WP4

Consolidated report of Training Pilots (France, Spain and Portugal)

Author: ESTIA

Date: 05/06/2019

Summary

Table of illustrations

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 between $ 17 and $ 20 billion by 2020. [1], [2], [3], [4]

According to Wohlers, 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.

The Work Package 4 (WP4) of the ADDISPACE project with title: Specialized Training oriented to absorption of additive manufacturing technologies in the aerospace sector has the aim to develop and produce 6 training modules in 3 categories:

- Higher Education Engineering School or University
- Continuous training
- Professional training

In the Activity 4.2: Consolidated report of training pilots' results, ESTIA has to propose a deliverable for the definition of these Educational modules, this is the objective of this document.

This deliverable summarizes all the results of the 6 training modules we have developed in the ADDISPACE consortium:

- Pilot 1: Higher Formation – ESTIA / IPLEIRIA – Introduction to MAM
- Pilot 2: Vocational Formation – LORTEK / Don Bosco – Introduction to MAM
- Pilot 3: Continuous Formation – IPLEIRIA – Level introductory
- Pilot 4: Continuous Formation – ESTIA – Level advanced
- Pilot 5: Continuous Formation – FADA CATEC – Level advanced
- Pilot 6: Continuous Formation – LORTEK – Level introductory

Pilot 1: Higher Formation – ESTIA / IPLEIRIA – Introduction to MAM

Terms of Reference

Main information of the working group

MAIN INFORMATION OF THE WORKING GROUP
Title of the education pilot
Master 2 – Higher training for Engineering School / University
Members of the working group
ESTIA IPLEIRIA
Leader of the working group
ESTIA and IPLEIRIA

General information of the training module

GENERAL INFORMATION OF THE TRAINING MODULE
Name of the formation
Introduction to MAM technologies – Knowledge deepening
Type: (Higher Education, Continuous training, Professional training)
Higher education
Objectives:
• To contact with MAM technologies: Introduction, MAM processes, MAM machines, Materials, Positioning of the technology on the market. • To experience the workflow involved in MAM with cases study. • Discover this technology to students. • Have them manipulate through case studies. • Obtain certification on this technology. • Make this technology attractive to students
Target:
Mechanical engineering students from graduate and post-graduate levels
Number of participants:

Up to 20: 10 students from ESTIA and 10 students from IPLEIRIA
Duration of the module:
4 + 4 days 32H + 32h = 64 hours
Date of the formation:
Week 14 & 15 2018 From April 03rd to 06th at ESTIA From April 10th to 13th at IPLEIRIA
Issuance of a diploma
Yes: Expertise Certification by ESTIA and IPLEIRIA (4 ECTS credits) and Training Attestation
Reiteration possible for the following years?
Yes

Detailed specification of the training module

DETAILED SPECIFICATION OF THE TRAINING MODULE
Lack of current training: Gap / Training needs identified:
In Portugal, only 2 higher education institutions have courses that approach AM technologies, and from those, only the Polytechnic Institute of Leiria offers units that specifically approach MAM technologies and equipment. In France, about 15 training modules on MAM but few trainings deepen the subject. Training need identified: - Design Rules - Topological Optimization - Process Simulation - Controls, tests and measurements (Non-Destructive Testing) - Post-treatment / Surface finishing - Materials for MAM - MAM Machines
Content of the module:
IPLEIRIA - Introduction to SLM technologies - Dimensional control / NDT

- Structural Simulation
- Post treatment / Surface finishing
- Visit to ADIRA

ESTIA

- Introduction to MAM technologies in general (context, genesis, different processes, MAM machines, advantages and disadvantages, limits, etc.)
- The LMD/Powder technology (Process, Software, Influent parameters)
- The LMD/Wire technology
- The WAAM technology
- Material for MAM
- Design rules for LMD/P, WLAM, WAAM
- Topological Optimization of one part
- Simulation of trajectory (PowerCLAD or G-Code)
- Metallographic characterization
- Visit of ADDIMADOUR: Machine beam discovery, CMT, etc.

Teaching methods:

IPLEIRIA

1. Theoretical part
    a. An introduction about AM technologies, and specifically SLM technologies has been addressed
2. Practical part
    a. Participants has conducted through the process by direct observation and participation on CDRsp laboratories.
    b. Participants has visit one of the partners, ADIRA, and have taken contact with additional MAM technology.

ESTIA

1. Theoretical part
    a. Discover of MAM technologies and the different processes
    b. Discover the materials for MAM
    c. Discover the Design Rules for MAM
    d. Discover the interest of Topological Optimization
    e. Discover the Process simulation

2. Practical part
    a. Case study on Design rules
    b. Case study on topological optimization
    c. Case study on Process Simulation
    d. Visit of the technical platform ADDIMADOUR

Technologies to be taught:

- General AM technologies
- MAM technologies
- Dimensional control
- Structural simulation
- LMD/P
- WLAM
- WAAM
- SLM

Use of equipment:

- SLM machine
- 3D scanning equipment
- Machine Beam Magic 2.0
- CMT TransPuls Synergic 3200 (Fronius) + Kuka 6 axis robot (KR240)
- ALTAIR software
- PowerCLAD / PowerMill / PowerShape
- Metallography laboratory
- Classroom with equipment (Computer and software, video projector, table, whiteboard, internet, etc.)

Link with the pilots:

Pilot 1 – Manufacturing a part by SLM using different materials – in the case, a Ti alloy has been used
This introductory formative program is linked with all the pilots from WP2 according to the technologies used. In this case SLM, LMD powder, LMD wire and WAAM have been explained and shown in use. Their fundamental concepts were explained according to their advantages, disadvantages, main applications and designing and optimization possibilities. MAM were introduced, and 4 different technologies explained broadly (SLM, LMD powder, LMD Wire and WAAM).

Admission requirements and prerequisites:

Mechanical engineering student

This pilot has been offered to 20 volunteer students (10 per entity) of the last year (Master 2) of ESTIA and IPLeiria.

A publicity has been made:

- On the ESTIA website
- In an ATTRACTIVE JOBS on Metallic Additive Manufacturing. ATTRACTIVE JOBS is a module organized by ESTIA to speak about different subjects with the ESTIA students. The module of Higher Education Training has been presented to ESTIA students who were present.

In the case there are more people interested, ESTIA and IPLeiria have selected them taking as a criteria their marks, interest and behavior, for which the opinion of their tutors will be taken into account.

Evaluation mechanism:

- Student evaluation
  - Written report
  - CAD files and simulation files
  - Questionnaire to resume all the module
- Module evaluation by students
  - Inquiry to be submitted by students

Impact of this training module:

Students were aware of specific challenges on TA6V manufacturing by MAM processes.

- Knowledge about the MAM technologies
- Knowledge of the value chain
- Knowledge on materials
- Knowledge on software
- ESTIA and IPLeiria have certificated this training module as an Expertise (4 ECTS credits)

Roles and planning

ROLES AND PLANNING

Distribution of roles in the implementation fo the module:

ESTIA

- Definition of the formative program
- Selection of ESTIA students
- Logistic for Accommodation, meals and travel for ESTIA Students
- Assessment of formative methods
- Evaluation of students and pilot
- Equipment for the pilot (Computer, whiteboard, table, room, internet, software, …)
- Teaching about MAM

IP Leiria

- Definition of the formative program
- Selection of IPLeiria students
- Logistic for Accommodation, meals and travel for IPLeiria Students
- Assessment of formative methods
- Evaluation of students and pilot

- Equipment for the pilot (Computer, whiteboard, table, room, internet, software, …)
- Teaching about MAM

Working plan:

ESTIA:

Thuesday, April 3rd, 2018		
Time	**Item**	**Presenter**
08:30-12:30	**Introduction on Metal Additive Manufacturing**	Thomas ELCRIN
14:00 – 16.00	**Materials & Metallurgy**	Pierre MICHAUD
16:00 – 18:00	**Visit of ADDIMADOUR**	Pierre DIAZ

Wednesday, April 4th, 2018		
Time	**Item**	**Presenter**
08:30-12:30	**Design rules for Metal Additive Manufacturing**	Federico GARCIA BRAGADO
14:00 – 18.00	**Topological Optimization**	Federico GARCIA BRAGADO

Thursday, April 5th, 2018		
Time	**Item**	**Presenter**
08:30-12:30	**G-Code Programmation for Additive Manufacturing**	Thomas ELCRIN
14:00 – 18.00	**Introduction to PowerClad**	Thomas ELCRIN

Friday, April 6th, 2018		
Time	**Item**	**Presenter**
08:30-10:30	**Group 1: Manufacturing with BeAM Magic 2.0** **Group 2: Assignment report**	Thomas ELCRIN
10:30 – 12.30	**Group 1: Assignment report** **Group 2: Manufacturing with BeAM Magic 2.0**	Thomas ELCRIN
14:00 – 16:00	**Introduction to process simulation for MAM**	Fabien POULHAON
16:00 – 16:10	**Selective electron beam melting**	João Miguel Oliveira Carreira
16:10 – 16:20	**Selective Laser Melting (SLM) of Aluminium Alloys**	Vicente Maria Martins Bértolo Marques Caneiro
16:20 – 16:30	**Metal Additive Manufacturing for Inserts in Plastic Injection Molds**	Paula Tomaz
16:30 – 16:40	**Metal Additive Manufacturing in Maritime Industry**	Vitor Fernandes
16:40 – 16:50	**Metal Selective Laser Melting**	Ricardo Jorge da Silva Viola
16:50 – 17:00	**Hybrid systems**	Ana Monteiro
17:00 – 17:10	**Topological Optimization for Metal Additive Manufacturing**	Ana Ramos
17:10 – 17:20	**Applications of Metal Additive Manufacturing in mold making industries**	Sachin Nanjunda
17:20 – 17:30	**Defects in metal additive manufacturing powder fusion processes**	Nuno Pedro
17:30 – 17:40	**Shape Optimization for MAM Part Design**	Jordan Palmer

IPLEIRIA:

Tuesday, April 10th, 2018	
Time	**Item**
09 :30 – 11 :00	**Introduction to SLM Technologies**
11 :30 – 13 :00	**Part Manufacturing using SLM equipment (part 1)**
14:00 – 17:30	**Part Manufacturing using SLM equipment (part 2)**

Wednesday, April 11th, 2018	
Time	**Item**
09 :30 – 10 :00	**Part Manufacturing using SLM equipment (part 3)**
10 :00 – 13 :00	**Dimensional control / NDT**
14:00 – 17:30	**Dimensional control / NDT + Visit to FAMOLDE**

Thursday, April 12th, 2018	
Time	**Item**
09 :00 – 13 :00	**Post-treatment / Surface finishing + Thyssen Steels presentation**
14:00 – 17:30	**Structural Simulation + Visit to Thyssen Steels**

Friday, April 13th, 2018	
Time	**Item**
09 :00 – 13 :00	**Visit of the University of Coimbra**
14:00 – 17:30	**Visit to ADIRA + Visit to CEIIA**

Evaluation of the pilot 1

All the students who have participated to this training module have filled a questionnaire concerning the evaluation of this pilot. The Figure 1, Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6 show all the results of the evaluation.

