EWF Guideline for European/International Process Engineer Directed Energy Deposition – Laser Beam

PERSONNEL WITH QUALIFICATION FOR METAL ADDITIVE MANUFACTURING

Minimum Requirements for the Qualification and Examination

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MINIMUM REQUIREMENTS FOR
QUALIFICATION AND EXAMINATION

European/International Process Engineer Directed Energy Deposition – Laser Beam (E/I DED-LB PE)

Guideline - General information for the public and organizations that implement this qualification

For more information regarding the Qualifications System, the EWF Management Team or the AM ANB should be contacted
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Table of Contents

Preface

The present document consists in European/International DED-LB Process Engineer Guideline, developed by EWF.

This guideline for the European education, training, examination and qualification of additive manufacturing personnel has been prepared, evaluated and formulated by the EWF International Additive Manufacturing Qualification Council (IAMQC). Contains general information for the public and organizations that implement this qualification.

Copies of this document can be downloded from EWF website: www.ewf.be or requested to Authorized Nominated Bodies for Metal Additive Manufacturing (AM ANBs) or EWF Management Team.

MINIMUM REQUIREMENTS FOR THE EDUCATION, TRAINING, EXAMINATION AND QUALIFICATION OF PERSONNEL

Introduction

This guideline covers the minimum requirements for education and training, which have been agreed upon by all EWF AM ANBs, in terms of Learning Outcomes (Knowledge and Skills) and the recommended contact (teaching) hours to be devoted to achieving them. It will be revised periodically by EWF IAMQC to take into account changes to reflect the "state of the art".

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/IE PBF-LB	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 01: DED-Arc Process	42	84
CU 08: DED-LB Process	35	70
CU 15: PBF-LB Process	35	70
CU 25: Post Processing	14	28
CU 34: Process selection	28	56
CU 35: Metal AM integration	21	42
CU 36: Coordination activities	7	14
CU 40: Production of DED-LB parts	21	42
CU 41: Conformity of DED-LB parts	35	70
CU 42: Conformity of facilities featuring DED-LB	14	28
TOTAL	**259**	**518**
Optional CUs		
CU 26: Introduction to materials	14	28
TOTAL	**273**	**546**
Materials CUs* **		
CU 27: AM with steels feedstock (excluding Stainless Steel)	21	42
CU 28: AM with Stainless Steel feedstock	14	28
CU 29: AM with Aluminium feedstock	7	14
CU 30: AM with Nickel feedstock	7	14
CU 31: AM with Titanium feedstock	14	28
CU 32: AM with Tungsten feedstock	3,5	7
CU 33: Biomedical metallic materials	7	14

* 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.

***A minimum of 2 CUs shall be selected from the list **Materials CUs** in order to successfully complete the qualification

Within EWF´s 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 workshop training(C), as showed in the following example:

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

Professional Profile

DED-LB Process Engineers are the professionals with the specific knowledge, skills, autonomy and responsibility to implement DED-LB process in the manufacturing chain assuring the efficient production and post-processing of additively manufactured parts. His/her's main tasks are to:

- Evaluate manufacturing suitability for customers' requests defining which processes are fit for the request, based on the application, material, design and cost of the part.
- Apply a wide variety of engineering techniques, contributing to projects in a teaming environment and compare, investigate, transfer, and adapt procedures, techniques, or methods to new applications.
- Develop and execute DED-LB plans including validation of design, implementation, pre and post processing operations, assurance of parts conformity and identification of the causes and the corrective actions of technical production problems;
- Coordinate the tasks distribution between the operators according to the workplan as well as manage the link between them and the management..

1 Routes to Qualification

Two distinct routes to gaining the qualifications described in this document have been agreed.

1. The Standard Route
2. Blended Learning Route

1.1 The Standard Route

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

1.2 Blended Learning Route

The Cross-Cutting Competence Units (theoretical knowledge and skills) may be taught using Distance Learning Programs under the control of the AM ANB and all the Functional Competence Units (practical knowledge and skills) must be taught at the Authorized Training Bodies for Metal Additive Manufacturing (AM ATB) facilities.

