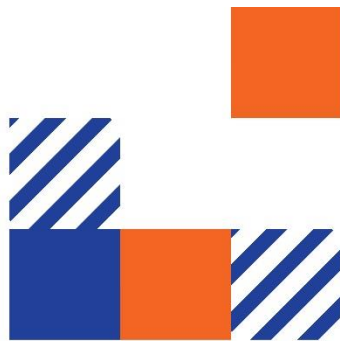




Co-funded by the
Erasmus+ Programme
of the European Union

Project title:

Creating know**L**edge and skill**L**s in **A**dd**I**tive **M**anufacturing



CLLAIM

Reference number:

2017-3309/591838-EPP-1-2017-1-ES-EPPKA2-SSA

Working Package WP03

Working Package Leader TWI

Deliverable 3.3

**Title: Pedagogical kit for trainers in the field
of Additive Manufacturing**



Co-funded by the
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Introduction

The main aim of Creating KnowLedge and SkillS in AddItive Manufacturing (CLLAIM), set to address the Manufacturing & Engineering sector, is to develop a brand-new International, sector-oriented qualification system and body in Additive Manufacturing (AM) through the exchange among EU partners of an innovative training curriculum.

The pedagogical kit for trainers gathers several pedagogical methodologies, focused on work-based learning and learner-centred methods applied to professional qualifications, as well as integration of new training materials and exercises, among other tools.

This document aims to ensure a coherent and homogenised use of the training methodologies applied in the courses, among the different countries.

1. Use of the pedagogical toolkit

The information in this document outlines the tools that an AM trainer shall use. Personnel involved in AM training shall complete a formal documented train the trainer programme, which should contain the following information.

The term ‘pedagogy’ essentially refers to the processes and relationships of learning and teaching. A toolkit aids this by providing the candidate and trainer with a platform to engage in these activities, within a subject base.

1.1. Teaching approaches

The pedagogical toolkit is designed to offer tools to aid in the learning and teaching process. When we look at teaching the subject matter there are several aspects to consider:

- 1) **Expert:** Similar to a coach, experts share knowledge, demonstrate their expertise, advise candidates, and provide feedback to improve understanding and promote learning.
- 2) **Formal authority:** Authoritative trainers incorporate the traditional lecture format and share many of the same characteristics as experts, but with less candidate interaction.
- 3) **Personal model:** Incorporates blended teaching styles that match suitable techniques with the appropriate learning scenarios and candidates in an adaptive format.
- 4) **Facilitator:** Designs participatory learning activities and manages classroom projects while providing information and offering feedback to facilitate learning.
- 5) **Delegator:** Organizes group learning, observes candidates, provides consultation, and promotes interaction between groups and among individuals to achieve learning objectives.

We have listed these under teaching approaches and every trainer will have aspects of these within their teaching styles. There is no single approach in itself that is the best; it will depend upon the subject material, information to be conveyed and the candidates’ learning styles.

1.2. Learning styles

In addition to the above we also need to consider how candidates prefer to learn. These can be listed in seven separate categories:

- 1) **Visual (spatial):** You prefer using pictures, images, and spatial understanding.
- 2) **Aural (auditory-musical):** You prefer using sound and music.
- 3) **Verbal (linguistic):** You prefer using words, both in speech and writing.
- 4) **Physical (kinaesthetic):** You prefer using your body, hands and sense of touch.
- 5) **Logical (mathematical):** You prefer using logic, reasoning and systems.
- 6) **Social (interpersonal):** You prefer to learn in groups or with other people.
- 7) **Solitary (intrapersonal):** You prefer to work alone and use self-study.

1.3. Teaching tools

It is essential to have teaching tools as we have information to impart and we need to ensure the candidate reaches a level of competency, including theoretical knowledge as well as practical knowledge. We often have a set amount of time in which we need to do this. All of this helps to facilitate the learning process.