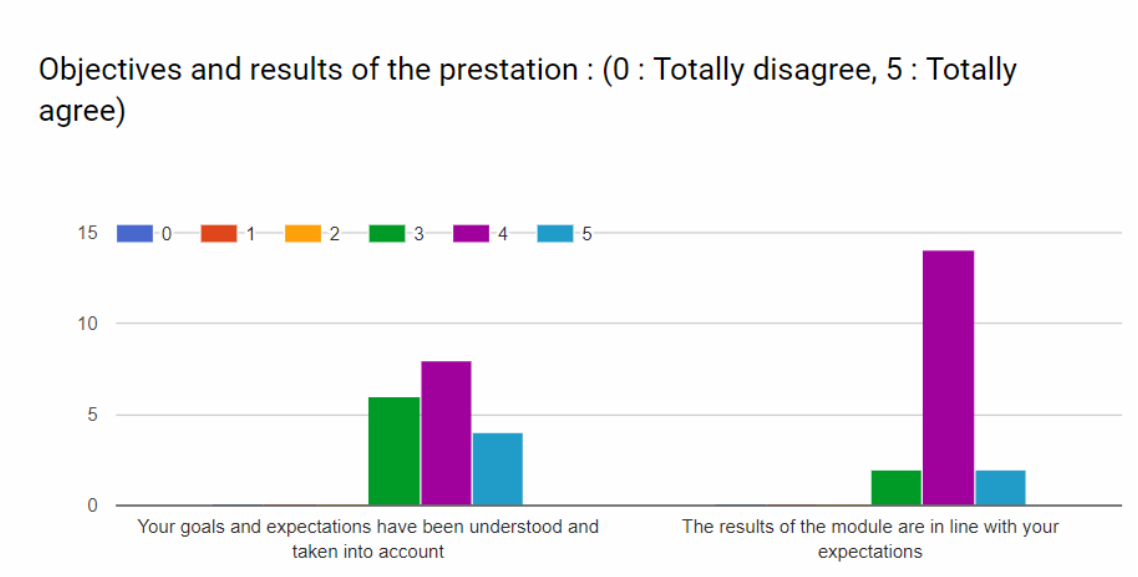


Figure 1: Pilot 1 Objectives and results of the prestation

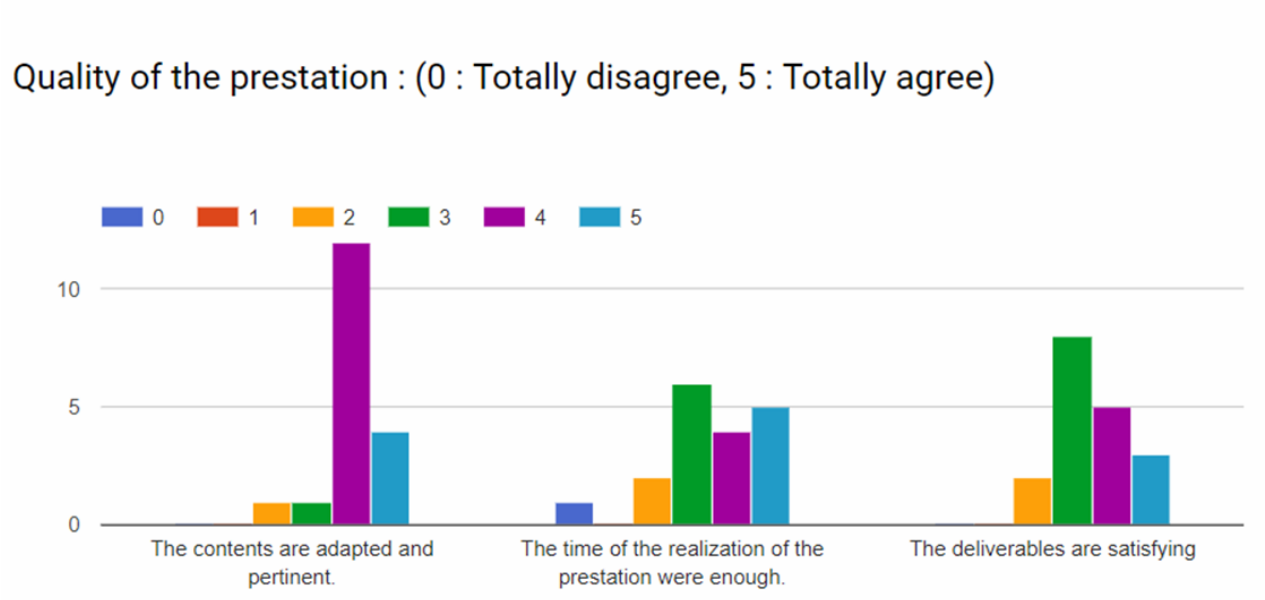


Figure 2: Pilot 1 Quality of the prestation

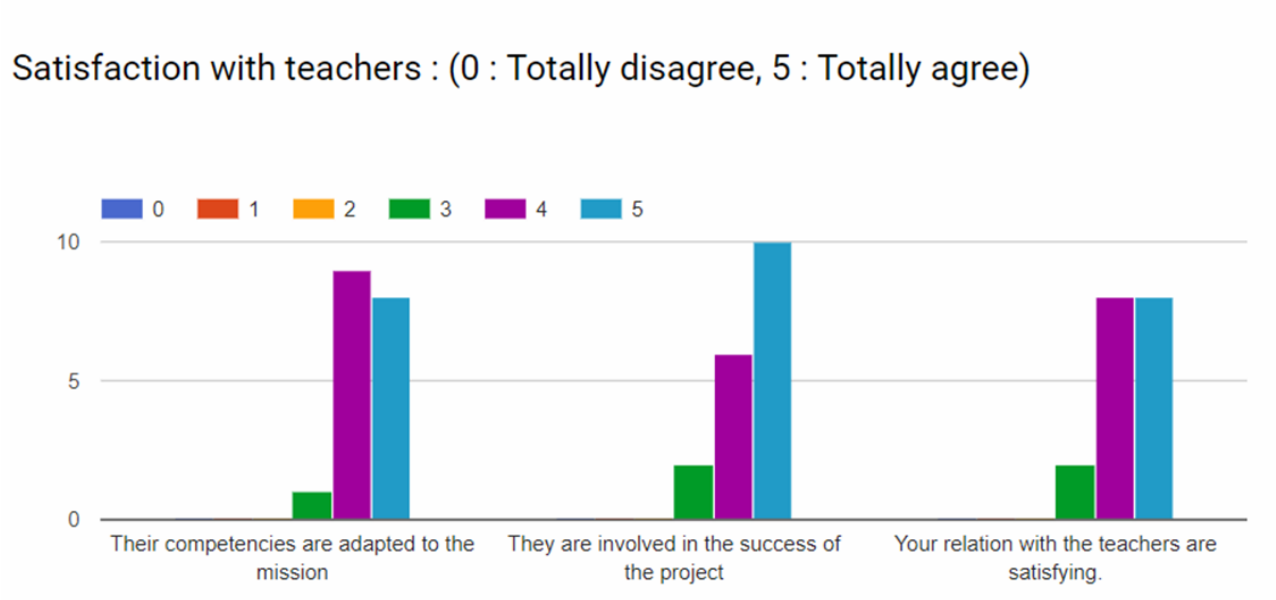


Figure 3: Pilot 1 Satisfaction with teachers

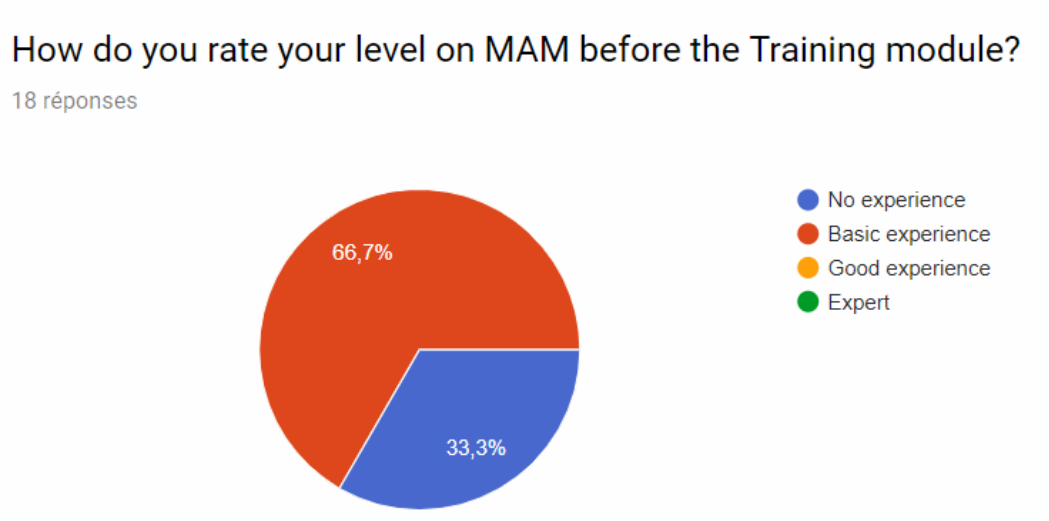


Figure 4: Pilot 1 Level before the formation

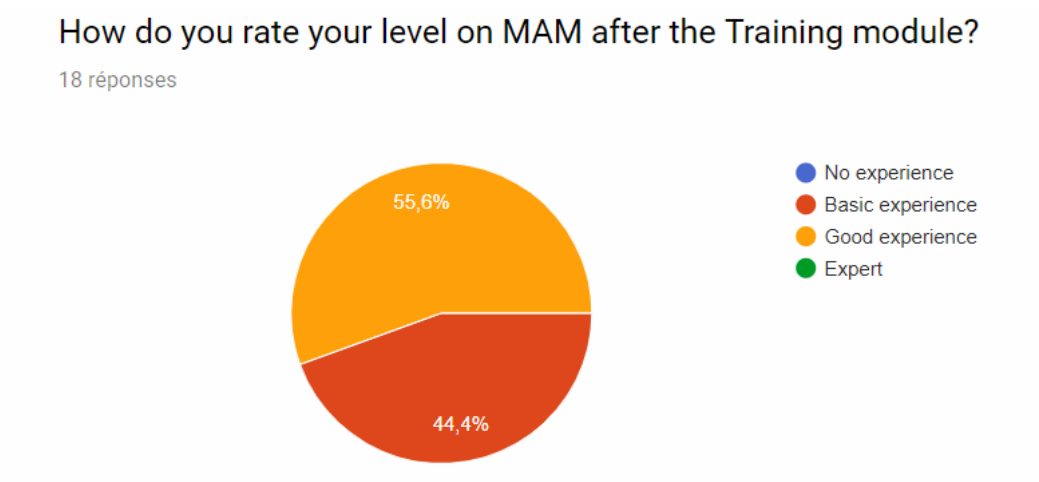


Figure 5: Pilot 1 Level after the formation

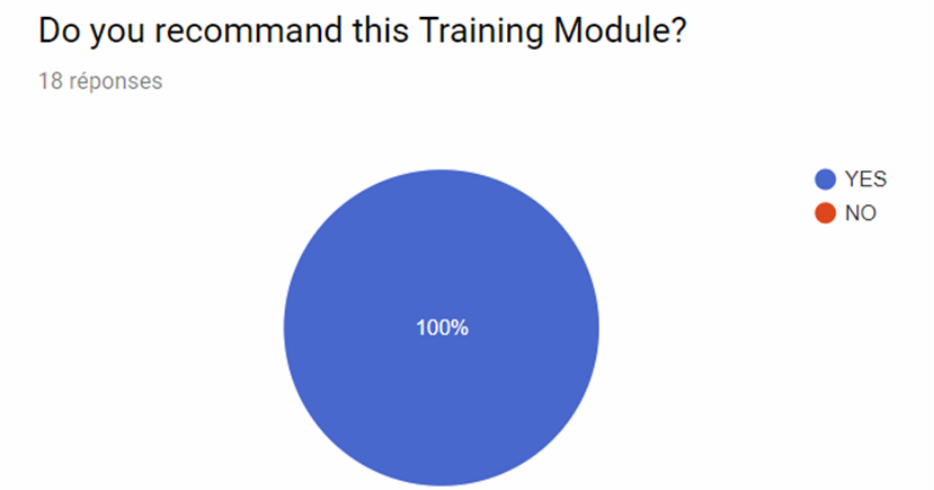


Figure 6: Pilot 1 Recommendations

In general, the results of these pilots are very convincing. The students were able to develop their knowledge on additive manufacturing by working on concrete cases and real methods.

It is important to note that before the training module, almost 33% had no experience in Additive Manufacturing, 67% had basic experience and after training, 44% have basic knowledge and 56% estimate they have good experience.

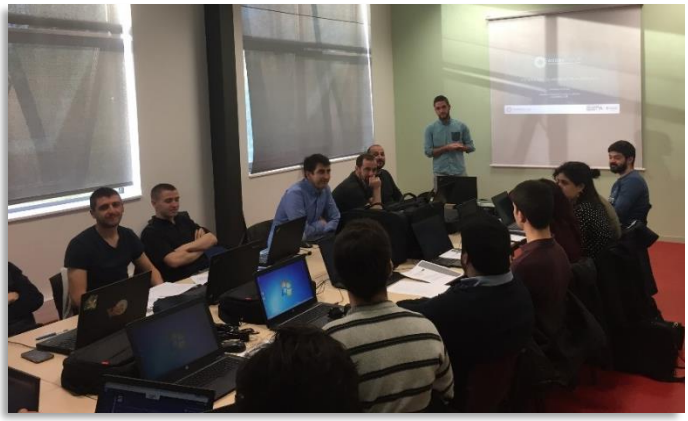
Also, according to the free comments:

- Some students want more manipulation on machine
- Some students are satisfying with the format 1 week / 1 week
- Some students want longer module

To finish, 100% of students recommend this module.

Pictures

Figure 7: Pilot 1 Photos of the group



Pilot 2: Vocational Formation – LORTEK / Don Bosco – Introduction to MAM

Terms of Reference

Main information of the working group

MAIN INFORMATION OF THE WORKING GROUP
Title of the education pilot
MAM module for professional training
Members of the working group
IK4-Lortek Don Bosco
Leader of the working group
Lortek

General information of the training module

GENERAL INFORMATION OF THE TRAINING MODULE
Name of the formation
Introduction to MAM for Professional training
Type: (Higher Education, Continuous training, Professional training)
Vocational training / Professional training
Objectives:
• Knowledge about Additive Manufacturing technology. • Learn the process for printing 3D parts. • Know and use different software of Additive Manufacturing. • Know the parameters of the software that influence the quality of the prints. • Adjust and configure printers for an optimal printing. • Know and use of different printing materials. • Knowledge of basic concepts of metallurgy. • Interiorization of the importance of design. • Learn the process of Metal Additive manufacturing with different technologies. • Knowledge about post-production processes.

Target:
Design a formative program for professional training according to the identified current and coming demand from industry.
Number of participants:
6 students of two different modules (Metallic constructions and Industrial mechatronic): 12 students in total
Duration of the module:
20 hours
Date of the formation:
10 – 23 January 2018
Issuance of a diploma
Yes
Reiteration possible for the following years?
Yes

Detailed specification of the training module

DETAILED SPECIFICATION OF THE TRAINING MODULE
Lack of current training: Gap / Training needs identified:
At this moment there is no MAM training in the program. Overall knowledge of Additive manufacturing, technologies, materials and their applications will give an introduction to this field.
Content of the module:
Tknika (external entity): • History, Additive Manufacturing. Low Cost Machines • Parts of a 3D printer. • Printing process. File formats. • Mostly used software (Cura, Repetier Host) • Printing of parts • Repositories. • Replace the filament.

- Printing with supports.
- Design of parts.
- Topological optimization, internal channels, weight reduction.
- Cuts and joints. Repair Parts (NetFabb)
- PAW technology for WAAM

LORTEK:

- Overall contents of metallurgy
- MAM technologies and applications
- Materials
- Applications
- Post processes, NDT
- Software used (Materialise magics, …)
- SLM machine
- LMD-cladding powder machine
- Metallographic characterization

Teaching methods:

- The course was eminently practical.
- For a proper understanding of principles of Additive Manufacturing, the course has begun with the 3D printing of polymers and then continued with the Metal Additive Manufacturing.
- After the necessary theoretical explanation, the precise practices have been realized until assimilating the matter explained.
- Parts have been printed with different materials to check the behavior of the same, both polymers and metal.
- The importance of the design of the piece (topological optimization, weight reduction, methods to avoid supports, ...) and its orientation when printing have been studied.