2 General Access Conditions

The defined access conditions approved by EWF Technical Working Groups Area of competence “Implementation and Authorisation” of the EWF are given in detail for all countries participating in the EWF system.
The access conditions to European/International Engineer DED-LB Qualification admission are the following:

– Engineering degree in Mechanical, Materials, Aeronautic, Materials or similar.

3 Special Requirements

3.1 Standard Route

Applicants shall satisfy the access conditions, to be accepted for the attendance of a training course conducted by an AM ATB.

There will be written, oral and practical examinations (where applicable) for the award of the applicable EWF Diploma.

It is not obligatory to follow exactly the order of the Competence Units given in this guideline and choice in the arrangement of the detailed knowledge is permitted, with the exception that **the first Competence Unit to be provided must be CU 00: Additive manufacturing Process Overview.**

In the case of attendance and evaluation of the optional competence unit, **CU26: Introduction to Materials**, this shall be done before lecturing any of the CUs numbered from 27 to 33.

The rules for the conduct of the examinations by the AM ANB are prescribed under Examination and Qualification in each Competence Unit guideline.

Complementary to the Competence Units that are required for the purpose of the European/International DED-LB Process Engineer Diploma issuing, a set of optional Competence Units that can also be of added value for the student and can be implemented by the AM ATB as a supporting training and education offer.

For these optional Competence Units, separate Records of Achievement will be issued after examination approval. Whenever these optional Competence Units are considered mandatory for a certain EWF Qualification, they can be recognized for the purpose of such Qualification Diploma.

The examination of any Competence Unit for the purpose of being validated individually, not included in a Qualification course, shall be completed within a period of 1 year from the starting day of the Competence Unit.

If the Competence Unit “A” is done as a part of a qualification course, the examination shall be completed within a period of 4 years from the date of the completion of the first Competence Unit from the qualification where Competence Unit “A” is integrated in. Failure in the examination shall require re-examination.

Each Competence Unit has a period of validity of 4 years. When applying for a Qualification course, the period of validity of the completed CUs are at discretion of the AM ANB.

3.1.1 Section I: Theoretical and Practical Education – Qualification Descriptors and Learning Outcomes

I.1. Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
E/I DED-LB PE	**ADVANCED**	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing processes.	Advanced problem-solving skills including critical evaluation, allowing to choose the proper technical and economical solutions, when applying metal additive manufacturing processes, in complex and unpredictable conditions	Manage the applications of metal additive manufacturing processes in a highly complex context. Act autonomously in decision making and definition in the definition of the metal additive manufacturing personnel's tasks.

I.2. Mandatory Competence Units Learning Outcomes

Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	CONTACT HOURS
SUBJECT TITLE	
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 – CU 00; Additive Manufacturing Processes Overview Error! Reference source not found.	
KNOWLEDGE	Factual and broad knowledge of theory, principles and applicability of: – 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

Competence Unit 01: DED-Arc Process

CU 01 DED-Arc Process	RECOMENDED CONTACT HOURS	
LEVEL	INDEPENDENT (I) (applied to Operators and Engineers)	ADVANCED (A) (applied only to Enginners)
DED-Arc System (Hardware & Software)	5	0
DED-Arc Physical Principles, Processes and Parameters	5	0
DED-Arc Build platform, feedstock and other consumables	3	0
Post processing operations	1	0
DED-Arc Processes	0	14
DED-Arc Build platform, feedstock and other consumables	0	5
DED-Arc Equipment and accessories	0	3
DED-Arc Manufacturing strategy	0	6
Subtotal Per Level	**14**	**28**
Cumulated Subtotal	**14**	**42**
		WORKLOAD
PER LEVEL	28	56
CUMULATED	**28**	**84**

LEARNING OUTCOMES – CU 01: DED-Arc Process		
LEVEL	**INDEPENDENT (applied to Operators and Engineers)**	**ADVANCED (applied only to Enginners)**
KNOWLEDGE	Factual and broad of: – DED-Arc systems – Arc physics – Processable materials with DED-Arc – Processing atmosphere requirements with DED-Arc – Sensors and process controls with DED-Arc	Advanced knowledge and critical understanding of the theory, principles and applicability of: — DED-Arc equipment, accessories, including build platform, feedstock and other consumables — DED-Arc process parameters and variables, including post processing operations
SKILLS	Assess the possibility of manufacturing a specific part with DED-Arc based on the characteristics and limitations of the process Relate the influence of the process parameters, build platform, feedstock and other consumables with the properties of the as built part. Implement different methodologies related with to process parameters and deposition strategies for reducing distortion of as built parts Distinguish the different regimes and processes of failure and describe the factors controlling them and the boundaries and limits between them. Select specific materials for different applications to meet part requirements. Identify specific metallurgical aspects of DED-Arc parts Define DED-Arc parameters for manufacturing specific parts Adjust process parameters, manufacturing strategy and set up to prevent part defects and process related issues	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

