WP4

Study of training needs on Metallic Additive Manufacturing (MAM) in the SUDOE sector (France, Spain and Portugal)

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Introduction

Given the multiplication of uses and a certain maturity of technology, the Metal Additive Manufacturing market is evolving rapidly in recent years with an increase in sales of machinery, consumables and associated services of more than 27% per year. [1]

Wohlers Associates and AT Kearney estimate the additive manufacturing market to be bigger than $ 4 billion by the end of 2014 and a growth of until reaching between $ 17 and $ 20 billion by 2020. [1], [2], [3], [4]

According to Wohlers, in 2014, 14.8% of the Metal Additive Manufacturing market is destined for the aeronautics sector, sector known to be a leader in the development of advanced technologies. This amount makes an amount about $ 800 million, with growing expectations between 15% and 20% over the next five years. The market for Metallic Additive Manufacturing in the aerospace sector would represent a volume of more than $ 2.6 billion by 2020. [1], [2]

However, the challenges of additive manufacturing involve the sharing of knowledge and the necessary support for the exploitation of this technology, over the different sectors.

Indeed, the needs in this field are varied, ranging from basic knowledge to advanced specializations, from design to manufacturing, from materials to certifications, and so on. It opens new design methodologies and new means of manufacturing.

Despite the appearance of some training modules on these new processes, new competence profiles must be specified for all the domains that this technology implies.

This survey is part of Work Package 1: Diagnostic Study of Metallic Additive Manufacturing and Work Package 4: Training.

Its aim is to qualify and identify the needs of the players in the aerospace sector in terms of equipment, recruitment and training.

This document summarizes the training needs identified, the current available training offer on Metallic Additive Manufacturing in all the value chain of MAM (Design, Simulation, Manufacturing, etc.), highlighting the current gap in the SUDOE sector between the needs and the training offers.

Analysis of training needs

Context of the ADDISPACE survey

In order to assess this lack of formation, the members of the consortium carried out a survey of the aerospace companies of SUDOE area in the context of the ADDISPACE project. This study is based on more than 80 responses with participants from France, Spain and Portugal within different backgrounds:

- Aerospace integrators and Aerospace Tier 1 suppliers
- Manufacturers of Metallic Additive Manufacturing
- Clusters
- Public entities
- Universities and research centers
- Engineering offices of Metallic Additive Manufacturing

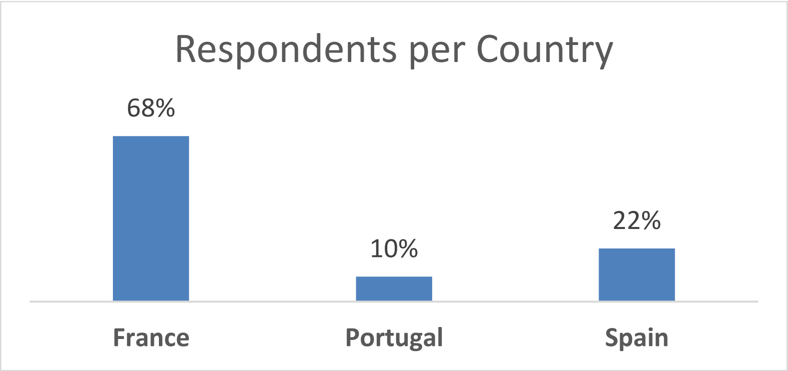

Figure 1 : Breakdown of responses by country

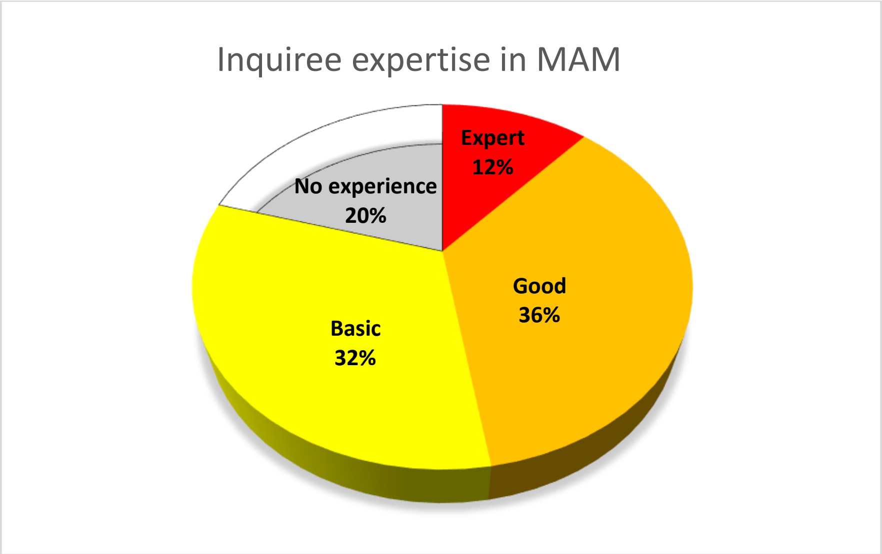

Figure 2 : Level of experience of participants in Metallic Additive manufacturing

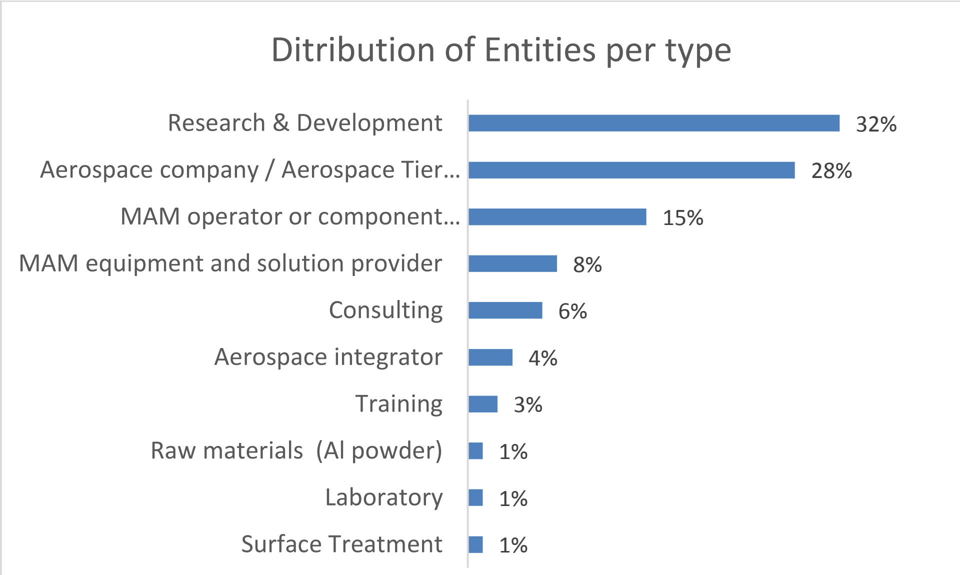

Figure 3 : Type of participants' companies

It is important to note that:

- 43% of respondents have an industrial engineer educational background
- 23% have an Electrical / Mechanical Engineering educational background
- 21% have a technical educational background
- 6% have an IT Engineer educational background

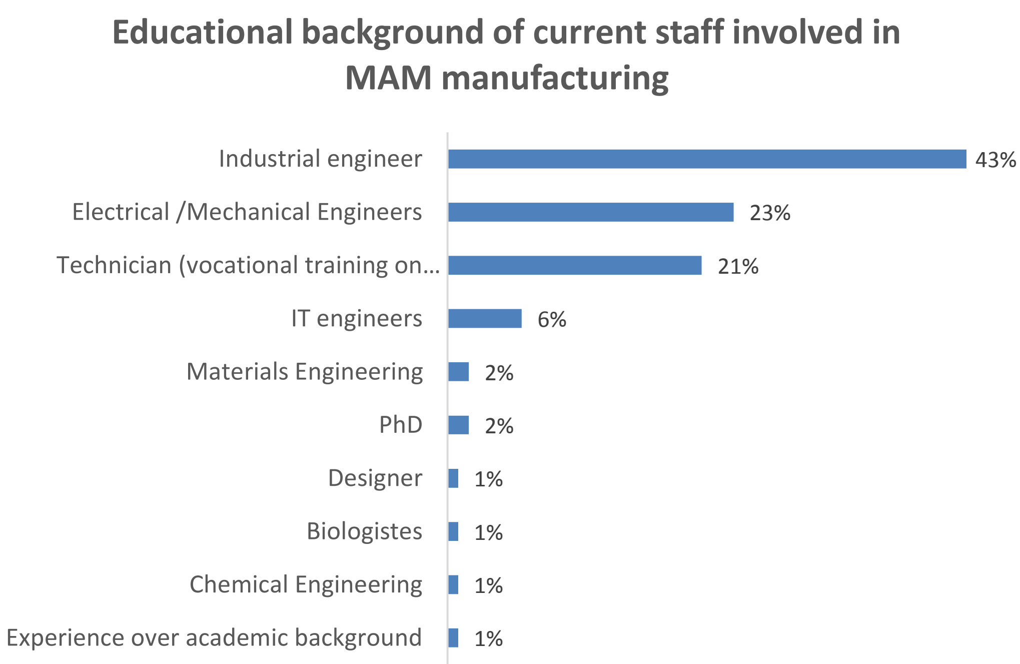

Figure 4 : Educational background of the participants

Each profile finds its way into the value chain of Metallic Additive Manufacturing. The training offers are supposed to meet all profiles and cover all this value chain.

Table 1: Profiles on the MAM value chain

Tertiary Education	**Design**	**Simulation**	**Production**	**Control**	**Machines**	**Materials**
Industrial Engineer			X		X	
Electrical Engineer				X	X	
Mechanical Engineer	X	X		X		X
Robotic Engineer		X		X	X	
IT Engineer					X	
Materials Engineer		X		X		X
Vocational Training	**Design**	**Simulation**	**Production**	**Control**	**Machines**	**Materials**
Mechatronics Technician	X	X		X	X	
Mechanical Technician	X	X		X	X	X
Automatization Technician			X	X	X	
Maintenance Technician			X		X	

Electrical Technician			X		X	

Analysis of training needs

Even though Metallic Additive Manufacturing is growing exponentially, there are still a number of obstacles to be overcome for its good development, one of which is particularly surprising: Lack of training.

According to all the answers, almost 14% consider that the lack of training and the lack of mastery of this technology is a brake on its deployment, faced with the lack of mechanical performance, the supply of raw materials and even certification!