- During the course they acquired the necessary knowledge to finally develop the project that has been assigned by the teacher.
- Search in Internet web sites the information available about 3D printing: development communities and parts repositories, etc.

Technologies to be taught:

- FDM (Tknika)
- WAAM (Tknika)
- SLM (Lortek)
- LMD cladding (Lortek)

Use of equipment:

The course was given in three different locations and in each of them the following equipment have been used:

Don Bosco:
- Ikaslab, 10 3D printers with 8 laptops.
- Electronic whiteboard with laptop for teacher.
- Coils of ABS plastic, PLA and other thermoplastic materials
- All computers were networked and had Internet access both by cable and Wi-Fi.
- Necessary tools.

Lortek:
- Necessary tools to give a class.
- SLM machine.
- Metallography laboratory (cutting machine, grinding and polishing machines, optic microscopes).
- LMD cladding.

Tknika (external entity):
- Classroom with PCs and a whiteboard.
- Robotic cell with plasma arc welding equipment with wire input.

Link with the pilots:

This introductory formative program is linked with all the pilots from WP2 according to the technologies used. In this case SLM, LMD powder and WAAM were explained and shown in use. Their fundamental concepts were explained according to their advantages, disadvantages, main applications and designing and optimization possibilities. Firstly, as an introduction to Additive Manufacturing, 3D printing with polymers were performed. After that, MAM was introduced, and 3 different technologies were explained broadly (SLM, LMD powder and WAAM).

Admission requirements and prerequisites:

This pilot has been offered to 12 volunteer students (6 per module) (if possible) of the last year (2nd year) of Don Bosco.
Don Bosco has selected them taking as a criteria their marks, interest and behavior, for which the opinion of their tutors has been taken into account.

Evaluation mechanism:

In order to pass the course, it was necessary to:

- Manufacture the proposed parts in the course.
- Attendance to the 100 % of the hours of the established training program.
- Answer a questionnaire to see what they have learned.
- Respond to a questionnaire to evaluate the pilot.

Impact of this training module:

- Knowledge about additive manufacturing and its advantages

- Knowledge of the differences of the performance of polymers and metals
- Knowledge about the technologies
- Knowledge of the value chain

Roles and planning

ROLES AND PLANNING
Distribution of roles in the implementation fo the module:
Don Bosco: • Definition of the formative program • Selection of students • Assessment of formative methods • Evaluation of students and pilot • Loan of equipment and installations **Lortek:** • Definition of the formative program • Teaching about metallurgy, materials, technologies (SLM and LMD), applications and post-processes **Tknika (external entity):** • Teaching about additive manufacturing with polymers and use of 3D printing machines • Teaching about WAAM principles and applications.
Working plan:

Day	Students	Topic	Time (h)	Entity
1	All	History, Additive Manufacturing. Low Cost 3D Machines	0,5	TKNIKA
		Parts of a 3D printer.	0,5	
		Printing process. File formats.	0,5	
		Software used (Cura, Repetier Host)	1,5	
2	All	Printing Parts	1	
		Repositories.	0,5	
		Change of filament.	0,5	
		Printing with support.	1	
3	All	Part design	1,5	
		Optimization, internal channels, weight reduction.	0,5	
		Cuts and joints. Repair parts...	1	
4	All	Metallurgy, materials and powder used in MAM	0,5	LORTEK
		MAM technologies	0,5	
		Real applications	0,5	
		Post processes, NDT	0,5	
		Visit to the facilities	1	
5,6,7	Group 1	Introduction to the processes by electric arc with contribution of wire	0,5	TKNIKA
		Software used for the robotic cell	0,5	
		Practices with WAAM technology	2	
	Group 2	Use of supports	0,5	LORTEK
		Software used (Materialise Magics)	1	
		Practices with SLM technology	1	
	Group 3	Metallographic characterisation	1	
		Software used	0,5	
		Practices with LMD technology	1	
7	All	Evaluation of the pilot and acquired knowledge	0,5	LORTEK & TKNIKA

Evaluation of the Pilot 2

All the students who have participated to this training module have filled a questionnaire concerning the evaluation of this pilot. The Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, Figure 14 and Figure 15 show all the results of the evaluation.