Competence Unit 08: DED-LB Process

CU 08: DED-LB Process	RECOMENDED CONTACT HOURS	
LEVEL	INDEPENDENT (I) (applied to Operators and Engineers)	ADVANCED (A) (applied only to Enginners)
DED-LB System (Hardware & Software)	5	0
DED-LB Physical Principles	2	0
DED-LB Parameters	3	0
Build platform, feedstock and other consumables	3	0
Post processing operations	1	0
DED-LB Processes	0	7
DED-LB Build platform, feedstock and other consumables	0	5
DED-LB Equipment and accessories	0	2
DED-LB Manufacturing strategy	0	7
Subtotal Per Level	**14**	**21**
Cumulated Subtotal	**14**	**35**
		WORKLOAD
PER LEVEL	28	42
CUMULATED	**28**	**70**

LEARNING OUTCOMES – CU 08: DED-LB Process		
LEVEL	**INDEPENDENT (applied to Operators and Engineers)**	**ADVANCED (applied only to Enginners)**
KNOWLEDGE	Factual and broad of: – DED-LB systems – Laser Characteristics – Build platform – Powder/wire – Gases – Processable materials with DED-LB	Advanced knowledge and critical understanding of the theory, principles and applicability of: – DED-LB equipment, accessories, including build platform, feedstock and other consumables – DED-LB process parameters and variables, including post processing operation
SKILLS	Describe the DED-LB systems, including the com-ponents 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 prepa-ration 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	Explain how the DED-LB process works Explain the influence of modifying process parameters on the as built part Discuss the influence of build platform, feedstock and other consumables characteristics on part manufacturing Identify areas that will need thermal compensation Identify the cause of defects and propose methods for their mitigation Discuss the adequacy of selected equipment and accessories on the part manufacturing Distinguish the different regimes and processes of failure and describe the factors controlling them and the boundaries and limits between them Select specific materials for different applications to meet part requirements Identify specific metallurgical aspects of DED-LB parts Identify the variables used to define the DED-LB manufacturing strategy

Competence Unit 15: PBF-LB Process

CU 15: PBF-LB Process	RECOMENDED CONTACT HOURS	
LEVEL	INDEPENDENT (I) (applied to Operators and Engineers)	ADVANCED (A) (applied only to Enginners)
PBF-LB Process Principles	2	0
PBF-LB System – Hardware and Software	4	0
PBF-LB Parameters	3	0
PBF-LB Feedstock	2	0
PBF-LB Consumables	2	0
Post Processing	1	0
PBF-LB Processes	0	7
PBF-LB Build substrate, feedstock and other consumables	0	5
PBF-LB Equipment and accessories	0	2
PBF-LB Manufacturing strategy	0	7
Subtotal Per Level	**14**	**21**
Cumulated Subtotal	**14**	**35**
		WORKLOAD
PER LEVEL	28	42
CUMULATED	**28**	**70**

LEARNING OUTCOMES – CU 15: PBF-LB Process		
LEVEL	INDEPENDENT (applied to Operators and Engineers)	ADVANCED (applied only to Enginners)
KNOWLEDGE	Factual and broad knowledge of: – PBF-LB systems – Laser characteristics – Build platform – Powder – Gases – Processable materials with PBF-LB	Advanced knowledge and critical understanding of the theory, principles and applicability of: – PBF-LB equipment, accessories, including build platform, feedstock and other consumables – PBF-LB process parameters and variables, including post processing operation
SKILLS	Describe the PBF-LB systems, including the components and their functions Recognise the characteristics of the PBF-LB build platform, feedstock and other consumables Recognise the PBF-LB parameters and the influence of their adjustment on the as built part Recognise the interaction of the process heat source with the feedstock 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	Explain how the PBF-LB process works Explain the influence of modifying process parameters on the as built part Discuss the influence of build platform, feedstock and other consumables characteristics on part manufacturing Identify areas that will need thermal compensation Identify the cause of defects and propose methods for their mitigation Discuss the adequacy of selected equipment and accessories on the part manufacturing Distinguish the different regimes and processes of failure and describe the factors controlling them and the boundaries and limits between them Select specific materials for different applications to meet part requirements Identify specific metallurgical aspects of PBF-LB parts Identify the variables used to define the PBF-LB manufacturing strategy

