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Creating knowLedge and skilLs in AddItive Manufacturing

CLLAIM

Metal AM Operator DED-LB

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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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Guideline - General information for the public and organizations that implement these qualifications
Metal AM Profiles
Approved: April 2019 -

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1. Preface

The present document consists in European Guideline for Metal AM Operator DED-LB, developed in the framework of the European project “Creating KnowLedge and SkilLs in AddItive 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.

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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.

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3. Guideline for Metal AM Operator DED – LB

3.1 Introduction to Metal AM Operator DED - LB

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	EO DED-LB	
	Recommended Contact Hours*	Expected Workload**
CU 00: Additive manufacturing Process Overview	7	14
CU 08: DED-LB Process	14	28
CU 09: Quality Assurance (QA) in DED-LB	14	28
CU 10: Health, Safety and Environment (HSE) in DED-LB	7	14
CU 11: Fit and set-up of DED-LB systems	21	42
CU 12: Manufacturing of DED-LB parts	7	14
CU 13: Post processing of DED-LB parts	7	14
CU 14: Maintenance of DED-LB systems	14	28
Subtotal (without optional CUs)	63	126
CU 48: Powder Handling	14	28
CU 49: Laser Beam Characterisation	7	14
Total	84	168

* Recommended 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.

** Expected Workload is calculated in hours, corresponding 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.

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Although the hours indicated in the above table are merely recommended, it is mandatory that in total the qualification has a minimum of 40 contact hours.

Within CLLAIM project'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 Sectoral 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), etc., as shown in the following example:

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

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3.2 Occupational Standard

EO DED-LB are the professionals with the specific knowledge, skills, autonomy and responsibility to operate metal AM machines using DED-LB Process. His/her main tasks are to:

- Operate Laser based DED machines for AM, including, fitting and setting up, basic maintenance and repair.

He/She will be able to:

- Verify Laser beam measurement and positioning in DED-LB machines for AM;
- Self-manage the handling of feedstock (approval, storage, contamination, traceability);
- Develop solutions on basic and specific problems related with Laser based DED machines and processes for AM

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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 European Metal AM Operator Qualification admission are the following:

- National compulsory school diploma

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3.4 Qualification Outcome Descriptors

QUALIFICATION	EWF LEVEL	KNOWLEDGE	SKILLS	AUTONOMY AND RESPONSIBILITY
EO DED-LB	INDEPENDENT	Factual and broad concepts in the field of DED-LB metal additive manufacturing process.	Fundamental cognitive and practical skills required to develop proper solutions and application of procedures and tools on simple and specific of DED-LB manufacturing problems	Self-manage of professional activities and simple standard applications of DED-LB manufacturing in predictable contexts but subject to change.

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3.5 Mandatory Competence Units Learning Outcomes

Each of the Competence Units that compile the Guideline for Metal AM Operator DED-Arc is listed below.

3.5.1 Competence Unit 00: Additive Manufacturing Processes Overview

CU 00: Additive Manufacturing Processes Overview	RECCOMMENDED 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	
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

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3.5.2 Competence Unit 08: DED-LB Process

CU 08: DED-LB Process	RECCOMMENDED
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	Factual and broad of: – DED-LB systems – Laser Characteristics – Build platform – Powder/wire – Gases – Processable materials with DED-LB
SKILLS	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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3.5.3 Competence Unit 09: Quality Assurance (QA) in DED-LB

CU 09: Quality Assurance (QA) in DED-LB	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
General QA principles	2
AM Machine QA	4
AM Parts QA	4
Visual Inspection Overview	4
Total	14
WORKLOAD	28

Learning Outcomes – CU09: Quality Assurance (QA) in DED-LB	
KNOWLEDGE	Factual and broad knowledge of: – Quality Assurance in DED-LB – Visual Inspection of DED-LB parts
SKILLS	Recognise the broader use of QA within engineering Recognise the scope of the DED-LB operator qualification within the AM industry Support the qualification and requalification procedures of DED-LB equipment Identify the main procedures, equipment and their role Prepare test reports based on the requirements specified by the manufacturer Compare geometry and dimensions specified in the technical drawings with the as built parts Use simple measurement devices and techniques to carry out a basic visual inspection of the as built part Identify problems in the as build parts distinguishing between imperfections and defects Report defects suggesting either their removal with post processing operations or part disposal

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3.5.4 Competence Unit 10: Health, Safety and Environment (HSE) in DED-LB

CU10: Health, Safety and Environment (HSE) in DED-LB	RECCOMMENDED
SUBJECT TITLE	CONTACT HOURS
Health, Safety and Environment	7
Total	7
WORKLOAD	14

Learning Outcomes – CU10: Health, Safety and Environment (HSE) in DED-LB	
KNOWLEDGE	Factual and broad of: – Health, Safety and Environment related to DED-LB
SKILLS	Identify the main hazards and safety measures associated with DED-LB systems Recall existing legislation and requirements on HSE related to DED-LB

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3.5.5 Competence Unit 11: Fit and set-up of DED-LB systems

CU 11: Fit and set-up of DED-LB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
DED-LB process requirements and operational parameters	12
Materials knowledge and how it relates to the process	4
Type of files and work documentation	4
HSE procedures	1
Total	21
WORKLOAD	42

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Fit and set-up of DED-LB systems	4 Independent	Fit and set-up the DED-LB system	Verifying the DED-LB system set-up according to the procedure determined by the machine manufacturer and required operational conditions	21	42
			Preparing and verifying the build platform and feedstock		
			Performing Additive Manufacturing file loading and build jobs specs verification based on the AM procedure specification *(includes inserting/verifying process parameters if needed)*		
			Following HSE procedures for the fit		