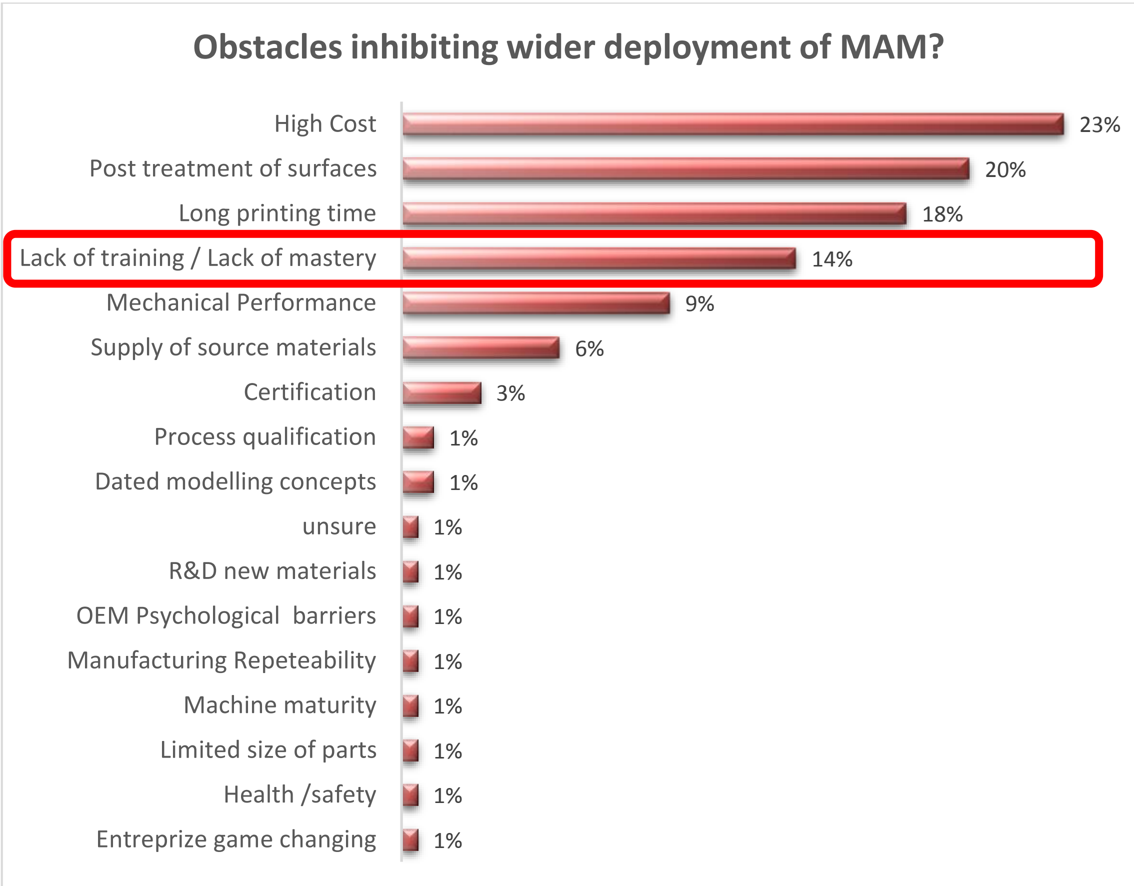

Figure 5 : Obstacles to the deployment of Metallic Additive Manufacturing Technology

This obstacle is confirmed as nearly 58% of surveyed participants are dissatisfied with the training modules currently offered. In the SUDOE sector, the training courses on Metallic Additive Manufacturing are clearly inadequate and do not meet the current needs of the market.

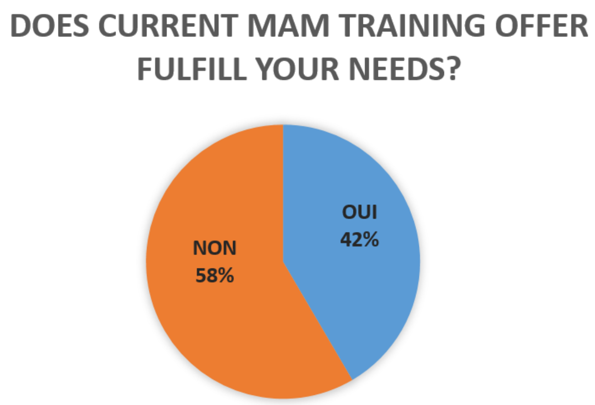

Figure 6 : Dissatisfaction with the current training offer

Currently, industrialists note the absence of Metallic Additive Manufacturing in the school and in post-school programs. There is very little knowledge enhancement or deepening and most of the current training are often for technology awareness or description of the process.

Today, despite the variety of degrees, Metallic Additive Manufacturing requires many skills in mathematics, physics, computer science, design, electrical engineering and mechanics, and cannot justify a specific degree at all school and university levels.

However, industrialists want to see the development of specific modules in BTS, DUT, engineering schools / universities and even continuous training modules for staff.

As a result, the main needs expressed in terms of training naturally concern the whole production chain by Additive Manufacturing:

- **Design Rules**: Metallic Additive Manufacturing imposes new ways of thinking about the design of parts and almost 59% (38% + 21%) have human resources needs on the designer profile.

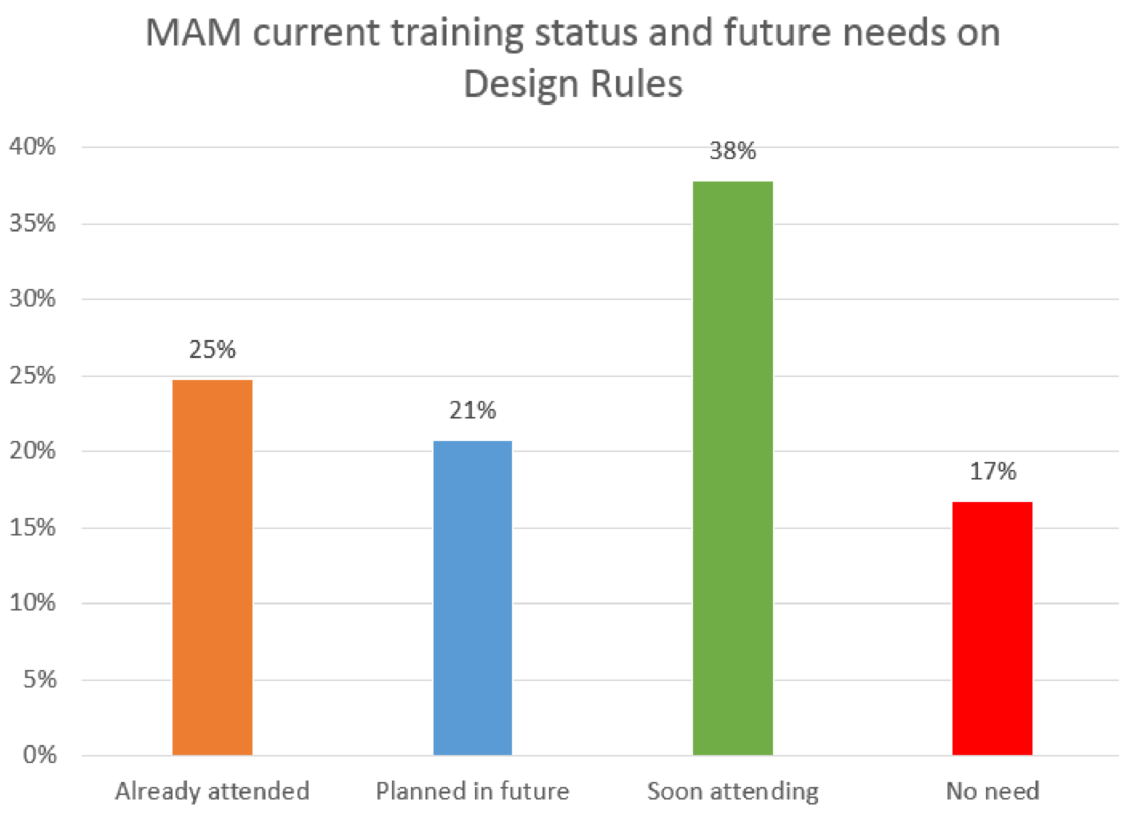

Figure 7 : Needs in terms of Design rules

- **Topological Optimization**: Topological Optimization goes directly related with Metallic Additive Manufacturing, especially within the aeronautics sector, where weight reduction is a major problem and nearly 57% (33% + 24%) have training needs or recruitment needs in this area.