Teaching tools can be wide and varied and include:

- Course material (notes/handouts)
- Videos
- Case studies (could be singular or group activities)
- Additional reading material
- List of standards
- Diagrams and flowcharts
- Animations
- Images, including CAD files and engineering drawings
- Written Instructions and procedures
- Sample questions
- Practical exercises
- Blended online learning material, which may include all of the above

1.4. Best practice for presentations

When preparing to give a presentation, you want your audience to be engaged and interested in the information that you are delivering. Implementing the following practices will improve your presentation and audience engagement:

- ☑ **Focus on one idea per slide.** Avoid too much information in one slide, your slideshow will be much more visually appealing if you break your content into multiple slides.
- ☑ **Use two or three fonts max.** Use only two or three fonts throughout your presentation. Consistency is key, and you want to make sure your slides look cohesive and like they belong together.
- ☑ **Keep it to less than six lines of text.** Your slide should not be just a wall of text. Instead, be sure to keep it to less than six lines of text at a maximum; ideally fewer. The content included on your slide should be limited to your main talking points and your voice should do the rest. Visuals are just as important.
- ☑ **Reduce or avoid the use of bullet points.** There are other more engaging and visually appealing ways to design your presentation slides. Use icons, images, graphs.
- ☑ **Create strong contrast.** In your audience, you might have people sitting in the back of the room, relatively far away from your screen. To make sure they can still see your presentation slides, you need to create strong contrast. This means your text should easily stand out against your background.
- ☑ **Stick to two or three colours.** Just like you should use no more than two or three fonts throughout your presentation, the same goes for colours. When you start to get four, five, six colours into a presentation, it can start to look messy and like the slides do not

actually match or go together in the same slideshow. Colours can also be used to link ideas or learning points.

- ☑ **Add audio and video.** One great way to create an interactive presentation is by adding audio and video elements to your slides. This helps you take a break from talking and can give your presentation another dimension.
- ☑ **Stick to one image per slide.** For images and photographs, it is best to incorporate just one in each slide. There are several different ways to use these images, like as a background, an accent photo or with a colour overlay.
- ☑ **Use high-quality graphics.** Always use high-quality vector graphics that look great no matter how big or small they are. Icons and graphics can be an effective way to visually represent your words and context and further help your audience understand what you're saying.
- ☑ **Use data visualization.** Data visualization can include anything from charts and graphs to radials and icon charts. It is essentially taking numbers and statistics and showcasing them in a visual form so that it's easier for your audience to understand at a glance.
- ☑ **Make it interactive.** We mentioned about how adding audio and video to your presentation slides can help make it interactive. Adding links to your presentation, whether between slides or even between elements in a single slide, is a great way to create a unique slideshow. You can also put together an interactive quiz by linking elements in a single slide.
- ☑ **Keep transitions and animations consistent.** It is important to keep all transitions and animations consistent within your presentation or it can easily overwhelm your audience. It is recommended to maintain a single transition and animation type throughout your entire slideshow. Avoid the animation of every single one of your elements. Let some of them stay static while other, more important elements are animated on the screen.
- ☑ **Be energetic.** Your audience can feel your energy, and if you are standing up at the front of the room and speaking through each slide with an unenthusiastic and monotone voice, your audience will quickly lose interest. Move around the front of the room or use hand motions.
- ☑ **Know your audience.** Understand who is going to be in your audience—how many people, what their backgrounds are.
- ☑ **Summarize.** Taking time throughout your presentation to summarize what you have said so far is a good way to help your audience fully understand the material and remember it for the future. Create a summary slide after every main point and/or at the end of your presentation to conclude.
- ☑ **Regularly update and adapt.** To keep your presentation relevant, make sure you regularly update and adapt your content to be current and accurate. You can also include an area in the footer of your first or last slide with the creation date alongside the last date of update so your audience knows it's being revisited often with updated information.

2. Pedagogical toolkit

Due to the current system most equipment manufacturers in AM carry out training for clients using their own training course formats based upon the set operation and maintenance of their equipment. It is envisaged that manufacturers and training providers could cross-reference their syllabus to comply with the '**CLLAIM AM qualification guideline**' which covers the minimum training hours and experience requirements under the different qualification routes:

1. Standard Route: Conventional classroom training
2. Blended Learning Route: Cross-cutting Competence Units (theoretical knowledge and skills) may be taught using a combination of distance learning and traditional classroom or work-based training programs.
3. Alternative Route: Recognition of Prior Learning (RPL), allows those who already have relevant knowledge and skills in a particular job function through formal, informal and non-formal means of education to proceed to examination without a compulsory attendance of an approved training course or specific Competence Unit.

