refractory material. However, it is particularly costly. It is mostly used in jet engines, for rockets for instance.

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https://www.3dnatives.com/top-5-des-videos-de-la-semaine-tout-savoir-sur-le-binder-jetting/.

11 Mélanie W, 'Un procédé d'impression 3D FFF plus rapide et précis', 3Dnatives, 9 August 2022, https://www.3dnatives.com/procede-mf3-impression-3d-10082022/.

12 Mélanie W, 'Un procédé d'impression 3D FFF plus rapide et précis', 3Dnatives, 9 August 2022, https://www.3dnatives.com/procede-mf3-impression-3d-10082022/.

13 Mélanie W, 'EOS développe une solution d'impression 3D métal sans support', Newspaper, 3Dnatives, 19 February 2023, https://www.3dnatives.com/eos-impression-3d-metal-sans-support-20022023/.

14 Mélanie W, 'Knust-Godwin mise sur la technologie de VELO3D pour imprimer en 3D des pièces métal sans supports', 3Dnatives, 22 June 2020, https://www.3dnatives.com/velo3d-et-knust-godwin-impression-3d-23062020/.

15 Chapman, 'World's Largest 3D Metal Printer Unveiled in Melbourne'.

16 Mélanie W, 'Czinger présente une première boîte de vitesses imprimée en 3D en aluminium', Newspaper, 3Dnatives, 21 March 2023, https://www.3dnatives.com/czinger-boite-de-vitesses-3d-22032023/.

Companies have also been working on new metal alloys to exploit their advantages. The most common metal used is aluminium as it's sturdy and light. Other metals are used in different industries such as steel in the manufacturing sector for its mechanical properties and good surface finish, a cobalt-chrome alloy for medical applications, titan for corrosion resistance, and precious metals in the jewellery sector. However, using precious metals makes it difficult to manage the finishing stages of a product. But compagnies working on high end products in automotive for instance are working on ways to use these metals more easily, like Bentley Motors[17]. Recently a new alloy made of steel and bronze was used in 3D printing, thus combining the advantages from both components[18].

2.3.7 IMPACTS ON SECTORS

New metal alloys and 3D printing techniques are key factors in improving 3D printed metal products, for instance in terms of weight. 3D metal products are used in sectors where lightness is a priority and thus always an axis for improvements, such as in the aerospace, automotive, and sports sectors. For instance, companies such as Mythos[19] and the Italian Pinarello[20] have both made bicycles using 3D printed parts.

In the defence sector, the use of 3D printing has also evolved. In the US[21] and the Dutch[22] marines, ships are being equipped with printers to avoid the obsolescence of parts while out at sea. As 3D printers allow the creation of parts in small quantity it is a very useful tool in these circumstances. In France, the company Dassault Aviation has tasked Addup in setting a 3D metal printing workshop for 2025.[23]

2.3.8 PRICE

Companies are also working on making 3D metal printers more accessible, as most are at least 100 000$ Because of the price-range for printers, companies are deterred to switch their manufacturing process from machining to 3D printing.

This explains the large difference in growth between 3D plastic and 3D metal printing.

As such, the German Fraunhoffer Institute[24] and the American company IRO3D[25] for instance have

[17] 'Bentley Motors Uses Ground-Breaking 3D Printed Gold in Mulliner Batur', The Manufacturer, 19 December 2022, https://www.themanufacturer.com/articles/bentley-motors-uses-ground-breaking-3d-printed-gold-in-mulliner-batur/.

[18] Mélanie W, 'Un nouvel alliage de bronze et d'acier développé grâce à l'impression 3D DED', 3Dnatives, 16 January 2023, https://www.3dnatives.com/alliage-bronze-acier-impression-3d-160120233/.

[19] Tom Comminge, 'Mythos et IXO, sa nouvelle potence imprimée en 3D métal', 3Dnatives, 9 December 2022, https://www.3dnatives.com/mythos-potence-velo-091220223/.

[20] Mélanie W, 'Tour d'horizon des vélos qui ont misé sur l'impression 3D', 3Dnatives, 30 March 2023, https://www.3dnatives.com/velo-imprime-en-3d-22092020/.

[21] Tom Comminge, 'La Marine américaine intègre l'impression 3D métal dans ses navires de guerre', 3Dnatives, 8 November 2022, https://www.3dnatives.com/marine-americaine-impression-3d-metal-081120228/.

[22] Tom Comminge, 'La Royal Netherlands Navy fait appel aux solutions d'impression 3D de Nanoe', 3Dnatives, 16 September 2022, https://www.3dnatives.com/marine-neerlandaise-impression-3d-nanoe-160920223/.

[23] Gautier Virol, '[L'instant tech] Chez Dassault Aviation, AddUp automatise l'impression 3D métallique', L'Usine Nouvelle (www.usinenouvelle.com, 6 December 2022), https://www.usinenouvelle.com/editorial/l-instant-tech-chez- dassault-aviation-addup-automatise-l-impression-3d-metallique.N2074551.