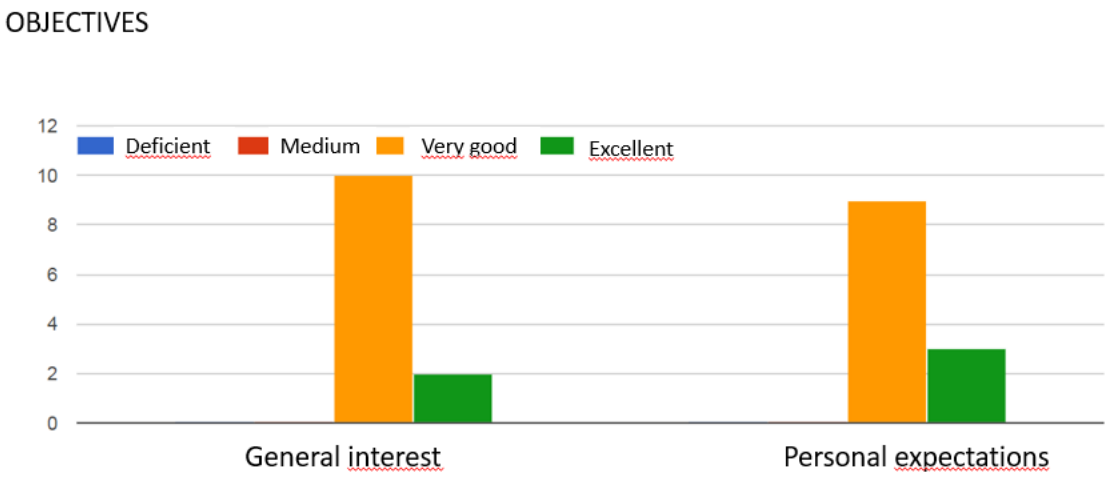


Figure 8: Pilot 2 Objectives

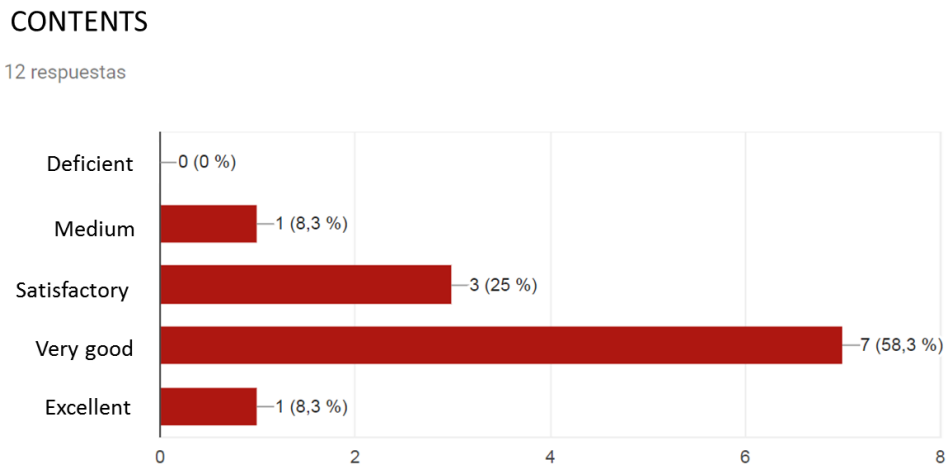


Figure 9: Pilot 2 Contents

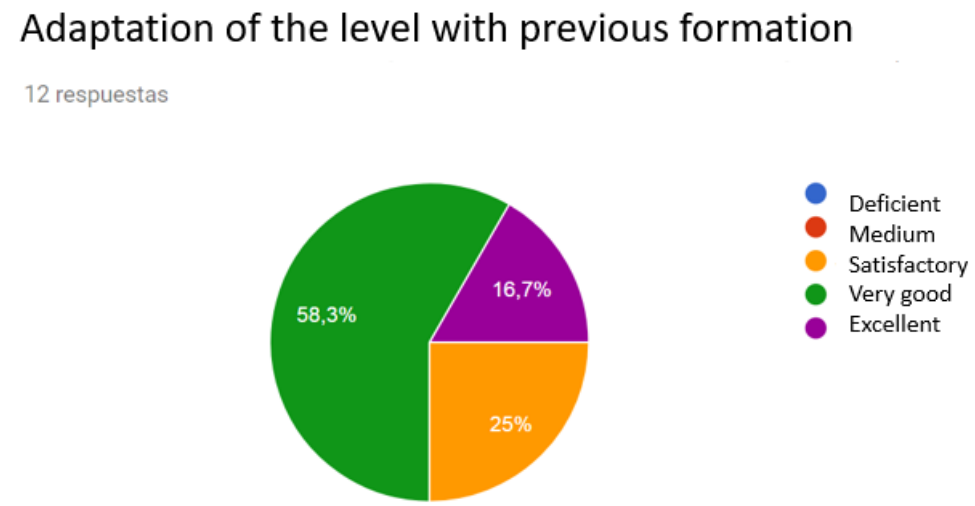


Figure 10: Pilot 2 Adaptation of the level

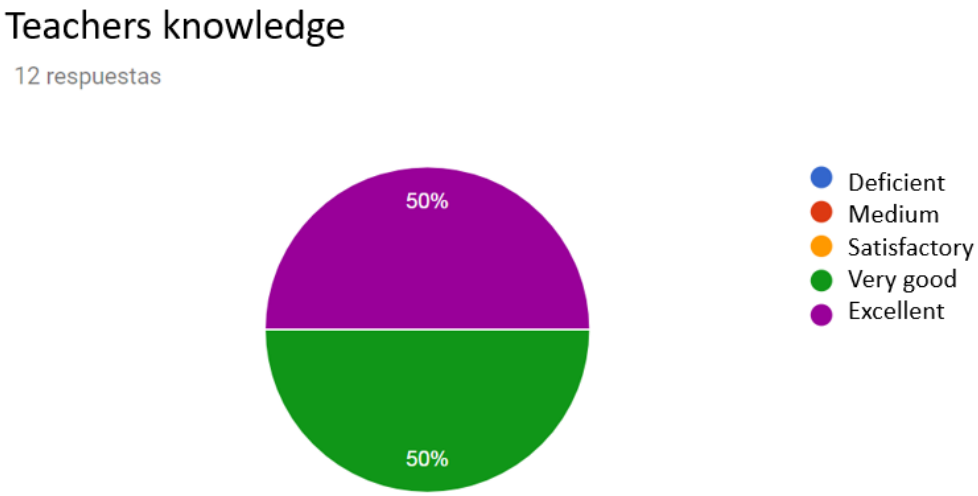


Figure 11: Pilot 2 Satisfaction with teachers

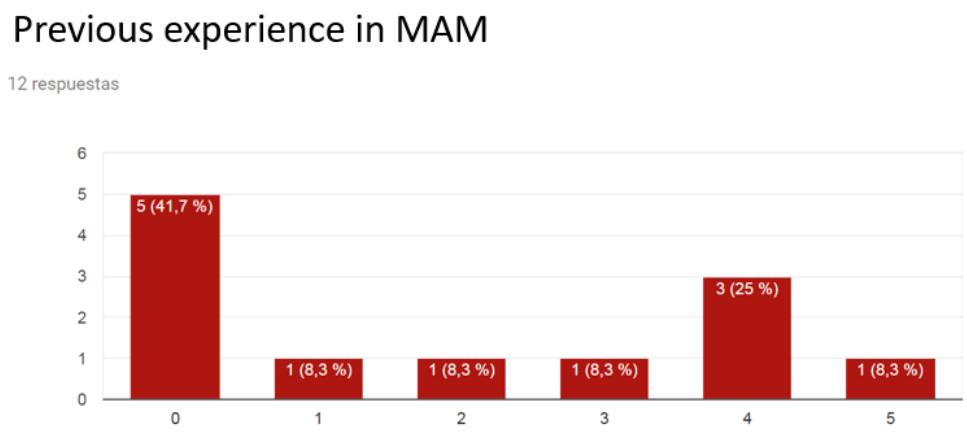


Figure 12: Pilot 2 Previous experience in MAM

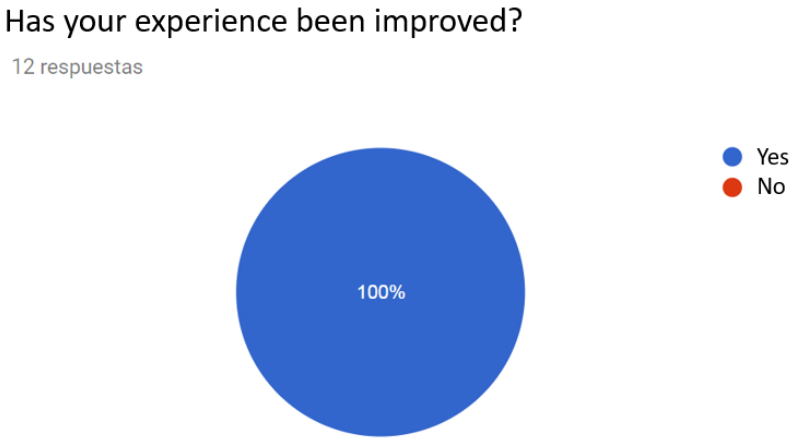


Figure 13: Pilot 2 Improvement of the experience

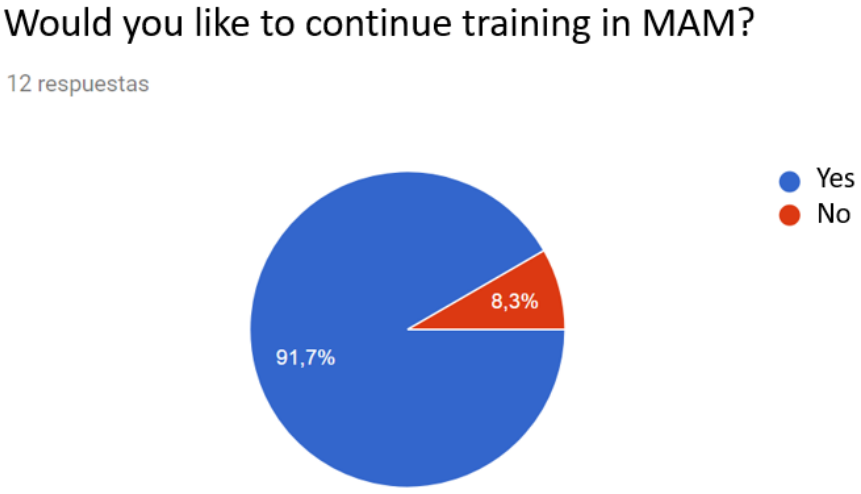


Figure 14: Pilot 2 Willingness to continue in MAM

Figure 15: Pilot 2 Recommendations

The evaluation of pilot by students of different modules did not reply significant differences as it is introductory.

