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Creating knowLedge and skills in Additive Manufacturing



Metal AM Supervisor

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3.1 European AM Designer, Specialist, Operator and European AM Inspector's Occupational Standards

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3.2 LOs' Guideline for the AM Qualifications



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1. Preface

The present document consists in European Guideline for Metal AM Supervisor, developed in the framework of the European project “Creating KnowLedge and SkillS in Addltive Manufacturing / CLLAIM”.

This guideline, for the European education, training, examination and qualification of additive manufacturing personnel, has been developed and approved by all partners involved in the project: EWF, CESOL, DVS, FhG, LZH, Lloyd’s Register, IDONIAL, TWI. Contains general information for the public and organisations that implement this qualification.

This guideline was developed with a close relation to industry and standardization bodies. The guideline was validated in workshops directed to industry and education centres. Moreover, the guideline was validated by experts from EWF’s International Additive Manufacturing Qualification Council and was built with close relation to ISO and ASTM.

Furthermore, this guideline englobes Occupational Standards and Learning Outcomes for the qualifications identified by the Industry as more relevant: Operator, Designer, Supervisor and Inspector.

Copies of this document can be downloaded from CLLAIM website: cllaimprojectam.eu or requested from European Union dissemination platform.

2. Routes to Qualification

Three distinct routes to gaining the qualifications described in this document have been agreed to all AM profiles developed under project CLLAIM scope.

1. The Standard Route
2. Blended Learning Route
3. Alternative Route

2.1 The Standard Route

The Standard Route requires successful completion of AM approved courses which are designed to meet all the requirements in this Guideline. This is the route recommended, as offering the fastest, most comprehensive manner in which the detailed knowledge may be covered.

2.2 Blended Learning Route

The Cross-Cutting Competence Units (theoretical knowledge and skills) may be taught using Distance Learning Programs under the control of European harmonized system and all the Functional Competence Units (practical knowledge and skills) must be taught at the facilities of a Training Centre that has the capacity to do so.

2.3 Alternative Route

The alternative route allows those who have gained 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 addressed by it. The alternative route encompasses two possibilities for the validation of knowledge and skills, through: the direct recognition of the Competence Unit.

3. Guideline for Metal AM Supervisor

3.1 Introduction to Metal AM Supervisor

This guideline covers the minimum requirements for education and training, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them.

Students successfully completing examinations will be expected to be capable of applying the achieved learning outcomes at a level consistent with the qualification diploma level. The modular course contents are given in the following structure (overview):

COMPETENCE UNITS	E S	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 01: DED-Arc Process	14	28
CU 08: DED-LB Process	14	28
CU 15: PBF-LB Process	14	28
CU 46: Quality Assurance for Metal AM Processes	14	28
CU 47: HSE for Metal AM Processes	14	28
CU 48: Powder Handling	14	28
Total	91	182

* Contact Hours are the minimum recommended teaching hours for the Standard Routes. A contact hour shall contain at least 50 minutes of direct teaching time.

** Workload is calculated in hours, corresponds to an estimation of the time students typically need to complete all learning activities required to achieve the defined learning outcomes in formal learning environments plus the necessary time for individual study.

Within CLLAIM's projects qualifications, there are two types of Competence Units:

Cross-cutting Competence Unit - A competence unit whose learning outcomes are not directly linked with one job function since the knowledge and skills achieved will be mobilized in several job functions and activities.

Functional Competence Unit - A competence unit whose learning outcomes are directly linked with at least one job function and in which the knowledge and skills achieved will be mobilized in specific job functions and related activities.

The expected learning outcomes are described in two ways: generic outcome descriptors organized in knowledge, skills, autonomy and responsibility; and in detail for each competence unit, organized in job functions and related activities, knowledge and skills corresponding to a specific proficiency level within EWF's Systems Framework levels (see Appendix I).

On each Competence Unit, objectives and scope are defined for a specific depth of knowledge and skills.

Recommended contact hours are distributed between theoretical (A), assigned projects/exercises (B), practical work-shop training(C), as showed in the following example:

Qualification: Example 1	
RECOMMENDED CONTACT HOURS	X = SUM (A:C)
Subject Contents	A + B + C

3.2 Occupational Standard

Metal AM Supervisors are the professionals with the specific knowledge, skills, autonomy and responsibility to Supervise AM production on shop floor, being its main tasks to:

- Ensure quality Procedures
- Ensure Health & Safety Environment procedures

3.3 General Access Conditions

The defined access conditions are given in detail for all training institutions participating in the European AM Qualification System.