Competence Unit 25: Post Processing

CU 25: Post Processing SUBJECT TITLE	CONTACT HOURS
General considerations	2
Thermal treatment	4
Plastic deformation methods	2
Subtractive manufacturing	2
Finishing operations	2
Practical application	2
Total	14
WORKLOAD	**28**

Learning Outcomes – CU 25: Post Processing	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Post processing methods (heat treatment, cold work methods, subtractive manufacturing, finishing operations)
SKILLS	Discuss methods to reduce distortion, using different post processes, for a variety of part geometries and AM processes. Explain the applicable post processing methods to several AM processes as built parts Describe the effect of different heat treatments on microstructure, mechanical properties, residual stress and defects Explain the requirements that the as built part needs to have/comply according to each post process

Competence Unit 26: Introduction to materials

CU 26: Introduction to materials	CONTACT HOURS
SUBJECT TITLE	
Structure and properties of metals and alloys	3
Solidification and Phase Diagrams	3
Solid state transformations and TTT diagrams	4
Failure mechanisms: fracture, fatigue, creep	4
Total	14
WORKLOAD	**28**

Learning Outcomes – CU 26: Introduction to materials	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Structure and properties of metals and alloys; – Solidification and solid-state transformations – Microstructures – Degradation and Failure
SKILLS	Describe the structures of pure metals and alloys. Explain, in detail, the principles of transformation and conditions of structure under which it occurs. Interpret in detail the phase diagrams information and apply phase diagrams to define microstructures, mechanical properties and alloys. Realise the mechanical properties of metallic materials according to their structures. Describe the differences between elastic, plastic, cold and hot deformation that can occur in metals. Explain the advantages and disadvantages of metals recrystallization, work hardening and strain ageing. Interpret crystalline lattice distortion from given alloying elements and subsequent structural changes. Compare the mechanisms of precipitation, types of precipitates and their location within the microstructure. Explain the effect of loading conditions and temperature on the mechanical properties of metallic materials. Explain in detail the differences between cracks and fractures comparing the mechanisms of different types of failures. Assess types of failures.

Competence Unit 27: AM with steels feedstock (excluding Stainless Steel)

CU 27: AM with Steels feedstock (excluding Stainless Steel)	CONTACT HOURS
SUBJECT TITLE	
Characteristics and classification of Low alloy Carbon Steels	3
Characteristics and classification of Cr-Mo steels	2
Characteristics and classification of Maraging steels	1,5
Characteristics and classification of High strength steels	1,5
Behaviour in AM – General considerations	2
Behaviour in AM of Low alloy Carbon Steels	2
Behaviour in AM of Cr-Mo steels	2
Behaviour in AM of Maraging steels	2
Behaviour in AM of High strength steels	2
Cracking phenomena in parts processed by AM	3
Total	21
WORKLOAD	**42**

Learning Outcomes –CU 27: AM with Steels feedstock (excluding Stainless Steel)	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Different types of Steels as feedstock for producing AM parts, namely: carbon steels, Cr-Mo, maraging and high strength steels
SKILLS	Describe the theory, principles and applicability of steels: – Describe processability with AM, including obtained properties and their relation with process parameters – Describe main causes of cracking and how to avoid – Identify possible imperfections, including metallurgical imperfections, and how to avoid – Select types of heat treatments when necessary For the following types of steels: low alloy, Cr-Mo, maraging and high strength steels: – Explain in detail the effects of micro-alloying, relating grain refinement to mechanical properties. – Discuss the AM conditions for a certain part taking into account the material ability for AM – Discuss carbon equivalent (CE), t 8/5 concept and preheating temperature – Discuss hardenability and maximum cooling rate – Identify the type of heat treatments requirements for a certain part, inferring the heat treatment conditions (depending of the shape and size of the part, the application and the code).