2.1. Tools for trainers in the field of AM

The objective of the pedagogical kit is to provide material and tools for trainers in the field of AM. The following list is a guide of the use of these tools:

2.1.1. Tools for recording evidence of training

During the training, the trainer shall record information of attendance and evidence of training per candidate as proof of the training provided (theory or practical assessments). A lesson plan based on the syllabus shall be produced and made available to candidates. The minimum information required for each document and suggested templates are provided in the following list:

- Annex 1.1: Lesson plan template
- Annex 1.2: Lesson plan example
- Annex 2.1: Attendance list template
- Annex 2.2: Attendance list example
- Annex 3.1: Evidence of assessment (theory) template
- Annex 4.1: Evidence of assessment (practical tasks) template

2.1.2.Tools for practical tasks

As part of the training, practical exercises are encouraged and clear guidance on the format of documents shall be provided. Templates for the different practical tasks that a trainer should have available are provided in the following list:

- Annex 5.1: Build card template – example
- Annex 6.1: Work instruction template
- Annex 7.1: Case study template

2.1.3.Attendance certificate

An attendance certificate shall be issued to candidates that successfully complete the training. A template for attendance certificates and the minimum information that this document shall contain is presented in:

- Annex 8.1: Attendance certificate
- Annex 8.2: Attendance certificate example.

2.1.4.Standards and reading material

The training provider is responsible for creating a list of references to reading material and standards relevant to the subject. This list of references shall be up to date and available to trainers and candidates. The aim of this is to provide access to resources that facilitate the understanding and control of the AM processes. EWF will be in charge of updating these resources; contact EWF to access the latest list of standards and reading material.

2.1.5.How to write and validate questions

General rules

A list of general rules to remember when writing multiple choice questions:

- Use objective questions with only one best answer.
- Word questions clearly and simply, avoiding double negatives, local terminology/slang/Idiomatic terms
- Test only a single idea in each item.
- Make sure wrong answers (distractors) are plausible.
- Make sure the position of the correct answer (e.g., A, B, C, D) varies randomly from item to item.
- Make sure the length of response items is roughly the same for each question.
- Keep the length of response items short.
- In multiple choice questions, use positive phrasing in the stem, avoiding words like “not” and “except.” If this is unavoidable, highlight the negative words (e.g., “Which of the following is **NOT** an example of...?”).
- Whenever possible, avoid using “All of the above” and “None of the above” in responses.
- Include questions of different levels of difficulty, to identify knowledge levels of candidates.

Analysis techniques to validate questions

Statistical analysis techniques can be used to validate questions. Useful techniques can be:

- Individual questions (Point Bi-serial or Bi-serial coefficient)
- Individual examination papers (KR20 – Kuder Richardson's Reliability Coefficient)

Questioning techniques

Trainers shall be aware of typical questioning techniques:

- **Clarify thinking**, for instance: "Why do you say that?" "Could you explain that further?"
- **Challenging assumptions**, for instance: "Is this always the case? Why do you think that this assumption is correct here?"
- **Encourage them to question evidence/data**, questions such as: "Why do you say that?" or "Is there reason to doubt this evidence?"
- **Viewpoints and perspectives**, this challenges the candidates to investigate other ways of looking at the same issue, for example: "What is the counter argument for...?" or "Did anyone see this another way?"
- **Implications and consequences**, given that actions have consequences line of questioning may include for instance: "But if that happened, what else would result?" or "How does... affect?" By investigating this, candidates may analyse more carefully before jumping to an opinion.
- **Question the question**, just when candidates think they have a valid answer maybe ask "Why do you think I asked that question?" or "Why was that question important?"

Questions techniques to avoid:

- **Not allowing wait time**, for instance: The trainer asks a question and virtually answers it in the next sentence, not allowing thinking time.
- Whilst addressing a class **a question is directed to a particular candidate by name**, others in the class may tend to switch off.
- **Using leading questions** that contain the answer, questions such as: "Don't we all agree that additive manufacturing has a great future?"
- **Using affirmative questions** such as, "Does everybody understand?" Yes/No, this is not a check for understanding
- **Vague redirection**, for example after the candidate answers: "That's not correct, try again", "Where on earth did you get an idea like that?"
- **Using only lower level questions**, Try to explore all the levels of Bloom's Taxonomy
- **Imprecise questioning**, for instance, "What does it mean in the procedure?" (Which procedure? Which paragraph? Which Statement?)