The access conditions to Metal AM Designer for PBF Processes admission are the following:

- National compulsory school Diploma
- Basic knowledge and skills related with Quality Assurance and HSE
- At least 1 year of experience in Quality and Safety supervision is recommended.

3.4 Qualification Outcome Descriptors

QUALIFICATION	EFW LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
E MAM S	INDEPENDENT	Factual and broad concepts in the field of Metal additive manufacturing processes.	Fundamental cognitive and practical skills on simple and specific of Metal additive manufacturing problems required to: <ul style="list-style-type: none"> • develop proper solutions • application of procedures and tools 	Self-manage of professional activities and simple standard applications of Metal AM manufacturing in predictable contexts but subject to change. Take responsibility for supervising routine metal AM production and related personnel.

3.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Supervisor is listed below.

3.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Directed energy deposition	1
Powder bed fusion	1
Vat photopolymerization	1
Material jetting	1
Binder jetting	1
Material extrusion	1
Sheet lamination	1
Total	7
WORKLOAD	14

Learning Outcomes – CU00: Additive Manufacturing Processes Overview	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: <ul style="list-style-type: none"> ☐ Directed energy deposition ☐ Powder bed fusion ☐ Vat photopolymerization ☐ Material jetting ☐ Binder jetting ☐ Material extrusion ☐ Sheet lamination
SKILLS	Distinguish parts produced by different AM processes Recognise the advantages and limitations of AM processes from a manufacturing process chain point of view Identify the applicability of different AM processes, according to the characteristics of each process

3.5.2 Competence Unit 01: DED-Arc Process

CU01: DED-Arc Process	CONTACT HOURS
SUBJECT TITLE	
DED-Arc System (Hardware & Software)	5
DED-Arc Physical Principles, Processes and Parameters	5
DED-Arc Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

Learning Outcomes – CU01: DED-Arc Process	
KNOWLEDGE	Factual and broad of: <ul style="list-style-type: none"> – DED-Arc systems – Arc physics – Processable materials with DED-Arc – Processing atmosphere requirements with DED-Arc – Sensors and process controls with DED-Arc
SKILLS	Describe the DED–Arc 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–Arc parameters and the influence of their adjustment on the as built part (e.g. deformation) Recognise the characteristics of the DED–Arc 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–Arc

3.5.3 Competence Unit 08: DED-LB Process

CU 08: DED-LB Process	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
DED-LB System (Hardware & Software)	5
DED-LB Physical Principles	2
DED-LB Parameters	3
Build platform, feedstock and other consumables	3
Post processing operations	1
Total	14
WORKLOAD	28

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	<p>Describe the DED-LB systems, including the components and their functions</p> <p>Distinguish different types of feedstock</p> <p>Associate the interaction of the process heat source with the feedstock</p> <p>Recognise the DED-LB parameters and the influence of their adjustment on the as built part (e.g. deformation)</p> <p>Recognise the characteristics of the DED-LB build platform, feedstock and other consumables</p> <p>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</p> <p>Recognise the basic principles of 3D CAD systems and machine control software</p>

3.5.4 Competence Unit 15: PBF-LB Process

CU 15: PBF-LB Process	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
PBF-LB Process Principles	2
PBF-LB System – Hardware and Software	4
PBF-LB Parameters	3
PBF-LB Feedstock	2
PBF-LB Consumables	2
Post Processing	1
Total	14
WORKLOAD	28

Learning Outcomes – CU15: PBF-LB Process	
KNOWLEDGE	<p>Factual and broad knowledge of:</p> <ul style="list-style-type: none"> – PBF-LB systems – Laser characteristics – Build platform – Powder – Gases – Processable materials with PBF-LB
SKILLS	<p>Describe the PBF-LB systems, including the components and their functions</p> <p>Recognise the characteristics of the PBF-LB build platform, feedstock and other consumables</p> <p>Recognise the PBF-LB parameters and the influence of their adjustment on the as built part</p> <p>Recognise the interaction of the process heat source with the feedstock</p> <p>Identify the problems associated with inadequate preparation and setup of the build platform, handling and storage of feedstock and application of the gases used in PBF-LB</p>

3.5.5 Competence Unit 46: Quality Assurance for Metal AM Processes

CU 46: Quality Assurance for Metal AM Processes	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
Quality Assurance and Quality Control	5.5
QA for different energy Source Machine	3.5
Wire vs Powder Parts QA	3.5
Communication workflows	1.5
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTION	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Quality Assurance for Metal AM Processes)	4	Supervise Quality Assurance on Shop Floor	Ensuring the implementation of QA/QC procedures and instructions (e.g. feedstock storage and handling);	14	28
			Monitoring the compliance of the AM production process and the AM parts with the relevant documents (e.g. standards, product specifications, legislation);		
			Monitoring/ Implementing corrective actions for eliminating defects;		
			Providing guidance to AM operators in the day-to-day activities;		
			Assigning tasks to Operators based on job requirements.		