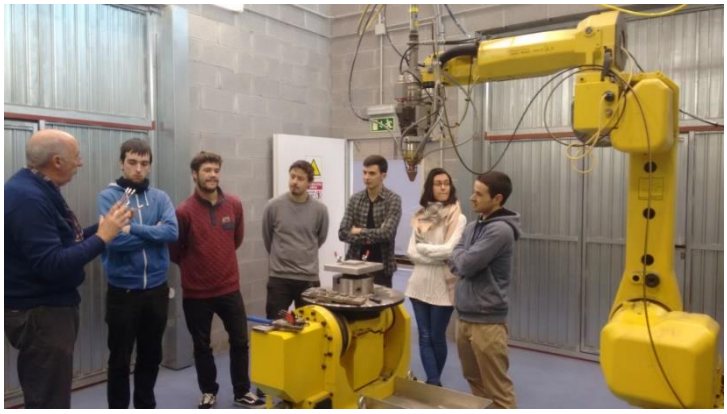
The main reason to join this training was curiosity in new technologies, in order to have more options in the market.

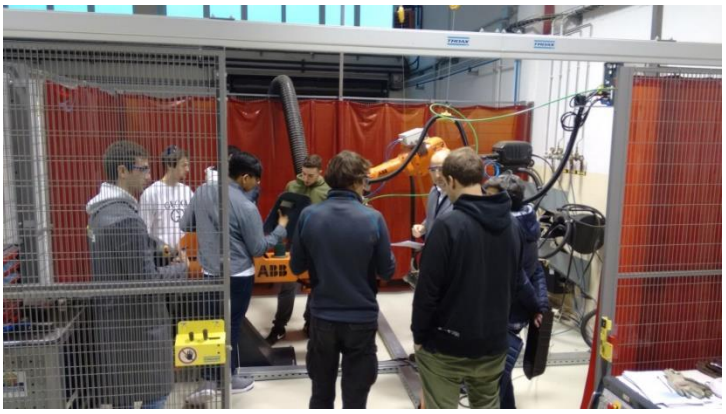
According to the possible improvements, the most required one is to dedicate less time to theory and amount of data.

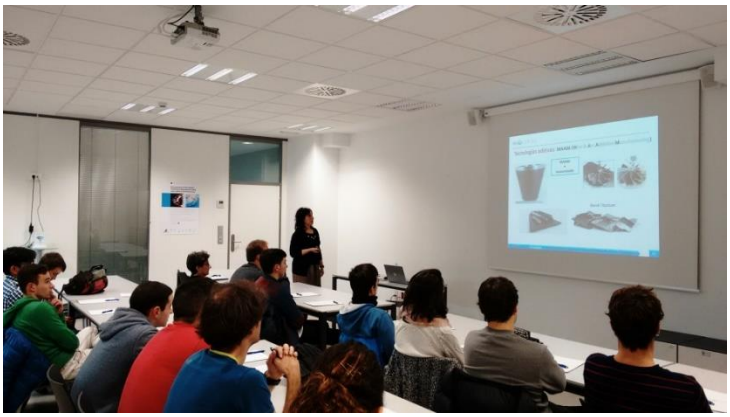
The general opinion is that it has been an interesting training pilot for them.

Also, 100% of students recommend this training module.

Pictures







Pilot 3 - Continuous Formation – IPLEIRIA – Level introductory

Terms of Reference

Main information of the working group

MAIN INFORMATION OF THE WORKING GROUP
Title of the Education pilot:
Continuous Training 3
Members of the working group:
IPLEIRIA
Leader of the working group:
IPLEIRIA

General information of the training module

GENERAL INFORMATION OF THE TRAINING MODULE
Name of the formation:
Fabrico digital direto de metais (Direct Digital Manufacturing of Metals)
Type: (Higher Education, continuous training, professional training
Continuous training
Objectives:
• To know the direct digital manufacturing processes applicable to metallic materials • To select the most appropriate manufacturing process taking into account functional and geometric aspects for a particular part to be obtained • To manufacture parts in metallic materials using direct digital manufacturing processes, namely additive manufacturing and subtractive manufacturing
Target:
Unemployed persons having an engineering or science background training.
Number of participants:

20
Duration of the module:
50 hours
Date of the formation:
From May 26th – to ?
Issuance of a diploma? (Yes / No):
Yes
Reiteration possible for the following years? (Yes / No):
Yes

Detailed specification of the training module

DETAILED SPECIFICATION OF THE TRAINING MODULE
Lack of current training: Gap / Training needs identified:
In Portugal, the training offer in additive manufacturing is scarce. Specifically, training offers on metal additive manufacturing processes do not exist. This offer will be the first of its kind and will provide trainees with a chance to shift their skill set towards this area of expertise.
Content of the module:
1. Additive Manufacturing Processes for Metallic Materials 1.1. Powder bed-based processes a) Metal powders b) Fusion mechanisms c) Selective laser fusion process (SLM) d) Handling and safety of powders e) Powder processing equipment 1.2. Directed Energy Deposition (DED) a) Powder deposition processes b) Wire deposition processes c) Laser-based processes d) Electron beam processes e) Other DED processes f) Materials for DED

g) DED production equipment

2. Manufacturing of metal parts by additive processes
   2.1. SLM technology
      a) Variables and equipment calibration
      b) Design of parts for SLM: geometry, orientation
      c) Production of parts and interpretation of results
   2.2. Post-processing technologies
      a) Finishing by milling

Teaching methods:

Theoretical sessions:
students will be taught the theoretical background of the contents

Practical sessions:
Students will experience the manufacturing workflow of a part using SLM technology.

Technologies to be taught:

Software related to MAM technologies: modeling and slicing.
SLM process.

Use of equipment:

SLM machine.

Link with the pilots:

The training is related to Pilot 1

Admission Requirements and Prerequisites:

Candidates should have a background formation in engineering or sciences.

Evaluation Mechanisms (student evaluation and module evaluation by students):

1. Students assessment
   1.1. Theoretical assessment:
      a) written test
   1.2. Practical assessment
      a) Report on case study part
2. Module assessment
   2.1. Inquiry at the end of the module

Impact of this training:
This training will be the first of its kind in Portugal. It will be offered within a wider training package that includes other AM technologies, in a total of 300 hours. Candidates not possessing the necessary background will be given the chance to acquire the minimum set of skills by taking an set of introductory modules, having a duration of 275 hours. At the end of the training, students will be provided the chance of taking an internship in local companies.

Roles and planning

ROLES AND PLANNING

Distribution of roles in the implementation of the module:

IPLEIRIA

- definition of objectives and contents of the module
- implementation of training at CDRSP facilities

IPLEIRIA is in close contact with IEFP institute. They will be selecting candidates for the training, as well as manage part of the teachers.

Work plan (Planning + methods):

Module	Duration (hours)
Introduction to Direct Digital Manufacturing	25
Materials for direct digital manufacturing	25
Additive and subtractive manufacturing technologies	25
Design and direct digital manufacturing	50
Direct digital manufacturing of polymers	50
Direct digital manufacturing of metals	**50**
Direct digital manufacturing of ceramics	25
Reverse Engineering	25
Post-processing of direct digital manufacturing parts	25
Total	**300**

Evaluation of the Pilot 3

Since this pilot is enrolled in a program in collaboration with the IEFP for a period of 1 year, this module has not yet been evaluated, the training is still ongoing.

Pictures

None for the moment.

Pilot 4 - Continuous Formation – ESTIA – Level advanced

Terms of Reference

Main information of the working group

MAIN INFORMATION OF THE WORKING GROUP
Title of the Education pilot:
Design Rules for Metallic Additive Manufacturing
Members of the working group:
ESTIA
Leader of the working group:
ESTIA

General information of the training module

GENERAL INFORMATION OF THE TRAINING MODULE
Name of the formation:
Design Rules for Metallic Additive Manufacturing
Type: (Higher Education, continuous training, professional training
Continuous training – Advanced level
Objectives:
- Knowledge about MAM processes (SLM, EBM, EBAM, LMD-P, WLAM, WAAM (TIG, Plasma, CMT), Binder Jetting, MELD, Cold Spray - Deepening knowledge on Design Rules for MAM through 3 technologies (SLM, LMD-P, WAAM-WLAM) - Discovery and introduction to topological optimization - Sensibilization to costs for Additive Manufacturing
Target:
- Industrialist from SMEs with knowledge on CAD tools (CATIA V5) - Mechanical engineering office from SMEs
Number of participant:
10

Duration of the module:
2 days
Date of the formation:
28 and 29 May 2019
Issuance of a diploma? (Yes / No):
Training Attestation
Reiteration possible for the following years? (Yes / No):
Yes

Detailed specification of the training module

DETAILED SPECIFICATION OF THE TRAINING MODULE
Lack of current training: Gap / Training needs identified:
At this moment, very few programs are available for continuous formation and according to our previous Addispace inquiry, it exists a real need of training in 5 main domains: - Design Rules - Topological Optimization - Simulation and Process - NDT / Control - Post-treatment Unlike with students' module, we don't consider interesting, for an advanced level module, to cover the entire value chain of Metallic Additive Manufacturing to train industrialists since each stage of this value chain will be carried out by different people: Mechanical Design Office, Calculation office, Quality controller, etc. That is why we prefer focus on 1 module to train industrialist. In this case, it is with the mechanical or engineering office that we will teach the design rules for the 3 processes of MAM.
Content of the module:

- Introduction with the 3 main processes (SLM, LMD/P&W, WAAM)
- Type of application
- Design rules for Powder Bed Fusion
- Design rules for DED Powder
- Design rules for Wire Deposition
- Case studies
- Choice of the part / process for manufacturing
- Technico-economic environmental feasibility
- Introduction to Topological Optimization

Teaching methods:

Theoretical + Practical course (use of softwares)

Technologies to be taught:

- SLM
- EBM
- LMD/P
- LMD/W - WLAM
- WAAM (MIG, MAG, CMT, TIG, Plasma, EBAM)
- MELD
- Cold Spray
- Binder Jetting

Use of equipment:

- 10 computers
- CATIA V5
- ALTAIR Inspire
- Autodesk PowerMill 2019

Link with the pilots:

The case studies are issued from the 4 pilots we have in ADDISPACE.