General and application based questions

The training and exam questions should include 'general factual' and 'application based' questions to ensure that the knowledge of general theory and specific topics for the different profiles are used during AM training.

- Example of general factual based questions in AM:

In AM, what does the abbreviation DED represent?

- a) *Digital environment deposition*
- b) *Digital energy deposition*
- c) *Drive energy digital*
- d) *Direct energy deposition*

Answer: d

- Example of application based question in AM:

The target part is a titanium honeycomb structure with a wall thickness of 3mm. Due to the complexity of the design, post-process surface machining or dressing should be minimal. Which of the following AM processes could be suitable?

- a) *DED arc or PBF laser*
- b) *DED laser or PBF laser*
- c) *DED EB or DED arc only*
- d) *PBF laser or DED arc only*

Answer: b.

2.1.6. Library of example questions during training

The training provider shall produce a library of training questions relevant to the knowledge (EXAM QUESTIONS ARE NOT TO BE USED FOR TRAINING) and syllabus required for candidates to gain an AM qualification. The training questions shall be produced based on the different CLLAIM profiles. The library shall be up to date and reviewed by at least two experts on the field. As part of the CLLAIM project, training questions were provided to CLLAIM partners. Annex 9.1: Training questions library contains examples of training questions, these examples may be used if permissions are granted.

2.1.7. Library AM components (CAD files)

The training provider shall provide to trainers and candidates a library of CAD files with examples varying in complexity. As part of the CLLAIM project, several CAD files were made available to partners. This library may be used if permissions are granted. Contact EWF to access these resources.

2.1.8. Library AM images and videos

To facilitate the learning process, the trainers shall have examples of both images and video footage available from a library created by the training provider. As part of the CLLAIM project,

AM videos and images were made available to partners. This library may be used if permissions are granted. Contact EWF to access these resources.

2.1.9.Examples AM case studies

A number of case studies that can be used to support the learning and thinking process of the candidates shall be made available to the trainer by the training provider. As part of the CLLAIM project, AM case studies were provided to CLLAIM partners. Annex 10.1: Case studies AM examples contains examples of case studies, these examples may be used if permissions are granted.

2.1.10. Final assessments and interviews

It is recommended to complete the process of training or interviews (in the case of Recognition Prior Learning) and then provide a period of time before arranging the final assessment, especially when the candidate is completing several competence units. This recommendation is to provide enough time to candidates to prepare and avoid extra pressure /stress for the final assessment.

3. Checklist of templates and tools to translate:

In the section of Annexes, this pedagogical kit provides templates of documents that can be used as a tool for trainers in the field of AM. If these documents are to be used, they must be translated to the appropriate language.


- ☐ **This procedure ‘D3.3 – Pedagogical kit for trainers in the field of AM’**
- ☐ Annex 1.1: Lesson plan template
- ☐ Annex 2.1: Attendance list template
- ☐ Annex 3.1: Evidence of assessment (theory) template
- ☐ Annex 4.1: Evidence of assessment (practical tasks) template
- ☐ Annex 5.1: Build card template – example
- ☐ Annex 6.1: Work instruction template
- ☐ Annex 7.1: Case study template
- ☐ Annex 8.1: Attendance certificate

4. Summary


The pedagogical kit is constantly evolving and requires updating as the technology evolves and changes. Additional templates and learning material should be contributed by all members for this purpose. Please note in all cases information given such as CAD files, case studies and training questions is for example purposes only and may not reflect the exact operation and processes adopted by all members of the CLLAIM project or equipment manufacturers.