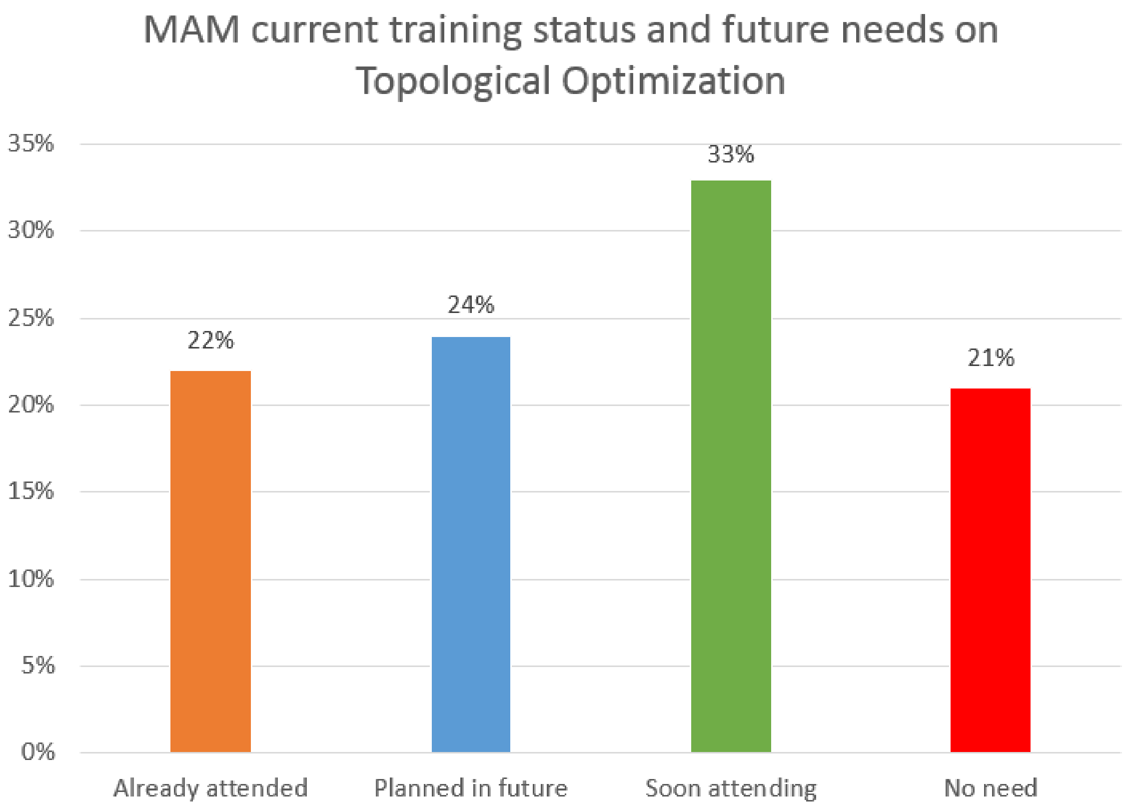

Figure 8 : Needs in terms of Topological Optimization

- **Process and regulation**: This step requires an overview of the process to evaluate the best possible orientation of the part, the best trajectory and machine parameters, considering the chosen process and the post-processing efforts. The implementation of the complete manufacturing process, involving initialization of production, preheating, supply of materials, fixing and extraction of the part, requires very good control not only of the various manufacturing machines but also post-processing methods to maintain the added value of the part during previous operations. Nearly 62% (36% + 26%) have needs in this area.