Admission Requirements and Prerequisites:

- CAD tools (Catia V5)
- Basic knowledge on AM

Evaluation Mechanisms (Industrialist evaluation and module evaluation by the industrialist):

Industrialist evaluation:

- Attendance to the 100% time of training module.
- None assignment

Evaluation by the industrialist:

- ADDISPACE evaluation questionnaire to be filled

Impact of this training:

- Open the mind to the possible uses of additive manufacturing in the industry.
- Realize the potential of different technologies
- If some parts currently manufactured by conventional methods become economically unsustainable, people from companies can think of investing in a technology. This will result in a growing MAM market, machine & materials sales, new parts, a new offer, etc.

Roles and planning

ROLES AND PLANNING
Distribution of roles in the implementation of the module:
ESTIA ADDIMADOUR is in charge to organize and to realize the module.
Work plan (Planning + methods):

Tuesday 28th May 2019		
Time	**Item**	**Presenter**
09:00 – 09:30	**History of MAM: A new market**	Pierre DIAZ
09:30 – 12:00	**Presentation of the technologies**	Pierre DIAZ
12:00 – 12h45	**Visit of Addimadour**	Pierre DIAZ
14:00 – 15:00	**General Design method / Value chain for LBM technology**	Pierre DIAZ
15:00 – 16:00	**LBM : Design Rules / Business rules**	Pierre DIAZ
16:00 – 17:00	**Costs for LBM**	Pierre DIAZ

Wednesday 29th May 2019		
Time	**Item**	**Presenter**
09:00 – 10:00	**General Design method / Value Chain LMD/P**	Thomas ELCRIN
10:00 – 12:00	**LMD/P – Design Rules / Business rules**	Thomas ELCRIN
12:00 – 12h30	**Costs for LMD/P**	Thomas ELCRIN
14:00 – 15:00	**General Design method / Value chain for WAAM**	Pierre DIAZ
15:00 – 16:00	**WAAM and WLAM Design rules / Business rules**	Pierre DIAZ
16:00 – 17:00	**Costs for WAAM and Summary of the training module**	Pierre DIAZ

Evaluation of the Pilot 4

All the industrialist who have participated to this training module have filled a questionnaire concerning the evaluation of this pilot. The Figure 16, Figure 17, Figure 18, Figure 19 and the Figure 20 show all the results of the evaluation.

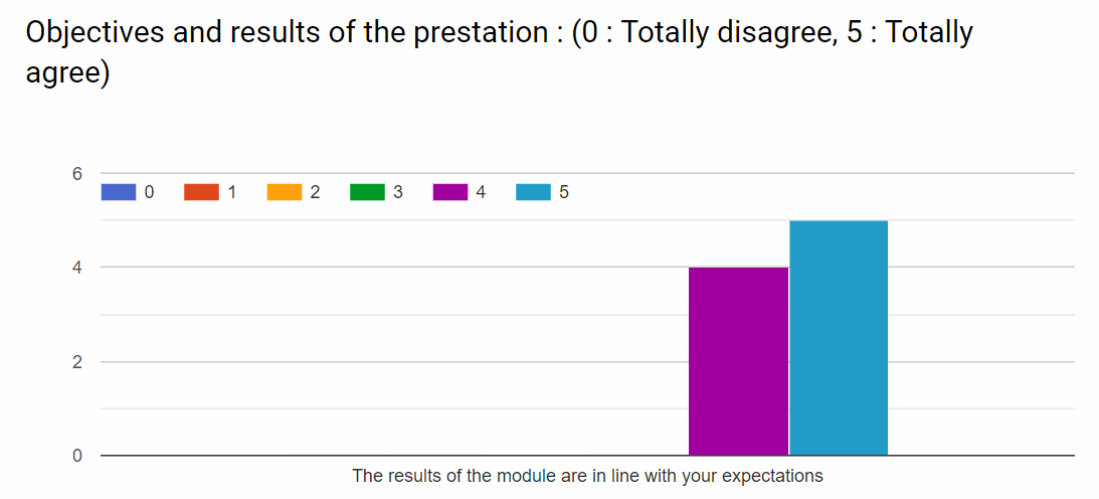


Figure 16: Pilot 4 Objectives and results

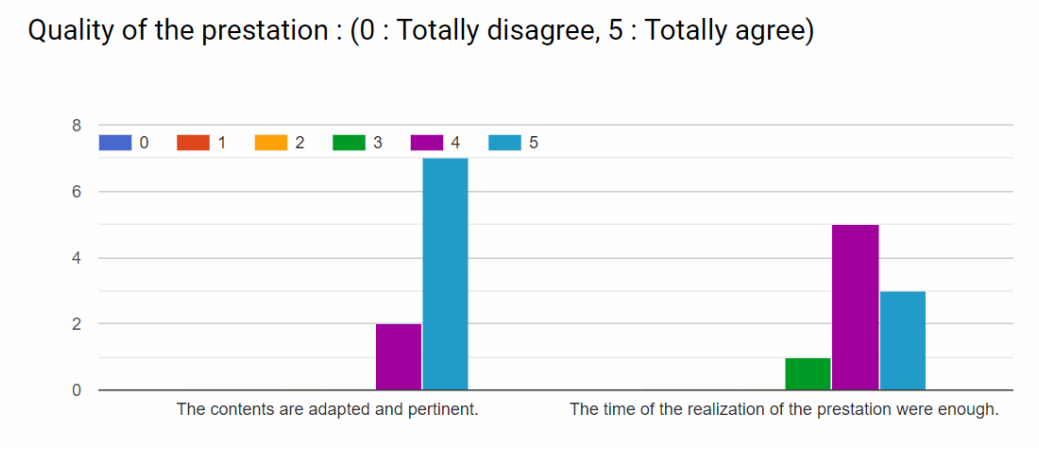


Figure 17: Pilot 4 Quality of the prestation

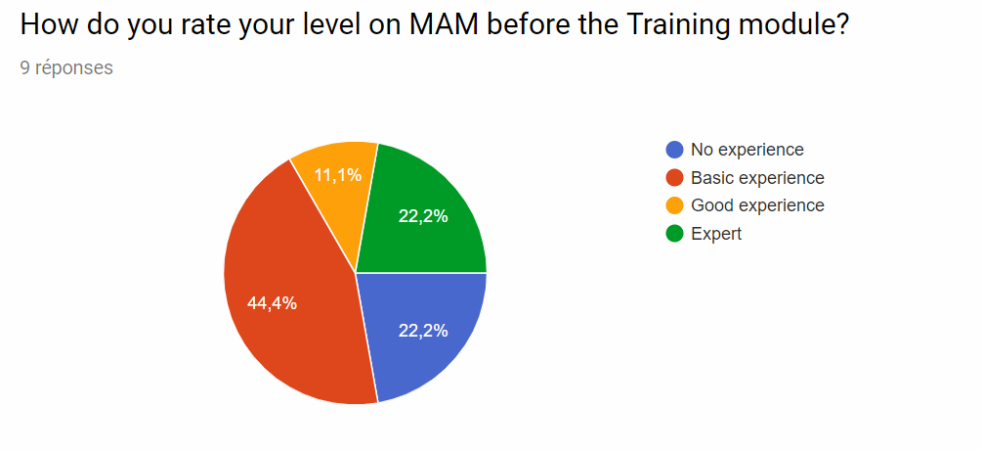


Figure 18: Pilot 4 Level before the training module

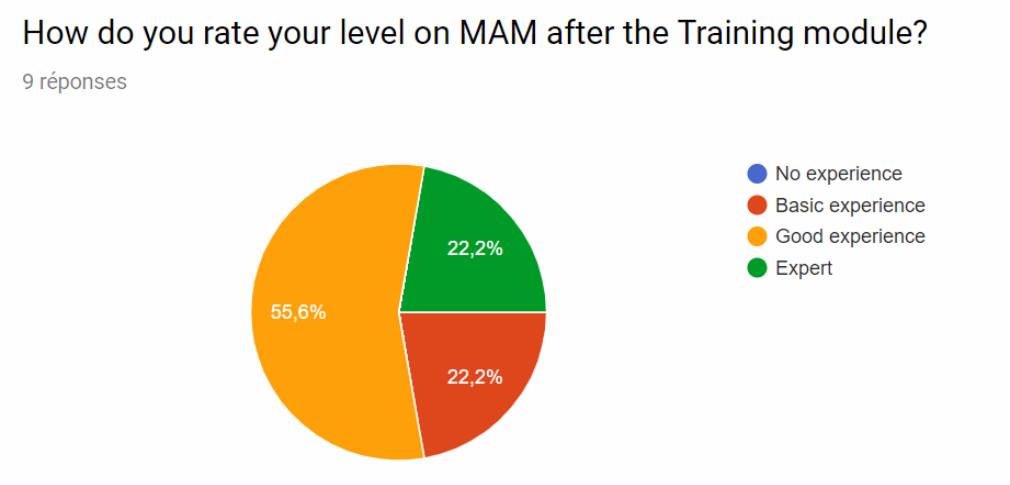


Figure 19: Pilot 4 Level after the training module

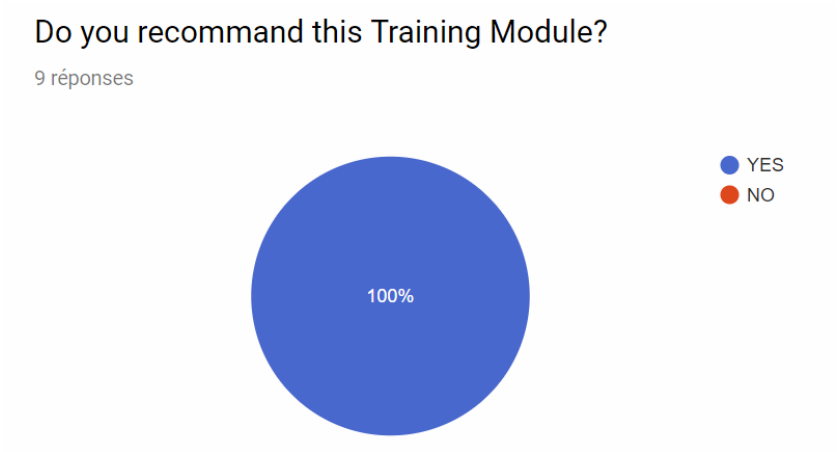


Figure 20: Pilot 4 Recommendations

In general, the results of this pilot are very convincing. The industrialists have deepened their knowledge on metal additive manufacturing by working on concrete cases, real methods and manipulation on software.