5. Annexes

Annex 1.1: Lesson plan template



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LESSON PLAN

Competence Unit:	Venue	Total contact hours	Start time:	End time:	Date:	Tutor/Trainer/Lecturer/Group:


Day 1					
Time schedule	Objectives	Activity	Resources	Student evaluation	Contact hours
Total contact hours:					

Lesson reflection/improvements:

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LESSON PLAN

Day 2					
Time schedule	Objectives	Activity	Resources	Student evaluation	Contact hours
Total contact hours:					

Lesson reflection/improvements:

Page 2/2

Annex 1.2: Lesson plan example



LESSON PLAN



Competence Unit	CLLAIM Profile	Venue	Total contact hrs	Start time	End time	Date	Tutor/Trainer/Lecturer/Group	Partner
CU08	Metal AM Inspector	Online: Teams	4.5 hrs	09:00	14:30			

Day 1						
Time schedule	Partner / presenter	Objectives	Activity	Resources	Student evaluation	Contact hrs
09:00 – 09:30		Personal introductions, course introduction and objectives, general information about CLLAIM	Introduction	Online access	n/a	½ hr
09:30 – 10:00		DED-LB - Process principles	Power point presentation	Online access	Final assessment	½ hr
10:00 – 10:15	Break					
10:15 – 11:15		DED-LB - System (hardware & software)	Power point presentation	Online access	Final assessment	1 hr
11:15 – 12:15		DED-LB - Parameters	Power point presentation	Online access	Final assessment	1 hr
12:15 – 13:00	Lunch break					
13:00 – 14:00		Build platform, feedstock, consumables & Post-processing	Power point presentation	Online access	Final assessment	1 hr
14:00 – 14:30		Feedback & Final assessment (14 questions)	Complete feedback and Final assessment	Feedback forms & 14 Multiple choice questions	Feedback & Final assessment	½ hr

Contact hrs: 4.5 hrs

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LESSON PLAN



Learning Outcomes – CU08: DED-LB Process

KNOWLEDGE	<p>Factual and broad of:</p> <ul style="list-style-type: none"> DED-LB systems Laser Characteristics Build platform Powder/wire Gases Processable materials with DED-LB
SKILLS	<ul style="list-style-type: none"> Describe the DED-LB systems, including the components and their functions Distinguish different types of feedstock Associate the interaction of the process heat source with the feedstock Recognise the DED-LB parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED-LB build platform, feedstock and other consumables Identify the problems associated with inadequate preparation and set-up of the build platform, handling and storage of feedstock and application of the gases used in DED-LB Recognise the basic principles of 3D CAD systems and machine control software

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Based on feedback received from tutors and candidates, include lesson reflection/improvements:


Page 3/2

Annex 2.1: Attendance list template


Competence Unit:	Start day:	Contact hours:	Training venue:	Instructor's name and signature

#	Candidate's name	Employer	Date day 1	Date day 2	Date day 3	Date day 4	Date day 5
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

Annex 2.2: Attendance list example



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ATTENDANCE LIST - TRAINING



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CIUDAD / City: Curso:

TEMA / Subject: FECHA / Date:

PROFESOR / Teacher:

NOMBRE Y APELLIDOS Name and Family Name	FIRMA Signature
B	
C	
C	ÁNZAZU
CI	
CI	
CC	
FE	OS
HI	
HI	
HI	
M	
RC	E

Annex 3.1: Evidence of assessment (theory) template



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EVIDENCE OF ASSESSMENT

Candidate's answer sheet

Profile:	Competence Unit:	Start day:	Training venue:

Question	Candidate's answer	Question	Candidate's answer	Question	Candidate's answer	Question	Candidate's answer
1.		11.		21.		31.	
2.		12.		22.		32.	
3.		13.		23.		33.	
4.		14.		24.		34.	
5.		15.		25.		35.	
6.		16.		26.		36.	
7.		17.		27.		37.	
8.		18.		28.		38.	
9.		19.		29.		39.	
10.		20.		30.		40.	

Type of assessment	Score

Tutor comments

Candidate's name:	
Signature:	
Date:	

Instructor's name:	
Signature:	
Date:	



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Annex 4.1: Evidence of assessment (practical tasks) template



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EVIDENCE OF PRACTICAL TASKS

Candidate's record for practical exercises

Profile:	Competence Unit:	Start day:	Training venue:

Date:	Description of practical task completed during training

Candidate's name:	
Signature:	
Date:	

Instructor's name:	
Signature:	
Date:	



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Annex 5.1: Build card template – example

[This build card template is in accordance with the ASTM Standard for additive manufacturing – Process characteristics and performance: Practice for metal powder bed fusion process to meet critical applications. It is recommended to revise the latest version and update as required.]