[24] 'L'Institut Fraunhoffer dévoile une imprimante 3D métal low-cost', 3Dnatives, 2 November 2016,

both designed cheaper 3D printers. The first one cost 30 000€ and the second one starts at 5 000$. However, despite the announcements they are not available on the market as of today.

To add to the steep price of 3D metal printers, materials are also expensive, especially those particularly resistant and lasting, such as titan and the alloy Inconel®.

Companies also need a CAO software to design parts before using the 3D metal printer. That can represent an additional spending.

These prices make 3D metal printing inaccessible to individuals and most companies apart from a niche that made the leap.

2.3.9 TRAINING

These prices also make it difficult to train anyone to 3D metal printing processes. Buying only one printer already requires a big budget and it may not be enough to teach multiple students.

Furthermore, as shown previously, there is a wide variety of technologies used in 3D metal printing, even in just the Powder Bed Fusion category. That means that ideally students should be able to train on different types of printers to acquire knowledge and experience on a range of processes. But buying multiple kinds of printers is difficult for training centres. That makes training more difficult as students are not able to get experience on many kinds of processes.

Moreover, while powder bed fusion printers are the most common, and thus the main kind of printer students should practice on, using metal in the form of powder poses health and safety risks.[26]

Finally, because of the health threats posed by the metal powders used in Powder Bed Fusion. There are many safety instructions to be taken to use these types of printers. These make training sessions more complicated to organise. As such, it's easier for training centres to buy cheaper and less dangerous printers. But that implies that students are being taught about 3D metal printing on printers such as FDM printers that are not common in companies using 3D.

Furthermore, to use 3D metal printers, students need to train not only on how to use to printer but how to design the part using CAO and how to do the necessary post treatments of the part for it to last.

As such these trainings are not meant to make students specialists in 3D metal printing. They are just introductions to the subject. That means that companies will have to train workers themselves if they need someone specialized in working on a 3D metal printer.

Training in 3D metal printing is limited by the prices of the printers and its adoption by companies. The investment required to switch to 3D metal printers is too important to risk it. It is a vicious cycle that slows the growth of a sector that shows a lot of promise.

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https://www.3dnatives.com/imprimante-3d-metal-low-cost-02112016/.

[25] Michelle J, 'Iro3d Lowers the Cost of 3D Metal Printing with a $ 5,000 Machine', 3Dnatives, 27 November 2018, https://www.3dnatives.com/en/iro3d-lowers-cost-3d-metal-printing-machine-271120185/.
[26] 'Health and Safety – Metal Powder AM', The National Centre for Additive Manufacturing, accessed 13 April 2023, https://ncam.the-mtc.org/resources/core-research-programme/health-and-safety-metal-powder-am/.

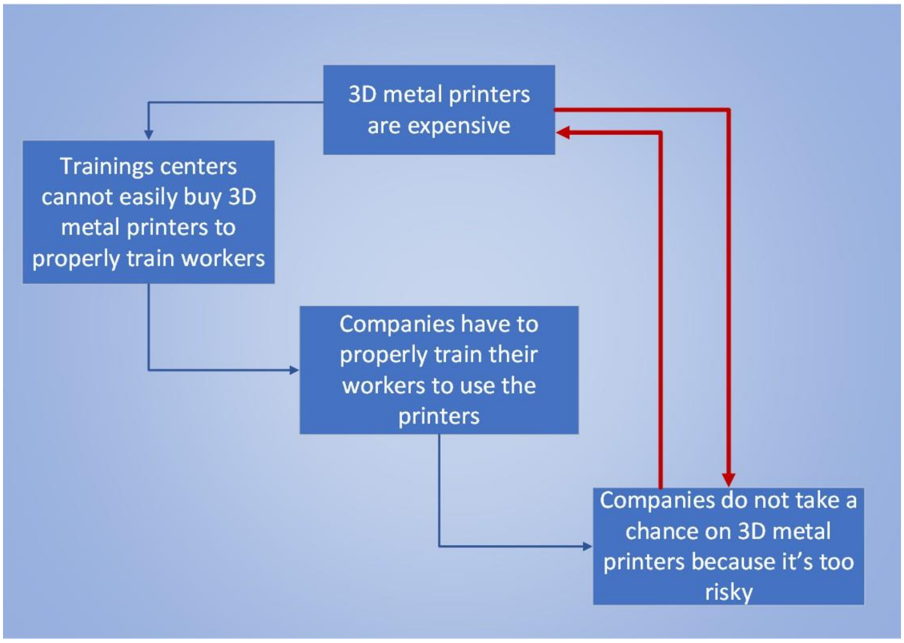

Figure 2 : Difficulties

2.3.10 PUBLIC ACCESS

Because of these reasons, public access to 3D metal printers is even more restricted, making self-training difficult.

3. CONCLUSION

Despite various advantages to 3D metal printings and various printing techniques, the 3D metal printing sector's growth is limited by the high price-range of the printers.

- 3D metal printing would be much more implemented in companies if the retail prices of printers were lower
- There are a wide variety of 3D metal printers which makes it harder to train people in using them.
- Future 3D metal printing innovations are expected to make using 3D metal printing more useful in the automotive and aerospace sectors

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