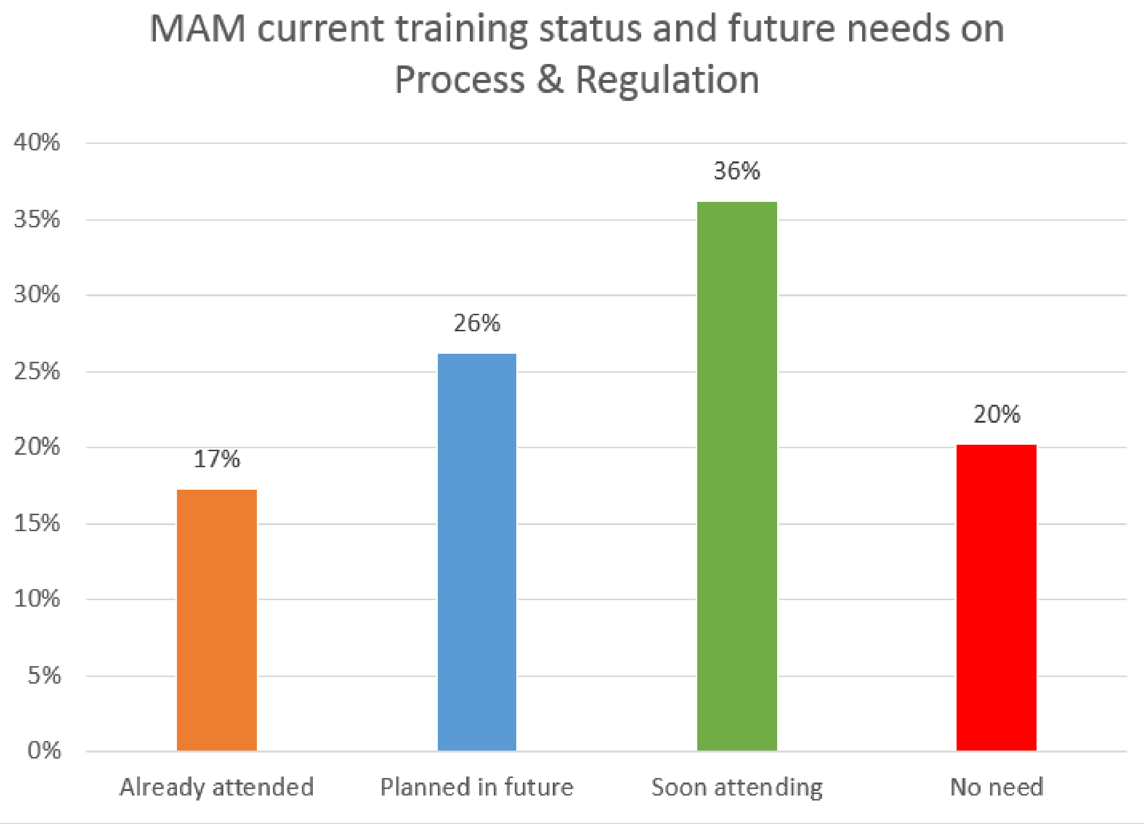

Figure 9 : Needs in terms of Process & Regulation

- **Non Destructive Control**: The current efforts in terms of standardization and control procedures (Non Destructive Control) in the field of Metallic Additive Manufacturing as well as the development of real-time measurement techniques is a new demand. Nearly 54% (31% + 23%) have needs in this area

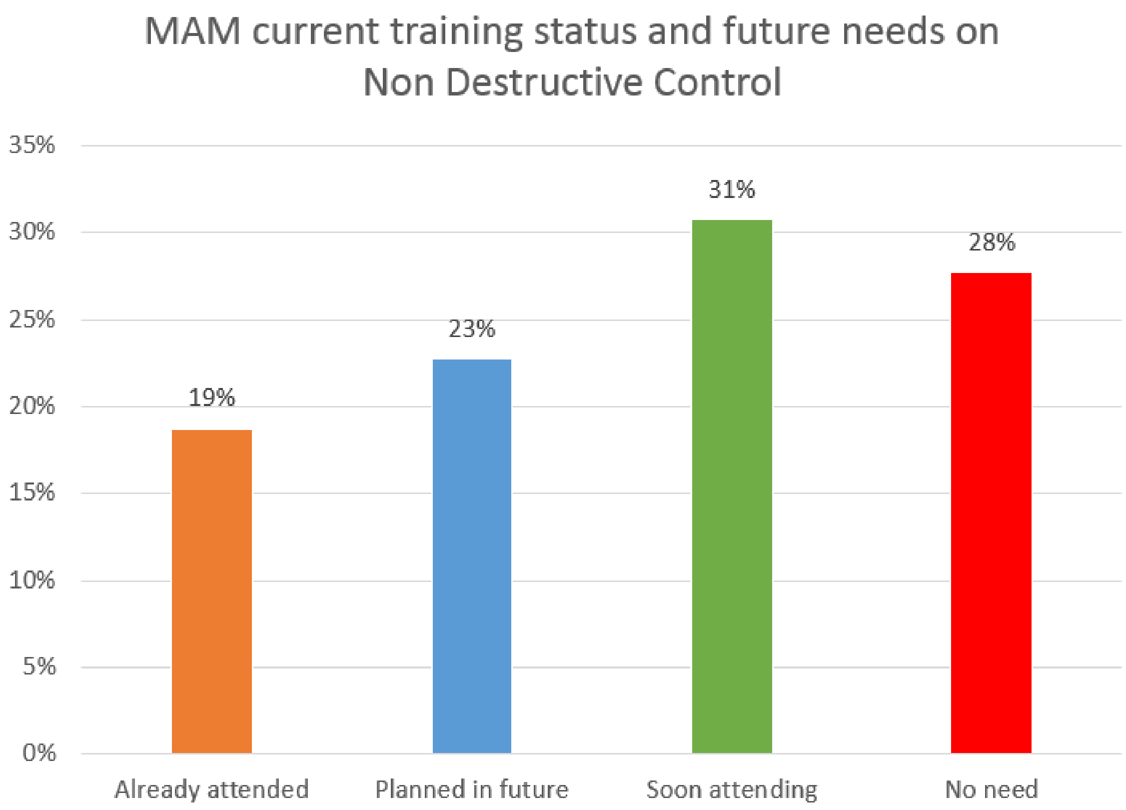

Figure 10 : Needs in terms of Non Destructive Control

- **Surface post-treatment**: This is one of the major disadvantages of Metallic Additive Manufacturing. Surface conditions are poor compared to conventional processes and very often it requires machining resumption. The complexity of implementing this post-processing is a training need for 59% (33% + 26%) of participants in the ADDISPACE survey.