Job start date:		Customer information	
Job completion date:		Purchase order No.:	
Total PBF Hours:		Contact:	
P.O. Delivery date:			

		Initials
Plan reviewed by:		
Sales:		
Operations:		
Quality		

Part Number	Rev	Manufacturing LOT quantity	Build job quantity

		Initials
Build file name:		
Machine serial number		
Laser(s) serial number		
Feedstock alloy		
Machine parameters		
Build platform serial number		
Feedstock state (virgin, used or mix)		
Heat treatment	<input type="checkbox"/> SR <input type="checkbox"/> ANN <input type="checkbox"/> HIP <input type="checkbox"/> STA <input type="checkbox"/> OTHER:	
Recoater material type		
Pre-build laser power		
Post-build laser power		
Feedstock lot number		
Virgin to used ratio %		
Build log file name		

Sec #	Product realisation operations	Date	Accept qty.	Reject qty.	Initials
100	JOB CHECK				
101	Receive the job file from engineering				
102	Confirm file revision is correct and matches the PO				
103	Check build orientation matches the engineering				
104	Confirm part markings and location are in accordance with engineering				
105	Setup build cycle and check machine certification is valid				
106	Record part quantity for the build cycle				
107	Confirm build set-up screen shot matches work order				
108	Confirm machine set-up performed according to work instructions				
109	Confirm powder lot number matches work order				
110	Record virgin to used powder ration above				
111	Verify correct process gas supply is sufficient for build time				
200	START BUILD				
201	Record build start time above				
202	Record the job in the daily machine build log				
203	Ensure that build chamber oxygen level is continuously monitored				
300	END BUILD				
301	Record the build end time above				
302	Record total build hours above				
303	Review build log file and reject all parts for unintended build interruptions				
304	Remove powder from the part cake using work instructions				
305	Move the build platform to the next operation				
306	Measure laser power using work instructions				
307	Record the build log file name above				
308	Review process monitoring for build anomalies and accept parts using work instructions.				
400	PROCESS BUILD PLATFORM				
401	Leave parts on build platform if applicable				
402	Brush any loose powder from the parts. Powder in contact with polymer brushes shall be scrapped.				
403	Visually inspect for foreign material or build anomalies				
404	Perform dimensional inspection on reference part				
500	THERMAL POST PROCESSING				
501	Perform thermal post processing per work order				
502	Perform dimensional inspection on reference part				
503	Perform NDE if required				
600	SECONDARY OPERATIONS				
601	Remove parts from build platform if required				
602	Process test specimens as required				
603	Remove support structure as required				
604	Machine parts as required per work order				
700	NDE				
701	Perform NDE as required on work order				
800	DATA REPORTING				
801	Compile data package including feedstock certificate of conformance, feedstock testing, test specimen results (chemical composition and mechanical properties), build set-up, build log, reference part inspection report, dimensional inspection, and NDE inspection report.				

FINAL ACCEPTANCE					
#	Part number / Identification	REV	Total qty accepted	Total qty. non-conforming	Initials
1					


Notes:

Feedstock supplied by the customer shall be reported in the notes

Inspection Notes: (Describe any non-conformance)

Final sign off:	
Name:	
Date:	

Annex 6.1: Work instruction template



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WORK INSTRUCTION

Applicable to machine type(s):			

Reference:	Work instruction:	Revision:	Date of revision:

Scope:

Instructions to follow step by step:
<ol style="list-style-type: none"> 1. .. 2. .. 3. .. 4. .. 5. .. 6.


Prepared by:	
Signature:	
Date:	

Reviewed by:	
Signature:	
Date:	

Authorised by:	
Signature:	
Date:	

First issued date:

Annex 7.1: Case study template



Creating knowLedge and skills in Additive Manufacturing
 Reference number: 2017-3309/591838-EPP-1-2017-1-ES-EPPKA2-SSA

CASE STUDY

Case study title:	
Background:	
Case study image:	<div style="border: 1px solid black; width: 100%; height: 100%; display: flex; align-items: center; justify-content: center;"> Insert image(s) here </div>
Technical challenge:	<ul style="list-style-type: none">
Detailed solution/process:	<ul style="list-style-type: none">
Candidate's name:	
Signature:	
Date:	
Tutor's name:	
Signature:	
Date:	