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			and set-up of the DED-LB system		
			Following and completing work documentation created by the DED-LB Engineer		

Learning Outcomes – CU 18: Hardware, software and build file set-up for DED-LB	
KNOWLEDGE	Factual and broad of: – Variables of DED-LB and related operational conditions parameters – DED-LB Equipment Requirements – Materials used for DED-LB – Type of files and Work documentation – HSE procedures under DED-LB
SKILLS	Identify and set-up the clamping system for the build platform characteristics (e.g. shape, thickness, material) Load powder/wire following mandatory safety procedures Prepare machines for operation, according to the Additive Manufacturing Procedure Specifications Verify if DED-LB machines are working in accordance with job specifications, in terms of process parameters Prepare feedstock, build platform and machines in accordance to used material Verify if DED-LB machines comply with manufacturer and/or internal specifications Load files to DED-LB machines Comply with HSE procedures associated to DED-LB machines Interpret technical information related to the DED-LB process and machines

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3.5.6 Competence Unit 12: Manufacturing of DED-LB parts

CU 12: Manufacturing of DED-LB parts	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Machine functionalities and monitoring systems	6
Documentation	1
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Manufacturing of DED-LB parts	4 Independent	Manufacturing of DED-LB parts	Ensuring that the layers are manufactured according to the quality requirements (i.e. first layers and periodically)	7	14
			Performing build cycle according to manufacturing instructions		
			Following HSE procedures when printing AM parts		
			Following and completing work documentation according to the quality requirements		
			Reporting issues and		

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			implementing corrective or preventive actions based on parts' requirements feedback from the Engineer		

Learning Outcomes – CU 12: Manufacturing of DED-LB parts	
KNOWLEDGE	Factual and broad of: – Manufacturing of DED-LB parts – DED-LB machine functionalities and monitoring systems
SKILLS	Perform parts manufacturing according to the build instruction applying HSE procedures Interpret technical documentation related to the requirements of the as built parts Identify the main reasons for failure during the manufacturing process Prepare reports on the manufacturing process, including identified issues Monitor and escalate errors of the build process

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3.5.7 Competence Unit 13: Post processing of DED-LB parts

CU 13: Post processing of DED-LB parts	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Post-build cycle operations	3
Manual tools and methods for post-processing operations	4
Total	7
WORKLOAD	14

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Post processing of DED-LB parts	4 Independent	Prepare DED-LB parts for post processing	Providing information from monitoring data about critical areas for extended testing	7	14
			Applying simple manual operations to parts (cleaning, subtractive & post processing)		
			Handing parts for post processing operations		
			Following applicable HSE procedures		

Learning Outcomes – CU 13: Post processing of DED-LB parts	
KNOWLEDGE	Factual and broad of: – Manual tools and methods for post-processing operations
SKILLS	Remove the as build parts and build platform from the machine applying the necessary HSE procedures Carry out simple manual preparation of the as built part for different post-processing methods

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3.5.8 Competence Unit 14: Maintenance of DED-LB systems

CU 14: Maintenance of DED-LB systems SUBJECT TITLE	RECOMENDED CONTACT HOURS
General maintenance aspects	3
Optical elements	1
Parts maintenance	2
Gas supply system	1
Auxiliary elements maintenance	2
Application driven material change	1
HSE procedures	2
Calibration	2
Total	14
WORKLOAD	28

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Maintenance of DED-LB systems	4 Independent	Maintain and repair the DED-LB system	Implementing equipment manufacturer's maintenance routines	14	28
			Cleaning and replacing materials components (e.g. filters, cover glass, powder containers, tubes, nozzles)		
			Reporting problems to the Engineer		

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			Following applicable HSE procedures		

Learning Outcomes – CU14: Maintenance of DED-LB systems	
KNOWLEDGE	Factual and broad of: – Maintenance aspects associated with DED-LB systems
SKILLS	Change protective lens and clean the nozzle Assess the need to perform maintenance operations in DED-LB system Perform maintenance operations in a DED-LB system Identify the consumables for the different machine parts Report the need to execute specific maintenance Support other technicians during system maintenance Verify the cleanliness of the optic system Verify if the optical system is working correctly Monitoring and calibration status (e.g. CNC encoders) Verify the level of wear of a mechanical component Verify the system gas flow Adequate maintenance routines to the material type Verify the condition and make use of the personal protective equipment

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3.5.9 Competence Unit 48: Powder Handling

CU 48: Powder Handling SUBJECT TITLE	RECOMENDED CONTACT HOURS
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	Factual and broad of: – Powder handling, storage and reconditioning

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Learning Outcomes – CU 48: Powder Handling	
SKILLS	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

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3.5.10 Competence Unit 49: Laser Beam Characterisation

CU 49: Laser Beam and Characterisation	RECOMENDED CONTACT HOURS
SUBJECT TITLE	
Laser Beam parameters and conditions	2
Measurement Equipment	5
Total	7
WORKLOAD	1

CU	EQF/ EWF LEVEL	JOB FUNCTIONS	JOB REQUIRED ACTIVITIES	CONTACT HOURS	WORKLOAD
Laser Beam Characterisation	4 Independent	Verify Laser Beam	Checking of the Laser beam characteristics and properties	7	14

Learning Outcomes – CU 48: Laser Beam Characterisation	
KNOWLEDGE	Factual and broad of: ☐ Laser Beam characterisation ☐ Measurement equipment
SKILLS	Safely carry out power measurements including power stability Safely carry out beam profiling in different areas of the build platform Use other measurement equipment to determine other Laser beam properties Carry out measurement in accordance with existing standards and/or internal specifications

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