Competence Unit 28: AM with Stainless Steel feedstock

CU28: AM with Stainless Steel feedstock	CONTACT HOURS
SUBJECT TITLE	
Characteristics and classification of Stainless Steels – general considerations	2
Characteristics and classification of Austenitic Stainless Steels	1
Characteristics and classification of Martensitic Ferritic Stainless Steels	1
Characteristics and classification of Duplex Stainless Steels	1
Characteristics and classification of Precipitation hardened SS	1
Behaviour in Additive Manufacturing (AM) of Austenitic Stainless Steels	2
Behaviour in AM of Martensitic Ferritic Stainless Steels	2
Behaviour in AM of Duplex Stainless Steels	1
Behaviour in AM of Precipitation hardened Stainless Steels	1
Cracking phenomena in Stainless Steel parts processed by AM	2
Total	14
WORKLOAD	**28**

Learning Outcomes – CU 28: AM with Stainless Steel feedstock	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Different types of Stainless Steels as feedstock for producing AM parts, namely: Austenitic, Ferritic, Martensitic, Duplex and Precipitation hardened
SKILLS	Identify stainless steels type: austenitic, ferritic, martensitic, precipitation hardened, duplex and its ability to be processed by AM in all processes with different feedstock Identify main problems for each Stainless Steels when AM processed by different AM processes and feedstock Identify the material processability with AM, the type of heat source and feedstock Discuss and predict how to prevent major cracking phenomena Decide the type of post treatment required for a certain part (according to the type of stainless steel, the shape and size of the part, the application and any relevant documentation)

Competence Unit 29: AM with Aluminium feedstock

CU 29: AM with Aluminium feedstock	CONTACT HOURS
SUBJECT TITLE	
Characteristics and classification of Aluminium and its alloys	2
Aluminium and aluminium alloys and their behaviour in AM	3
Cracking phenomena in parts processed by AM	2
Total	7
WORKLOAD	**10**

Learning Outcomes – CU 29: AM with Aluminium feedstock	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – Aluminium alloys and their processability with AM – Main causes of cracking and how to avoid – Types and objectives of heat treatment techniques
SKILLS	For the following metal and alloys – Aluminium: – Interpret the processability with AM for each alloy with different AM processes and feedstock – Discuss the applications, recommending processing parameters and shielding gases to achieve quality requirements for a specific part – Distinguish heat treatable and non-heat treatable alloys and problems in AM – Recommend methods to avoid cracking phenomena and solid-state micro fissures, providing alternatives where necessary.

Competence Unit 30: AM with Nickel feedstock

CU 30: AM with Nickel feedstock	CONTACT HOURS
SUBJECT TITLE	
Characteristics and classification of Nickel and its alloys	2
Nickel and nickel alloys and their behaviour in AM	3
Cracking phenomena in parts processed by AM	2
Total	7
WORKLOAD	**14**

Learning Outcomes – CU 30: AM with Nickel feedstock	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – Nickel processability with AM – Main causes of cracking and how to avoid – Types and goals of heat treatment techniques
SKILLS	For the following metal and alloys – Nickel: – Interpret the processability with AM for each alloy with different AM processes and feedstock – Discuss the applications, recommending processing parameters and shielding gases to achieve quality requirements for a specific part – Recommend methods to avoid cracking phenomena and solid-state micro fissures, providing alternatives where necessary.

Competence Unit 31: AM with Titanium feedstock

CU31: AM with Titanium feedstock	CONTACT HOURS
SUBJECT TITLE	
Characteristics and classification of Titanium and its alloys	4
Titanium and titanium alloys and their behaviour in AM	6
Cracking phenomena in parts processed by AM	4
Total	14
WORKLOAD	**28**

Learning Outcomes – CU 31: AM with Titanium feedstock	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – Titanium processability with AM – Main causes of cracking and how to avoid – Types and goals of heat treatment techniques
SKILLS	Describe in detail the theory, principles and applicability of: – Titanium processability with AM – Main causes of cracking and how to avoid – Heat treatments- types and techniques For the following metal and its alloys – Titanium: – Interpret the processability with AM – Discuss the applications, recommending heat input, shielding gases to achieve quality requirements for a specific part – Recommend methods to avoid cracking phenomena and solid-state micro cracks, providing alternatives where necessary.