Annex 8.1: Attendance certificate





CLLAM



CERTIFICATE OF COMPLETION

ADDITIVE MANUFACTURING INSPECTOR QUALIFICATION PILOT

THIS CERTIFICATE IS PROUDLY PRESENTED TO

COMPETENCE UNIT(S):
HOURS:
DATE:



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This Certificate is awarded in recognition of the applicant support in CLLAM Project Pilot Activities for Competence Units



Annex 8.2: Attendance certificate example



CERTIFICATE OF COMPLETION
ADDITIVE MANUFACTURING INSPECTOR
QUALIFICATION PILOT

CLLAIM

THIS CERTIFICATE IS PROUDLY PRESENTED TO

COMPETENCE UNIT(S):
 CU00: Additive Manufacturing Processes Overview
 CU01: DED-Arc Process
 CU08: DED-LB Process
 CU15: PBF-LB Process
 CU22: PBF-EB Process
 CU63: Quality Assurance for Inspection
 CU64: Inspection-Examination and Testing

DATE:

This certificate is awarded in recognition of the applicant support
 in CLLAIM Project Pilot Activities for Competence Units

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Annex 9.1: Training questions library



Creating knowLedge and skillS in AddItive Manufacturing
Reference number: 2017-3309/591838-EPP-1-2017-1-ES-EPPKA2-SSA

TRAINING QUESTIONS

Examples for training questions for operator profile

- Name the decade in which additive manufacturing processes were invented.
- List applications for which the use of the PBF-LB process is useful.
- Explain the processes that are suitable for the additive manufacturing with metals.
- List metallic materials for industrial, additive manufacturing.
- List materials that can be processed by material extrusion.

Example for training questions for Supervisor

- Name five important sections of a safety data sheet of a powder material.
- Compare the PBF-LB and PBL-EB processes with regard to the achievable component resolution and the powder materials used.
- When manufacturing customised products in large quantities, one often speaks of "mass customisation". Give reasons why additive manufacturing processes are particularly suitable for mass customisation in medical technology from an economic point of view.
- Create a risk assessment for powder handling for PBF-LB processes.
- Name a suitable heat treatment process for post-processing of DED-LB components and justify your choice.



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Example for multiple choice training questions for Inspector

Which method is NOT a typical volumetric inspection method?	Correct Answer
a) Radiography	
b) Computed tomography	
c) Ultrasonic	
d) Liquid penetrant	D

When is it absolutely necessary to remove powder from the AM part?	Correct Answer
a) Powder must be removed before any heat treatment	A
b) Powder must be removed to perform NDT	
c) Powder must be removed to improve mechanical properties of the AM part	
d) Removal of powder must not be performed as this can damage the surface of the AM part	

Impact testing requires that:	Correct Answer
a) Test piece shall have the dog-bone shape	
b) Test piece must be built at the maximum height of the final component	
c) Test piece must be built within the same build layers as the final component	C
d) A heat treatment is applied prior testing	

What is the first action as part of inspection survey following removal of the build assembly from the AM equipment?	Correct Answer
a) Visual inspection	A
b) Tensile testing	
c) Heat treatment	
d) NDE inspection	

Which of the following is NOT true about incomplete fusion in AM?	Correct Answer
a) Incomplete fusion can be completely eliminated through the optimisation of build parameters	
b) Incomplete fusion typically occurs when new material is used and the build parameters have not been optimized	
c) Incomplete fusion always occurs between the base metal surfaces and deposited material	
d) Sites where incomplete fusion occur are typically spherical in shape and contain gas	D