Learning Outcomes – CU 46 - Quality Assurance for Metal AM Processes	
KNOWLEDGE	<p>Factual and broad knowledge of theory and applicability of:</p> <ul style="list-style-type: none"> - Quality Assurance (QA) principles - Metal AM Systems QA - Quality Control in manufacturing chain
SKILLS	<p>Prepare daily work and tasks distribution based on production plans ensuring manufacturing on shop floor.</p> <p>Compare DED-Arc, DED-LB and PBF-LB processes QA/QC procedures identifying each process' QA/QC specific requirements.</p> <p>Name the most common standards used for Metal AM production, Metal AM operator's qualification, Metal AM procedures approval and Metal AM systems qualification.</p> <p>Provide technical inputs to improve QA/QC procedures and instructions related with the handling and storage of feedstock, AM systems and part production.</p> <p>Verify if parts' production (e.g. feedstock storage, in process monitoring) on the shop floor complies with Quality Control procedures and APS.</p>

3.5.6 Competence Unit 47: HSE for Metal AM Processes

CU 47: HSE for Metal AM Processes	RECOMMENDED
SUBJECT TITLE	CONTACT HOURS
HSE in facilities	5
HSE for different energy sources	4.5
HSE for different types of feedstock	4.5
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTION	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
HSE for Metal AM Processes	4	Supervise HSE on Shop Floor	Ensuring compliance with HSE requirements and instructions featuring Metal AM processes and systems;	14	28
			Providing support to management and operational teams in all aspects of safety, health, and environmental issues;		
			Monitoring/ Implementing corrective actions to avoid Hazard risks.		

Learning Outcomes – CU 47 HSE for Metal AM Processes	
KNOWLEDGE	Factual and broad knowledge of theory and applicability of: <ul style="list-style-type: none"> ☐ HSE requirements and instructions featuring Metal AM processes manufacturing ☐ Infrastructures/Facility Requirements featuring Metal AM processes manufacturing

Learning Outcomes – CU 47 HSE for Metal AM Processes

SKILLS	<p>Identify HSE training requirements for personnel operating at shop floor</p> <p>Describe the HSE hazards occurring on shop floor naming the different specifications applicable to the main metal AM systems</p> <p>Describe HSE procedures for handling and storage of metal AM feedstock naming the differences between wire and powder materials</p> <p>Describe metal AM HSE applicable legislation and standards ensuring personnel follows all the applicable HSE regulations at shop floor</p> <p>Verify if safety metal AM work procedures are properly followed monitoring personnel operations at shop floor</p> <p>Interpret Risk Assessment plans applying appropriate prevention and protection measures for reducing incidents at shop floor</p> <p>Produce incident/accident reports describing all the relevant factors related with the event.</p>
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3.5.7 Competence Unit 48: Powder Handling

CU 48: Powder Handling	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Overview of Powder Manufacturing Processes	3
Chemical Composition and Physical Properties	4
Particle Size Distribution	2
Powder storage, handling, ageing and documentation	3
Powder reusability	1
HSE procedures	1
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Power Handling	4 Independent	Manage powders for Metal AM	Implementing procedures for powder delivery and storage	14	28
			Preparing and analysing powder according to technical documentation		
			Performing powder reconditioning (e.g. sieving) after build cycle		
			Following HSE procedures		

Learning Outcomes – CU 48: Powder Handling	
KNOWLEDGE	<p>Factual and broad of:</p> <ul style="list-style-type: none"> – Powder handling, storage and reconditioning

Learning Outcomes – CU 48: Powder Handling	
SKILLS	<ul style="list-style-type: none"> Complete technical documentation related to powders for metal AM Characterise powders according to instructions from the engineer Ensure powder conditioning according to the AM Procedure Specification Control the reusability of powders Handle powders according to HSE procedures