Competence Unit 32: AM with Tungsten feedstock

CU32: AM with Tungsten feedstock	CONTACT HOURS
SUBJECT TITLE	
Characteristics and classification of Tungsten	1
Tungsten behaviour in AM	1.5
Cracking phenomena in parts processed by AM	1
Total	3.5
WORKLOAD	**7**

Learning Outcomes – CU32: AM with Tungsten feedstock	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – Tungsten processability with AM – Main causes of cracking and how to avoid
SKILLS	For Tungsten: – Interpret the processability of W with different AM processes and feedstock – Discuss the applications, recommending processing parameters and shielding gases to achieve quality requirements for a specific part

Competence Unit 33: Biomedical metallic materials

CU 33: Biomedical metallic materials	CONTACT HOURS
SUBJECT TITLE	
Metallic alloys used for biomedical applications	1
Noble metals (Au, Ag, Pd, Pt)	1
Pure Ti, Pure Mg	1
Alloys: Ti6Al7Nb, Ti13Zr13Nb, NiTi, 316L stainless steel Co-Cr-Mo,	1
Ability to AM	3
Total	7
WORKLOAD	**10**

Learning Outcomes –CU 33: Biomedical metallica materials	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – Biomedical metallic materials processability with AM – Main causes of cracking and how to avoid
SKILLS	Describe in detail the theory, principles and applicability of – Biomedical metallic materials processability with AM – Main causes of cracking and how to avoid – Heat treatments- types and techniques For the Biomedical metallic materials – Interpret the processability with AM – Discuss the applications, recommending heat input, shielding gases to achieve quality requirements for a specific part – Recommend methods to avoid cracking phenomena and solid-state micro cracks, providing alternatives where necessary.

Competence Unit 34: Process selection

CU 34: Process Selection	CONTACT HOURS
SUBJECT TITLE	
Economics and productivity	7
AM Job analysis	21
Total	28
WORKLOAD	**56**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Process selection	**6 ADVANCED**	Evaluate, for a specific part, which AM processes can be used for its production	Analysing manufacturing suitability of a client's specific requests	**28**	**56**
			Proposing AM processes based on part design (in the conceptual design phase, together with the Design Engineer), materials, other manufacturing operations, required properties and applications		
			Ensuring liaison with other technical areas (design, materials, etc.) to guarantee manufacturability of AM parts		
			Using cost models to establish comparisons between different AM processes/materials and other required processes considering the full manufacturing chain		
			Estimating manufacturing times according to each process		

Learning Outcomes – CU 34: Process selection	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Technical adequacy of AM processes to part requirements – Costing and manufacturing time assessment
SKILLS	Relate supply chain strategies to their effects on the performance of a manufacturing organisation Define the objectives, principles, terminology and systems of management accounting, including costing Elaborate quotations for clients, calculating the cost of a product made by AM, including labour costs, overhead costs, and consumable costs. Compare AM production costs to traditional manufacturing costs determining the return on investment. Estimate manufacturing duration based on the process and part designs specifications Recommend AM processes for specific applications based on job requirements analysis

Competence Unit 35: Metal AM integration

CU 35: Metal AM integration	CONTACT HOURS
SUBJECT TITLE	
Production Management	7
AM Commercial Integration	3,5
Case studies	10,5
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Metal AM integration	**6/ADVANCED**	Support the continuous technical and commercial integration of Metal AM in an industrial environment	Providing inputs for the design of production management procedures, based on the advantages and limitations of Metal AM processes	**21**	**42**
			Providing feedback to the management concerning Metal AM costs (e.g. collected from the production by the specialized engineers)		
			Promoting AM capability to relevant stakeholders within the company, for its range of products		