It is important to note that before the training module, almost 67% had no experience or basic experience in Additive Manufacturing, and after training, more than 77% have good knowledge or expert experience.

Also, according to the free comments:

- Some industrialists propose to add a supplementary day for this module (2 days is a little bit short – the module is very dense)
- Some industrialists are satisfying with the format 2 days
- Some industrialists propose to add a new module for the process simulation

To finish, 100% of the industrialists recommend this module.

Pictures

Pilot 5 - Continuous Formation – FADA CATEC – Level advanced

Terms of Reference

Main information of the working group

MAIN INFORMATION OF THE WORKING GROUP
Title of the Education pilot:
Introduction to MAM
Members of the working group:
FADA-CATEC
Leader of the working group:
FADA-CATEC

General information of the training module

GENERAL INFORMATION OF THE TRAINING MODULE
Name of the formation:
Curso Avanzado en Fabricación Aditiva Metálica: Fundamentos, procesos y verificación NDT aplicados al sector Aeroespacial.
Type: (Higher Education, continuous training, professional training
Continuous training – Advanced Level
Objectives:
With the aim of bringing the MAM technologies closer to new users, businesses, and consumers, this training module cover all the information regarding metal Additive Manufacturing Technologies and its value chain for aerospace industry.
Target:
All kind of SMEs and agents involved on MAM value chain without experience in the aerospace sector
Number of participants:

25 people
Duration of the module:
18h / 3 days
Date of the formation:
19-20-21 June 2018
Issuance of a diploma? (Yes / No):
No
Reiteration possible for the following years? (Yes / No):
Yes

Detailed specification of the training module

DETAILED SPECIFICATION OF THE TRAINING MODULE
Lack of current training: Gap / Training needs identified:
Although knowledge about additive manufacturing technologies is increasingly advanced at all levels, given the commercial growth called 3D-Priniting revolution, there is still a real gap in training those people who will be interested in the near future, so companies are not yet aware of the value chain of a MAM process and many times a lack of information both on basic and high level concepts that have to be clarified. This training has exposed and highlight almost this question, supported with real experience that can be finally revealed due a practical case of study.
Content of the module:

1. Additive Manufacturing Technologies *[Introduction]*
2. MAM-PBF [Powder Bed Fusion] - Selective Laser Melting *[Systems & Basis]*
3. *DfAM* – Design for Additive Manufacturing
   3.1. Mythos and Real Application.
   3.2. *Design Rules, Advantages and Constraints*
4. Topology Optimization: Basis and Case Studies
5. Quality Assurance & Non-Destructive Testing for MAM
6. MAM: Case of Studies
7. Lab experience of participant's User Case

Teaching methods:

General presentation of the technology based on analog and comparative method based on the experienced in the industrial field by the pilot leader.
The idea behind this method is to get training participant to involve in the main MAM concepts applying their knowledge acquired during the module as well as their own concerns by themselves through their own practical case of study where experts in the field will leading those cases.

Methods for teaching were:

- Oral presentations with PowerPoint support
- Design and Optimization software
- MAM facilities
- Collection of MAM parts
- Inspection and testing facilities
- Etc.

Technologies to be taught:

General Additive Manufacturing technologies as introduction and comparative purposes being the PBF-Powder Bed Fusion the key technology to be taught to a more advanced level of the process and operation

Use of equipment:

MAM Systems – SLM technology
CAD software design
Topology optimization software
Manufacturing software
NDT equipment (Computed Tomography and Industrial Radiography) and related soft

Link with the pilots:

This training covers the whole value chain of the MAM for aerospace industry, from the design till the final part. There is a close relation with Pilot 1 (post processing and machining issues within the value chain) and 4 (design and topology optimization for MAM)
Admission Requirements and Prerequisites:
Be member of an SME or Company
Evaluation Mechanisms (student evaluation and module evaluation by students):
Evaluation of students wasn't performed since there were no expedition of a diploma. Questionnaire for the evaluation of the training have been filled by the participants
Impact of this training:
This training have offered to potential new users and companies a real information about the technologies, based on the experience by the pilot leader and the near basic principles and a general overview position close to the industry as demanding as is the aerospace industry is. This introductory module has taken into account if they considering in the near future the implementation of this technology, knowing the advantages and disadvantage that the technology offer and how it can be implemented. Also, to develop skills in order to evaluate manufacturing methods for a part, having fundamentals for deciding if a MAM technology is suitable or not.

Roles and planning

ROLES AND PLANNING
Distribution of roles in the implementation of the module:
According to different topics planned to be training in the Pilot, CATEC team experts in the different topic have led the specific module of the training. This training was segregated into 3 main modules: - Manufacturing - Design & Calculation - NDT & QA
Work plan (Planning + methods):

	First day	Second day	Third day
8:30	AM	Calculation & Topology Optimization	QA
10:30			
10:30/11:00	Coffee		
11:00	AM	Calculation & Topology Optimization / DfAM	Lab. Experience
12:45			
12:45/13:00	Break		
13:00	DfAM	NDT	
14:30			

Evaluation of the Pilot 5

It is remarkable the major interest of the attendance for this kind of events and specifically a training-event of this characteristics. They appreciate more similar initiatives to spread cutting edge knowledge and its applications in the industry.

Although many people applied to the call, the maximum number was limited by the facilities. Finally, the attendance included:

- 9 companies
- 25 people

Among the main findings of interest for the project, it must be noticed the content that the attendance most values:

- Fabrication procedure
- Support removal / extraction, in general, post-processing operations
- Design and calculation
- Materials characterization

The pilot has been well received by the SMEs and professionals of the aerospace sector to increase their knowledge regarding MAM. This is a popular branch of technologies for which there is not great knowledge for the people of the sector. However, they are aware of its importance. The participants have thanked this initiative as a way to introduce MAM technologies in their companies and study the advantages and application that MAM offers.

It also has been an opportunity to contact with professionals of different expertise related to the aerospace sector, not only from the point of view of the Center but also among the participants of the event.

After the course, a survey of evaluation was performed in order to evaluate de initiative. The result of the survey is included in **Erreur ! Source du renvoi introuvable.**.

COMPANY	OBJECTIVES [Global evaluation]	OBJECTIVES [Expectatives satisfaction]
AEROTECNIC	-	Excelent
Inespasa	Excelent	Excelent
Alestis	Excelent	Excelent
Alestis Aerospace	Very good	Medium
INESPASA	Excelent	Excelent
alestis aerospace	Excelent	Excelent
INESPASA	Very good	Very good
Indaero Tecnigrab	Excelent	Excelent
Element Materials Technology	Excelent	Excelent
Alestis Aerospace	Very good	Very good
Alestis	Excelent	Very good, Excelent
Canagrosa Lab&Services	Very good	Very good
INDAERO	Very good	Very good
Sevilla Control	Excelent	Very good
CT Ingenieros	Excelent	Excelent
ALESTIS AEROSPACE	Excelent	Excelent

Figure 21: Pilot 5 results

Pictures

Pilot 6 - Continuous Formation – LORTEK – Level introductory

Terms of Reference

Main information of the working group

MAIN INFORMATION OF THE WORKING GROUP
Title of the Education pilot:
MAM module for Continuous training
Members of the working group:
IK4-Lortek Don Bosco
Leader of the working group:
IK4-Lortek

General information of the training module

GENERAL INFORMATION OF THE TRAINING MODULE
Name of the formation:
Introduction to MAM for Continuous training
Type: (Higher Education, continuous training, professional training
Continuous training
Objectives:
• Knowledge about Additive Manufacturing technology. • Learn the process for printing 3D parts. • Know and use different software of Additive Manufacturing. • Know the parameters of the software that influence the quality of the prints. • Adjust and configure printers for an optimal printing. • Know and use of different printing materials. • Knowledge of basic concepts of metallurgy. • Interiorization of the importance of design. • Learn the process of Metal Additive manufacturing with different technologies. • Knowledge about post-production processes

Target:
Design a formative program for continuous training according to the identified current and coming demand from industry.
Number of participants:
12 workers in total from at least 4 different companies and preferably from 12 different companies.
Duration of the module:
16 hours
Date of the formation:
26 – 27 September 2018
Issuance of a diploma? (Yes / No):
Yes
Reiteration possible for the following years? (Yes / No):
Yes

Detailed specification of the training module

DETAILED SPECIFICATION OF THE TRAINING MODULE
Lack of current training: Gap / Training needs identified:
At this moment few programs are available for continuous formation. Overall knowledge of Additive manufacturing, technologies, materials and their applications will give an introduction to this field.
Content of the module:

Tknika (external entity):
History, Additive Manufacturing. Low Cost 3D Machines
Parts of a 3D printer
Printing process. File formats
Mostly used software (Cura, Repetier Host)
Printing of parts
Repositories
Replace the filament
Printing with supports
Design of parts
Topological optimization, internal channels, weight reduction
Cuts and joints. Repair Parts (NetFabb)
PAW technology for WAAM

LORTEK:
MAM technologies
Materials and powder for MAM
Post processes
Quality (Metallographic characterization and NDTs)
Real applications
Software used (Materialise magics, …)
SLM machine
LMD-cladding powder machine

Teaching methods:

The course was eminently practical.

For a proper understanding of principles of Additive Manufacturing, the course has begun with the 3D printing of polymers and then continued with the Metal Additive Manufacturing.

After the necessary theoretical explanation, the precise practices have been realized until assimilating the matter explained.

Parts have been printed and manufactured with polymers and metals.

The importance of the design of the piece (topological optimization, weight reduction, methods to avoid supports, ...) and its orientation when printing have been studied.