Example for multiple choice training questions for Designer

Which of the following statements is TRUE? a) Thermal processing is typically performed once all geometry has been removed from the build platform to allow deflections to occur prior to stress relieve b) Thermal processing is typically performed before all geometry has been removed from the build platform to relieve residual stresses from the build c) Thermal processing is mainly used to minimise distortion from thermal stresses, but cannot be used to adjust the microstructure of the part Post-processing of the test specimens may differ from the post-processing of the component	Correct Answer B
At the time of designing a piece with supports, it is necessary to consider a) The support could be a part of the piece b) The support must be removed after the manufacturing c) The support must be lighter than the piece d) None of them	Correct Answer B
How would you design a piece with vertical walls in order to have a better positioning at the machine? a) A piece can be designed with vertical walls without any special consideration b) Vertical walls of the piece must be designed in the way that, at the manufacturing, they won't be placed at the parallel direction to the recourse c) It is not possible, due it is not possible to manufacture a piece with vertical walls by using this kind of technology e) None of them	Correct Answer B
Tell how would you avoid printing a final part if you're not sure about the proper performance of the part in service a) By creating the mesh b) By applying faceting c) By using post processing techniques d) By using FEA analysis	Correct Answer D
The thermal emissivity defines: a) The radiation properties of the material b) The convection heat transfer properties between material and fluid c) The conduction properties of the material d) The heat loss due to materials in contact	Correct Answer A




Annex 10.1: Case studies AM examples

- Background (Corrosion/wear prevention)
 - Replacement of unpredictable coatings processes (Nitriding / HVOF)
 - Need to operate at ever higher temperatures.
- Technical Challenge
 - Tribaloy T800 (cobalt alloy) . Low ductility but high hardness (~750 Hv).
 - Controlled thermal management for crack prevention (pre-heating and cooling)
 - Stem is a martensitic stainless steel which begins to scale above 550°C.

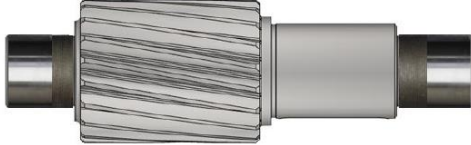
Based upon the information given create a detailed process for deposition and inspection of the above on the surfaces highlighted

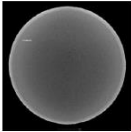
1. Case Study : Gear Stems

Failed HVOF Coating



DED Laser (Showing machine section)



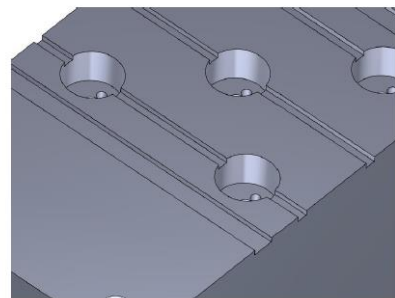
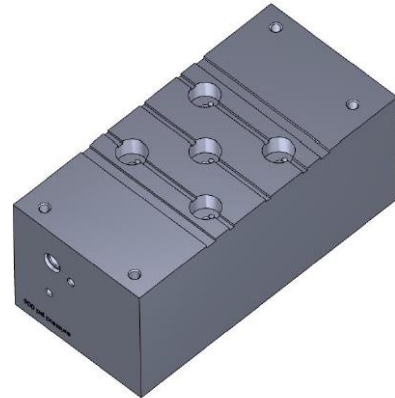
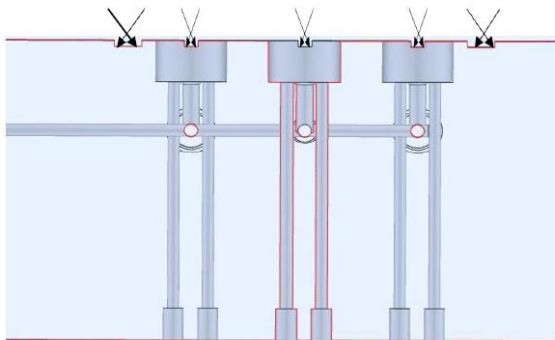


CT scanning for integrity inspection

2. Case Study: Manifold Die Repair

- Background
 - Tool Die edge/ recess repair
 - Common problem of in-service chipping and wear
- Technical Challenge
 - Remove and rebuild the worn edge of the parts contact face
 - Deposition material is a tooling steel

Create a step by step process including machining and inspection for the following repair.



3. Case Study: WC Utility Knife Edge

- Background
 - Improve wear resistance of box cutter knife blades for cutting dry lining boards.
- Technical Challenge
 - Develop procedures to deposit a WC (86%-volume) in a CoCr metal matrix onto knife edge blanks
 - Knife edge sharpened post DED laser processing
 - Homogeneity of WC distribution

Based upon the information given create a detailed process for deposition and inspection of the above on the surfaces highlighted