Learning Outcomes – CU 35: Metal AM integration	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – AM processes adoption on a company's business model – Technical and commercial implementation plans for AM production
SKILLS	Analyse all the manufacturing processes existing in the company comparing AM with other manufacturing processes Design AM cells including selection of AM machine and methods to manipulate the part, fixturing and sensing of the part, equipment for loading and unloading. Design a factory layout that incorporates all required manufacturing operations Provide inputs for a factory layout design that incorporates all required manufacturing operations Recommend procedures for integration of AM processes within the company's manufacturing chain Discuss the commercial aspects related to the integration of AM fostering the involvement of internal and external stakeholders in the adoption of AM

Competence Unit 36: Coordination activities

CU36: Coordination activities	CONTACT HOURS
SUBJECT TITLE	
Communications and coordination	3
Documentation	4
Total	7
WORKLOAD	**14**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Coordination activities	**6 ADVANCED**	Coordinate the work with the AM team	Ensuring the link with external suppliers, as well as management, staff and other company depart-ments	**7**	**14**
			Managing documentation related with the AM process		

Learning Outcomes – CU 36: Coordination activities	
KNOWLEDGE	Advanced knowledge and critical understanding of the theory, principles and applicability of: – Communications and coordination procedures – Document handling and control
SKILLS	Manage communications across all actors involved in the AM manufacturing chain Establish procedures for information control and traceability Control all the information generated within a given AM

Competence Unit 40: Production of DED-LB parts

CU 40: Production of DED-LB parts	CONTACT HOURS
SUBJECT TITLE	
DED-LB process simulation	7
DED-LB part production	7
Case studies	7
Total	21
WORKLOAD	**42**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Production of DED-LB parts	**7/Expert**	Specify the process chain for the DED-LB parts	Interpreting reports of simulation results	**21**	**42**
			Run simple simulations in toolpath planning		
			Establishing manufacturing plan (e.g. toolpath generation, Laser parameters, feedstock, gas, building plate, build file, post processing operations, standards)		
			Providing technical counselling to the decision of the acquisition of AM equipment		
			Defining the production of DED-LB parts together with other staff (e.g. including providing inputs to designers to optimize the shape of AM products)		
			Specifying post processing operations (e.g. subtractive manufacturing, heat treatment, surface finishing and treatment) to fulfil the product requirements		
			Design the tooling concept		
			Defining AM staff's tasks distribution according to the workplan		

Learning Outcomes – CU 40: Production of DED-LB parts	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – DED-LB part production specifications, including simulation information, process parameters, pre and post manufacturing operations and work instructions
SKILLS	Discuss Design for AM features with other AM staff. Adapt CAD files to build files (e.g. toolpath) Interpret reports of finite element analysis and numerical modelling to AM (e.g. topology optimisation, distortion, residual stresses) Apply workflows for virtual pre-processing (e.g. part orientation) Demonstrate competency in working with toolpath creation software Select specific materials for different applications to meet part requirements Propose a suitable toolpath for a given part and identify the areas that will need thermal compensation. Propose methods to reduce distortion for a variety of part geometries and processes. Identify the cause of defects and propose methods for their mitigation. Identify the most suitable post processing technique for a specific AM process and application Create a DED-LB AMPS Produce work instructions for the DED-LB Operator

Competence Unit 41: Conformity of DED-LB parts

CU 41: Conformity of DED-LB parts	CONTACT HOURS
SUBJECT TITLE	
Quality Assurance and Quality Control	7
Inspection and Testing Plan	21
Production chain qualification	7
Total	35
WORKLOAD	**70**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Conformity of DED-LB parts	**7/Expert**	Ensure the conformity of the AM process and AM parts	Preparing QA/QC procedures (e.g. reception, handling and storage of feedstock, manufacturing process monitoring)	**35**	**70**
			Supporting the development of testing and inspection plan (including acceptance criteria for NDT and DT)		
			Troubleshooting for causes of non-conformity in the production of AM parts		
			Determining corrective actions for eliminating defects (e.g. metallurgical, deformation, warping) based on technical reports (e.g. DT, NDT)		
			Ensuring the compliance of the AM production process and the AM parts with the relevant documents (e.g. standards, product specifications, legislation)		
			Identifying requirements in terms of AM training		
			Implementing AM process and AM parts certification procedures		
			Developing procedures to repair parts (e.g. parts damaged in service; together with the client)		
			Ensuring production chain qualification (i.e. equipment, operations, staff)		