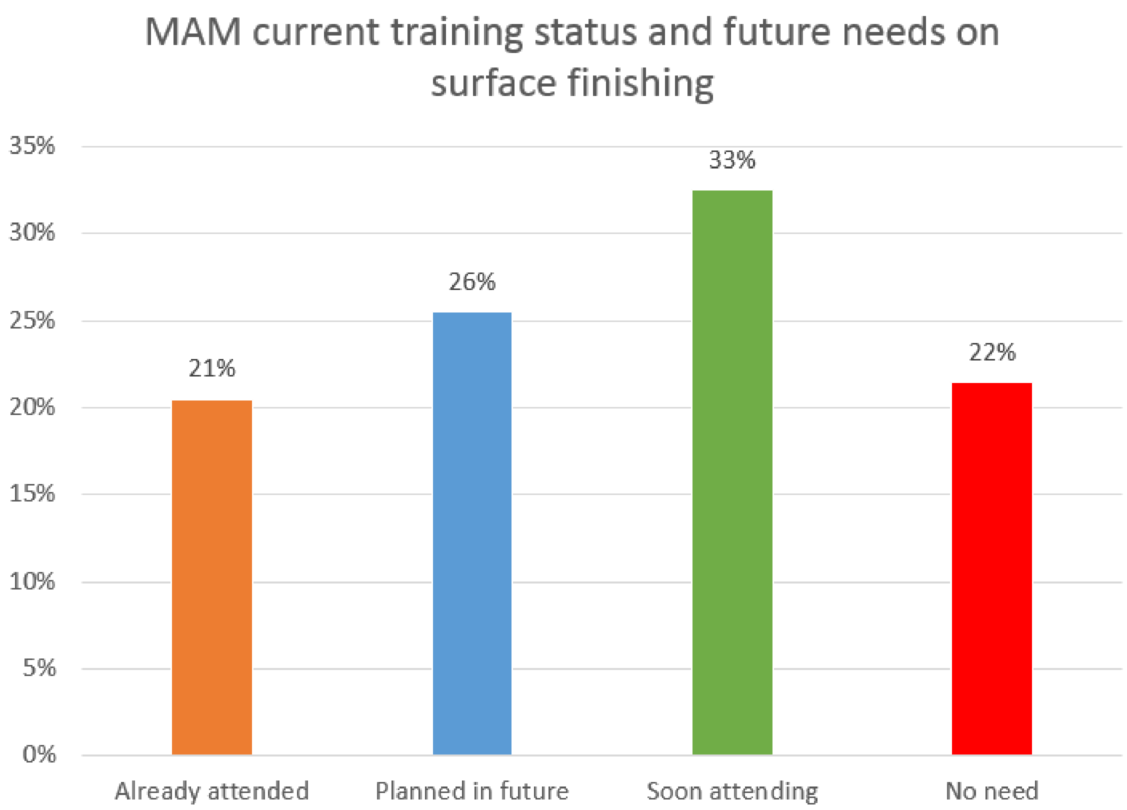

Figure 11 : Needs in terms of post-treatment / surface finishing

The industry wishes to be more involved in future training opportunities on the basis of cooperation with educational institutions, and local authorities. It will ensure that the knowledge taught corresponds to their needs and guarantees the employability of future workers.

It seems clear that competency profiles should cover all areas affected by Metallic Additive Manufacturing. Indeed, a misunderstanding of the key competencies required at all levels of the value chain corresponds to a poor structuring of the current training offer. [1]

In order to resume the needs in terms of training of the industrialist, we could note 5 major axes:

- **Design Rules for each MAM processes**
- **Topological Optimization**
- **Process Simulation & Regulation**
- **Control, tests, measurements / Non Destructive Testing**
- **Post-treatment / Surface finishing**

The ADDISPACE project will have to meet at least these needs by offering adequate training content.

The current supply of training is very poor, contrary to the needs of the sector, and to the growing expansion of this technology.

The ADDISPACE consortium has attempted to list all the existing training courses on the subject of MAM in the SUDOE sector (France, Spain and Portugal)

Current training offers in the SUDOE sector (France, Spain and Portugal)

Additive manufacturing involves new skills throughout the industrial value chain, with challenges. The cultural changes induced by these new technologies illustrate a real need for awareness-raising, training and skills development among all stakeholders in the value chain.

Training programs (Higher, Continuous and Professional) are essential and must cover all the technological aspects of Metallic Additive Manufacturing (design rules, topological optimization, process simulation, materials, post-treatment, etc.) and different levels of expertise expected (initiation, awareness-raising, specialization and development of strong skills ...).

Today, the Metallic Additive Manufacturing market is expanding and the need of human resources is increasing rapidly.

However, existing training offers on the SUDOE market remain scarce.

The ADDISPACE consortium has only listed 37 training courses on Metallic Additive Manufacturing, which is largely insufficient to meet the growing needs of manufacturers.

Training offers in France

Number of training offer: 15

Level of education:

- 1- Higher Education Engineering School or University
- 2- Continuous training (for in-company workers)
- 3- Vocational Training / Professional Training (for students in initial training)

Subjects:

- 1- Metallic Additive Manufacturing in general
- 2- Design for MAM
- 3- Topological optimization for MAM
- 4- Simulation and Processes for MAM
- 5- Metallurgy & Materials for MAM
- 6- MAM Machines
- 7- Non-destructive testing
- 8- Other than Metallic Additive Manufacturing (Mechanic, electronic, computer, etc.)

Table 2: Training offer in France

Entity that conducts the training	Name of the module	Website of the entity	Country	Level of education	Subjects	Hours
3D&P	Comment intégrer la Fabrication Additive dans un projet ?	http://www.3dandp.com/fr/formation-fabrication-additive	France	2	1-2	7
3DXpertise	?	http://3dexpert.enbeta.fr/contents/nos-services/formations	France	2	1-2-3-4-5-6-7	14
Centre de formation de la plasturgie	Fabrication additive métal	http://www.plasturgie-formation.com/formations-en-plasturgie/innovation/fabrication-	France	2	1-2-3-4-5-(7)	14

		additive-metal.html				
CETIM	Fabrication additive : les procédés et les applications métal, céramiques et polymères	http://www.cetim.fr/fr/Formation/Procedes/Production/Fabrication-additive/Fabrication-additive-les-procedes-et-les-applications-metal-ceramiques-et-polymeres-FA02	France	2	1-2-5-6-7	14
CETIM	Démarche de conception pour la fabrication additive métal	http://www.cetim.fr/fr/Formation/Procedes/Production/Fabrication-additive/Demarche-de-conception-pour-la-fabrication-additive-metal-FA03	France	2	1-2-3	14
CNAM	La fabrication additive pour les matériaux polymères et métalliques	http://cacemi.cnam.fr/la-fabrication-additive-pour-les-materiaux-polymeres-et-metalliques-898777.kjsp?RH=1302858582763	France	2	1-2-3-5	21
CTIF	FABRICATION ADDITIVE : UN PROCÉDÉ INNOVANT	http://www.ctif.com/lancement-dune-formation-en-fabrication-additive-metallique/	France	2	1-2-5-6-7	14
École des mines d'Albi	fabrication additive (Additive Layer Manufacturing, ALM)	http://www.mines-albi.fr/formation-fabrication-additive-lecole-des-mines-dalbi	France	1	1-2-3-4-5-6-7	X
École polytechnique	Fabrication additive, impression 3D - Nouveaux enjeux	https://exed.polytechnique.edu/fr/formations/32569/fabrication-additive%2C-impression-3d-	France	2	1-2-3-4-5	21