During the course they have acquired the necessary knowledge to finally develop the project that has been assigned by the teacher.

Search in Internet web sites the information available about 3D printing: development communities and parts repositories, etc.

Technologies to be taught:

FDM (Tknika)
SLM (Lortek)
LMD cladding (Lortek)
WAAM (Tknika)

Use of equipment:

The course was given in three different locations and in each of them the following equipment were used:

Don Bosco:

- Ikaslab, 10 3D printers with 8 laptops.
- Electronic whiteboard with laptop for teacher.
- Coils of ABS plastic, PLA and other thermoplastic materials
- All computers are networked and have Internet access both by cable and Wi-Fi.
- Necessary tools.

Lortek:

- Necessary tools to give a class.
- SLM machine.
- LMD cladding.

Tknika (external entity):

- Classroom with PCs and a whiteboard.
- Robotic cell with plasma arc welding equipment with wire input.

Link with the pilots:

This introductory formative program is linked with all the pilots from WP2 according to the technologies used. In this case SLM, LMD powder and WAAM were explained and shown in use. Their fundamental concepts were explained according to their advantages, disadvantages, main applications and designing and optimization possibilities. Firstly, as an introduction to Additive Manufacturing, 3D printing with polymers were performed. After that, MAM was introduced, and 3 different technologies has been explained broadly (SLM, LMD powder and WAAM).

Admission Requirements and Prerequisites:

This pilot has been offered to 12 workers in total.
Lortek and Don Bosco have selected them taking as a criteria of potential of implementing MAM in their facilities.

Evaluation Mechanisms (student evaluation and module evaluation by students):

In order to pass the course, it has been necessary to:
- Manufacture the proposed parts in the course.
- Attendance to the 100 % of the hours of the established training programme.
- Respond to a questionnaire to evaluate the pilot.

Impact of this training:

- Knowledge about additive manufacturing and its advantages
- Knowledge of the differences of the performance of polymers and metals
- Knowledge about the technologies
- Knowledge of the value chain

Roles and planning

ROLES AND PLANNING
Distribution of roles in the implementation of the module:

Don Bosco:
- Definition of the formative program
- Assessment of formative methods
- Evaluation of pilot
- Loan of equipment and installations

Lortek:
- Definition of the formative program
- Teaching about metallurgy, materials, technologies (SLM and LMD), applications and post-processes

Tknika (external entity):
- Teaching about additive manufacturing with polymers and use of 3D printing machines
- Teaching about WAAM principles and applications

Work plan (Planning + methods):

Day	Timetable	Contents	Time (h)	Entity
26/09/2018	8,00-13,00	History, Additive Manufacturing. Low Cost 3D Machines	0,5	DON BOSCO (Rentería)
		Parts of a 3D printer	0,5	
		Printing process. File formats	0,5	
		Software used (Cura, Repetier Host)	0,5	
		Printing Parts	0,5	
		Repositories	0,5	
		Change of filament	0,5	
		Part design	0,5	
		Printing with support	1	
		Optimization, internal channels, weight reduction	0,5	
		Cuts and joints. Repair parts…	0,5	
	14,00-17,00	Introduction to the processes by electric arc with contribution of wire	0,5	TKNIKA (Rentería)
		Software used with the robotic cell	0,5	
		Practices with WAAM technology	1	
27/09/2018	8-12,00	MAM technologies	0,5	LORTEK (Ordizia)
		Materials and powder for MAM	0,5	
		Post processes and quality	0,5	
		Real applications	0,5	
		Visit to the facilities	1	
	12,00-17,30	Software used (Materialise magics)	1	
		Powder characterisation	0,5	
		Practices with SLM technology	1	
		Practices with LMD technology	1,5	
		Software used (SKM)	1	
		Course evaluation		

Evaluation of the Pilot 6

OBJECTIVES

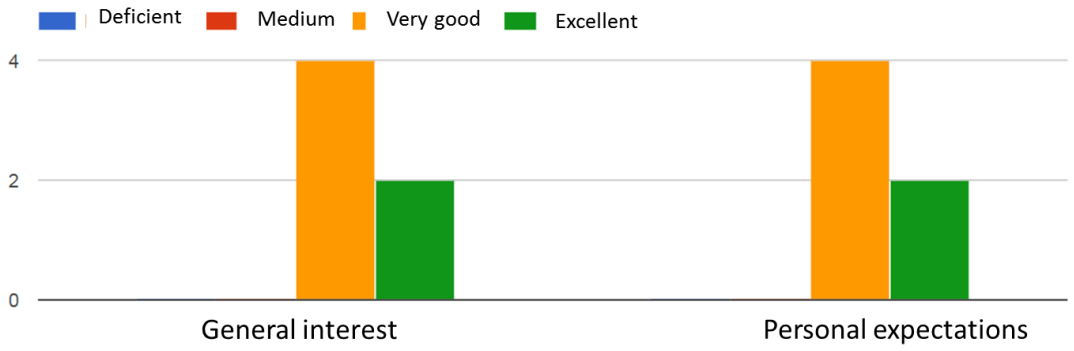


Figure 22: Pilot 6 Objectives

Regarding the contents all of them were interesting and in their opinion no topic was missed:

- 3D printing with polymers
- MAM theory

- SLM practises
- LMD practises
- WAAM practises

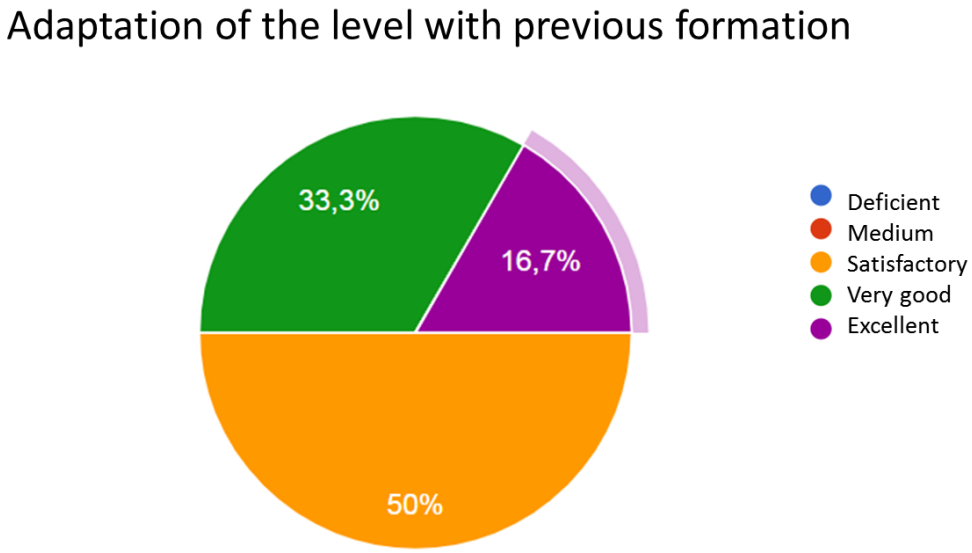


Figure 23: Pilot 6 Adaptation of the level

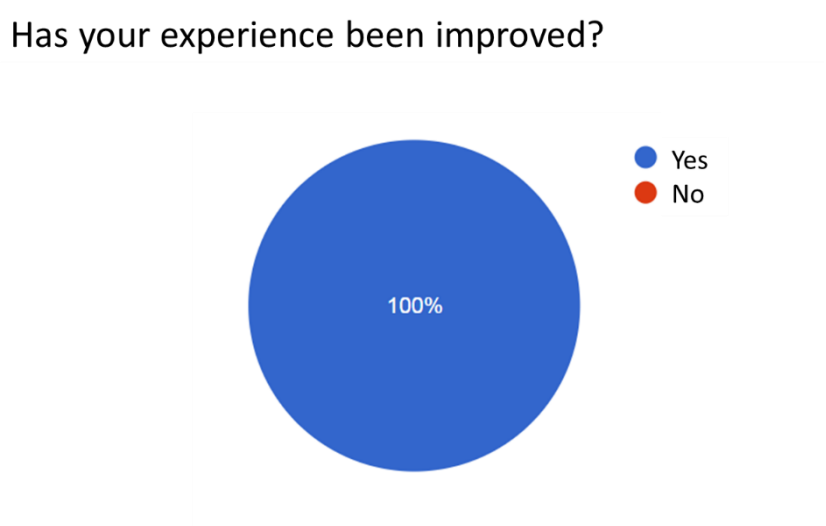


Figure 24: Pilot 6 Improvement of the experience

Figure 25: Pilot 6 Willingness to continue in MAM

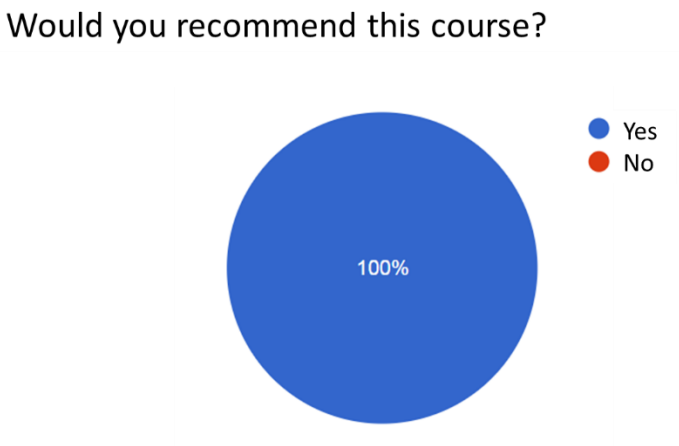


Figure 26: Pilot 6 Recommendations

For most of the participants the adaptation of the level of the course was satisfactory for their experience in AM.

All of them are interested in the continuation of their formation in AM.

According to the possible advanced courses could be focused on SLM, WAAM.

Also, it is important to note that 100% of the industrialist recommend this module.

CONCLUSION

According to Deliverable 4.1.1: Study of training needs, it was revealed that the training offer in France, Spain and Portugal was clearly insufficient to meet the expectations of industry.

Thanks to the ADDISPACE project and the efforts of the various partners, 6 new training modules could be built, developed and tested by people outside the project:

- Students Engineer / University BAC + 5
- High school students
- Postdocs
- Doctoral students
- Industrialists from various companies
- Etc.

The 6 modules proposed have met 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

It is important to note that all 6 modules were 100% approved by all participants, which shows a real enthusiasm for the development of new training modules.

These courses have allowed 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.

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