Learning Outcomes – CU 41: Conformity of DED-LB parts	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – Quality Management – Methods for DT and NDT, monitoring control and inline control systems – Certification of DED-LB parts – Repair procedures
SKILLS	Apply the principles of quality management to process and part qualification Evaluate feedstock characteristics required to qualify a part Develop AM procedures according to appropriate standards and other documentation Select Non-Destructive Testing and Destructive Testing methods to characterise a part Interpret Destructive and Non-Destructive Testing reports Adapt AMPS based on results from testing results Integrate troubleshooting techniques in manufacturing process chain Propose methods to perform the repair and re-certification of a damaged DED-LB part Guarantee process conformity to client's requests, standards and other requirements Define the manufacturing and approval of test artefacts Interpret inline control and monitoring systems data and define correction strategies

Competence Unit 42: Conformity of facilities featuring DED-LB

CU 42: Conformity of facilities featuring DED-LB	CONTACT HOURS
SUBJECT TITLE	
Health, Safety & Environment in DED-LB	10
Infrastructures/Facility Requirements	3
Group work	1
Total	14
WORKLOAD	**28**

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Conformity of facilities featuring DED-LB	**6/Advance**	Support the implementation of facility conformity procedures featuring DED-LB	Supporting the design of Health, Safety and Environment (HSE) procedures featuring DED-LB (e.g. Control of Substances Hazardous to Health (COSHH), risk analysis, mitigation plans)	**14**	**28**
			Providing safety requirements to be implemented to ensure people's safety on the shop floor		
			Providing inputs for waste management		
			Preparing incident reports		

Learning Outcomes – CU 42: Conformity of facilities featuring DED-LB	
KNOWLEDGE	Highly specialised knowledge and critical assessment of theory, principles and applicability of: – HSE in the DED-LB process
SKILLS	Explain in detail the health and safety hazards associated with Laser, electricity, gases, fumes, fire, radiation and noise, grinding, spatter, flame, fire, combustion. Predict the hazards, defining the health and safety requirements and working procedures, including the definition of the necessary PPE. Recommend healthy and safe workplace practices to be implemented in a manufacturing plant.

Appendix I: EWF Systems Framework

FIELD OF ACTIVITIY		EQF LEVEL	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY	EWF QUALIFICATION SYSTEM
INSPECTORS &SUPERVISORS/ COORDINATORS/MANAGERS	OPERATORS	7	EXPERT	Highly specialised and forefront knowledge including original thinking, research and critical assessment of theory, principles and applicability of metal additive manufacturing processes.	Highly specialised problem- solving skills including critical and original evaluation, allowing to define or develop the best technical and economical solutions, when applying metal additive manufacturing processes, in complex and unpredictable conditions	Manage and transform the metal additive manufacturing processes in a highly complex context. Fully responsible for the definition and revision of personnel's tasks.	AM
		6	ADVANCED	Advanced knowledge and critical understanding of the theory, principles and applicability of metal additive manufacturing processes.	Advanced problem-solving skills including critical evaluation, allowing to choose the proper technical and economical solutions, when applying metal additive manufacturing processes, in complex and unpredictable conditions	Manage the applications of metal additive manufacturing processes in a highly complex context. Act autonomously in decision making and definition in the definition of the metal additive manufacturing personnel's tasks.	
		5	SPECIALIZED	Specialised, factual and theoretical of theory, principles and applicability of metal additive manufacturing proce.sses	Specialised range of cognitive and practical skills, allowing to develop solutions or choose the appropriate methods, when applying metal additive manufacturing processes in common/regular problems.	Manage and supervise common or standard metal additive manufacturing processes, in an unpredictable context. Take responsibility in standard work and supervise the metal additive manufacturing personnel's tasks.	
		4	INDEPENDENT	Factual and broad concepts in the field of metal additive manufacturing processes.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific metal additive manufacturing problems.	Self-manage of professional activities and simple standard applications of metal additive manufacturing processes in predictable contexts but subject to change. Supervise routine tasks and similar function workers, as well as take responsibility for decision making in basic work.	

General reference descriptors transversal to all qualifications. Each Qualification has its own specific descriptors in terms of Knowledge, skills, autonomy and responsibility.