	technologiques et perspectives industrielles	nouveaux-enjeux-technologiques-et-perspectives-industrielles#bas				
ENSAM	MadMan	https://artsetmetiers.fr/sites/site_internet/files/fiches3an/Sp%C3%A9%203e%20ann%C3%A9e%20MadMan.pdf	France	1	1-2-3-(4)-5	150
ESTIA	La Fabrication Additive Métallique	http://estia.fr		1	1-2-5-6	24
FARINIA Group	Process & métallurgie en vue de la production série	http://www.farinia.com/fr/spartacus3d/formation-fabrication-additive-metallique	France	2	. 1-2-5-6-7	14
Grenoble INP (à travers sa plateforme AIP Primeca Dauphiné Savoie)	Fabrication additive : technologies et enjeux	http://formation-continue.grenoble-inp.fr/conception-production-et-organisation-industrielle/fabrication-additive-technologies-et-enjeux-547686.kjsp#page-presentation	France	1	1-2-3	14
IREPA LASER	Procédés de fabrication additive pour matériaux métalliques	http://www.irepa-laser.com/fr/nos-formations/procedes-de-fabrication-additive-pour-materiaux-metalliques	France	2	1-2-5	20
Pôle formation des industries technologiques	FABRICATION ADDITIVE : PRENEZ UNE NOUVELLE DIMENSION	http://afpi.formation-industries-ca.fr/formation/article/fabrication-additive-prenez-une	France	2	1-2-4-5-6-7	56

Training offers in Spain

Number of training offer: 19

Level of education:

- 1- Higher Education Engineering School or University
- 2- Continuous training (for in-company workers)
- 3- Vocational Training / Professional Training (for students in initial training)

Subjects:

- 1- Metallic Additive Manufacturing in general
- 2- Design for MAM
- 3- Topological optimization for MAM
- 4- Simulation and Processes for MAM
- 5- Metallurgy & Materials for MAM
- 6- MAM Machines
- 7- Non-destructive testing
- 8- Other than Metallic Additive Manufacturing (Mechanic, electronic, computer, etc.)

Table 3: Training offer in Spain

Entity that conducts the training	Name of the module	Website of the entity	Country	Level of education	Subjects	Hours
Ays formacion	?	http://www.aysformacion.com	Spain	2	2-3-4	variable
Cafai	Curso Avanzado de Fabricación Aditiva aplicada a la Industria (CAFAI)	https://cafai2017.wordpress.com/	Spain	2	1-2-3-5-7	400
Cogiti Formacion	Fabricación Aditiva (Impresión 3D)	https://www.cogitiformacion.es	Spain	1	1	120
CT formacion and CT Solutions Group	?	http://www.ctsolutions.es/ http://ctformacion.com/	Spain	2	1	8
EDDM	MÁSTER EN INGENIERÍA Y	https://eddm.es/master-impresion-3d-	Spain	1 2	1-2-3-4-5-6	400/600

	FABRICACIÓN ADITIVA MIFA	ingenieria-fabricacion-aditiva/				
EDDM	CURSO PROFESIONAL DE INGENIERÍA ADITIVA CPIA	https://eddm.es/wp-content/uploads/2017/02/Programa-CPIA-web.pdf	Spain	2	1	25
Eurecat	Fabricación aditiva: introducción, materiales y procesos (Impresión 3D) + Estrategias de diseño para la Fabricación Aditiva (Impresión 3D)	http://formacion.eurecat.org/	Spain	2	2	10
IMH	La Fabricación Aditiva: una tecnología alternativa	http://www.imh.eus/es/noticias/la-fabricacion-aditiva-una-tecnologia-alternativa	Spain	2	1-2-5-6	X
Lemon academy	Profesionales Expertos en las Tecnologías de Impresión 3D	http://lemonacademy.es/impresion-3d-universidad/titulacion-universitaria	Spain	1	1-2-5-6	300
Sicnova	?	http://sicnova3d.com/	Spain	2	1 2 3 4	X
Tecnun-Universidad de Navarra	Grado en Ingenieria	http://www.tecnun.es/estudios/grados	Spain	1	1-2-3-4-5	X
Universidad de Sevilla	Procesos de Fabricación Aeronáutica (Máster Universitario en Ingeniería Aeronáutica)	http://www.us.es/estudios/master/master_M143/asignatura_51430017	Spain	1	1-2-5	40
Universidad de Zaragoza	Diseño para fabricación aditiva	http://titulaciones.unizar.es/guias16/62953_es.pdf	Spain	1	1-2-3-6	12

Universidad del País Vasco	Máster en Ingeniería Mecánica: Diseño y Fabricación	http://www.ehu.eus/es/ikasketak	Spain	1	2-3-4-5-7	X
Universidad Deusto	Industria 4.0	http://www.deusto.es/	Spain	1	1	5
Universidad politécnica de Madrid	FABRICACIÓN AEROESPACIAL	https://www.etsiae.upm.es/titulaciones/gia/plan_estudios/Asignaturas_16_17/CTA/14IA-GA-145006001-6S-2016-17-FA_CTA.pdf	Spain	1	1-2-3	5
Universidad Rey Juan Carlos	?	https://miportal.urjc.es/guiasdocentes/	Spain	1	1-2-3-4-5-6-7	X
UPV (Universidad pública de Valencia)	Máster en Ingeniería, Procesado y Caracterización de Materiales	http://www.mastermateriales.upv.es/plan-de-estudios/	Spain	1	2-4-5	90/99
World3D	FORMACIÓN CONTINUA WORLD 3D	http://world3d.es/index.php/es/	Spain	2	2 3 4	X

Training offers in Portugal

Number of training offer: 3

Level of education:

- 1- Higher Education Engineering School or University
- 2- Continuous training (for in-company workers)
- 3- Vocational Training / Professional Training (for students in initial training)

Subjects:

- 1- Metallic Additive Manufacturing in general
- 2- Design for MAM
- 3- Topological optimization for MAM
- 4- Simulation and Processes for MAM
- 5- Metallurgy & Materials for MAM
- 6- MAM Machines
- 7- Non-destructive testing

Table 4: Training offer in Portugal

Entity that conducts the training	Name of the module	Website of the entity	Country	Level of education	Subjects	Hours
Polytechnic Institute of Leiria	?	https://www.ipleiria.pt/cursos/course/undergraduate-in-mechanical-engineering/	Portugal	1	6	X
Polytechnic Institute of Leiria	?	https://www.ipleiria.pt/cursos/course/master-in-product-design-engineering-2/?	Portugal	1	6	X
University of Coimbra	Tecnologias Avançadas	https://apps.uc.pt/courses/PT/unit/9229/12101/2017-2018?type=ram&id=360	Portugal	1	1	X

For comparison, and only for France, there exists approximately 15 training courses on Metallic Additive Manufacturing, compared to more than 800 training programs (Initial, alternating and continuous) for the aeronautics sector, which are divided into the following sectors: [5], [6], [7]

- Research &Development / Design
- Quality / Security / Environment
- Organization / Operation
- Maintenance
- Production
- Commercial / Management

It is also important to note that of the **37 trainings available in France, in Spain and in Portugal**:

- **30 modules** deal with the **Introduction of MAM**
    - France: 15
    - Spain: 14
    - Portugal: 1

- **30 modules** deal with **design for MAM**
    - France: 15
    - Spain: 15
    - Portugal: 0

- **18 modules** deal with **topological optimization**
    - France: 8
    - Spain: 10
    - Portugal: 0

- **14 modules** deal with **simulation and processes**
    - France: 6
    - Spain: 8
    - Portugal: 0

- **21 modules** deal with the subject of **metallurgy and materials for the MAM**
    - France: 12
    - Spain: 9
    - Portugal: 0

- **14 modules** deal with **MAM machines**
    - France: 7
    - Spain: 5
    - Portugal: 2

- **10 modules** deal with **Non Destructive Testing**
  - France: 7
  - Spain: 3
  - Portugal: 0

Whose:

- **18 modules** for **Higher Formation**
  - France: 4
  - Spain: 11
  - Portugal: 3

- **20 modules** for **Continuous Formation**
  - France: 11
  - Spain: 9
  - Portugal: 0

- **0 module** for **Vocational Formation**

First it may be noted that there is 0 training module for Vocational Formation and the majority of the training modules are distributed between Higher formation and continuous formation.

Portugal is very lagging behind the training topics on Metallic Additive Manufacturing, offering only 3 training modules.

In France, most of the training offered are mainly for industrialists, and very little training is offered for higher education.

Spain appears to have the greatest homogeneity in the global offers proposed and also has the largest number of modules.

However, 37 modules on the 3 countries are clearly insufficient to cover the human resources needs facing an increasing expansion of this technology.

This distribution highlights the small amount of deepening modules in a particular and specialized sector and that most of the current training is only technology awareness.

The need for specialized training modules becomes a priority and should be done in collaboration with research centers, companies and universities / schools.

Proposal of different training modules

It contributes to the achievement of Study Objective 02 of the ADDISPACE project, which is intended to increase the supply of education and training for future professionals and current staff in the aerospace industry for the use of Metallic Additive Manufacturing technologies.

This is to increase their capacity to absorb and use Metallic Additive Manufacturing technologies in the manufacture of metal components.

Within the framework of ADDISPACE project, 7 training courses will be organized as a pilot experiment, at different training levels, benefiting at least 80 people from different target groups (students in initial training, higher education and working people).

From the evaluation of the results achieved with the formation pilots, new formative programs will be designed and proposed.

In addition to these results, the study will consider reflection elements so that the teaching and vocational training community of SUDOE and of Europe can extend the offer of specialized training in this field and advance in the recognition of new certifications and new diplomas.

Here are the 6 training modules offered:

- **1 module of higher education** (Universities, engineers schools) organized by ESTIA and IPLEIRIA. The objective here is to develop and test a 15-day transnational training (1 week in France and 1 week in Portugal) for the last years engineering course students (Master 2).

- **1 vocational training modules** organized by LORTEK and DON BOSCO with students form two different background: Metal constructions and Industrial mechatronics. This module will then be distributed and delivered by AFPI Bayonne and CENTIMFE.

- **4 continuous training modules** organized by DON BOSCO, FADA CATEC, ESTIA, IPLEIRIA and LORTEK. These 4 modules will be directed to the staff of companies and will be designed together between the research centers, the universities / engineering schools and the industrialists. A call for interest suggestions will be put online and distributed to aeronautical companies in the SUDOE sector. This is done in order to respond as precisely as possible to their need in terms of Metallic Additive Manufacturing training.

Conclusion

Today, the Metallic Additive Manufacturing market is expanding and the need of human resources is increasing rapidly. However, existing training offers in the SUDOE market remain scarce and very few of them deliver certification.

Table 5: Matrix contrasting the gap between training needs and training offer

Subject	Number of modules in France	Number of modules in Spain	Number of modules in Portugal	TOTAL
Design rules	15	15	0	30
Topological Optimization	8	10	0	18
Process Simulation	6	8	0	14
Materials	12	9	0	21
MAM Machines	7	5	2	14
Control, test, measurement / NDT	7	3	0	10

ADDISPACE's final courses will be widely disseminated, not only in SUDOE but also beyond, at European level, in order to contribute to strengthening the supply of training.

Recognizing, attesting and certifying specialized training at different educational levels, enabling the adoption of FAM technologies.

The 7 modules proposed will have to meet the different needs previously stated by the industrialists, namely:

- Design rules
- Topological Optimization
- Simulation and Processes
- Controls, tests and measurements (Non Destructive Testing)
- Post-treatment / Surface finishing for MAM
- Materials for MAM
- The different machines of MAM

These courses will allow students, professionals and apprentices to address and deepen within specific subjects on the MAM, in order to be as operational as possible in their work and develop the MAM technologies for the future.

They will also be recognized in this expanding sector thanks to these diploma courses which enhance their skills and can easily permit them to integrate into the professional world.

References

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